DOCUMENTS IN AMERICAN TELECOMMUNICATIONS POLICY

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DOCUMENTS IN AMERICAN TELECOMMUNICATIONS POLICY

Edited by
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Volume Two

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TELECOMMUNICATIONS

A PROGRAM FOR PROGRESS

A Report by the

PRESIDENT'S COMMUNICATIONS POLICY BOARD

WASHINGTON : MARCH 1951

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Letter of Transmittal

February 16, 1951

Dear Mr. President:

We have the honor to transmit the report on policies and practices recommended to be followed by the Federal Government in the communications field, which was called for by Executive Order 10110 of February 17, 1950, establishing the President's Communications Policy Board.

During the year since our appointment, we have examined many phases of the problems of national telecommunications policy and practice. We have consulted the best-qualified Government and private sources. A small professional staff has studied special phases of the field. The major results of these consultations and special studies are embodied in our report.

The Board is in unanimous agreement on the conclusions expressed.

Respectfully submitted,

Lee A. DuBridge

William L. Everitt

James R. Killian, Jr.

David H. O'Brien

Irvin Stewart, Chairman

Introduction

THE PROBLEM POSED

Pressing problems in the operation of the nation's wire and radio communications facilities led to the creation of the President's Communications Policy Board on February 17, 1950.

In his letter of that date to our Chairman, the President declared that there is "a major public interest in assuring the adequacy and efficiency" of this "vital resource." He noted the close relationships of the telecommunications services—radio, telephone, and telegraph—and the influence of governmental operations on the system. The President therefore asked for a comprehensive inquiry that would view the specific problems as parts of the "broader problem of developing a total national communications policy." The text of the President's letter follows:

"My dear Dr. Stewart:

"Communications services represent a vital resource in our modern society. They make possible the smooth functioning of our complex economy. They can assist in promoting international understanding and good will; they constitute an important requirement for our national security. There is, accordingly, a major public interest in assuring the adequacy and efficiency of these services.

"Developments in this field during and since the war have created a number of problems which require careful consideration at this time. The extent to which the Government should, in time of peace, continue to operate its own communications facilities is one such problem of current importance. The question of merging the overseas operations of our commercial communications companies also requires objective review. The most pressing communications problem at this particular time, however, is the scarcity of radio frequencies in relation to the steadily growing demand. Increasing difficulty is being experienced in meeting the demand for frequencies domestically, and even greater difficulty is encountered internationally in attempting to agree upon the allocation of available frequencies among the nations of the world. In the face of this growing shortage, the problem of assuring an equitable distribution of the available supply of frequencies among all claimants, both governmental and private, is rapidly assuming major prominence.

"Problems such as these cannot adequately be considered on a piecemeal basis. They must be viewed as parts of the broader problem of developing a total national communications policy, designed to assure the most effective utilization of the various forms of communication facilities, and the full satis-

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faction of those needs which are most essential to the broad public interest. An over-all, objective review of this entire situation is urgently needed.

"I am therefore establishing by Executive Order a temporary Communications Policy Board of 5 members to study and to make recommendations to me on the policies and practices which should be followed by the Federal Government in this field in order best to meet the broad requirements of this Board. In view of the need for early action in this field, I should like to receive the Board's final report by no later than October 31, 1950.

"The Executive Order establishing this Board states that the Board shall study the present and potential use of radio and wire communications facilities by governmental and non-governmental agencies. The Order further states that the Board shall make recommendations in the national interest concerning (a) policies for the most effective use of radio frequencies by governmental and non-governmental users and alternative administrative arrangements in the Federal Government for the sound effectuation of such policies, (b) policies with respect to international radio and wire communications, (c) the relationship of government communications to non-government communications, and (d) such related policy matters as the Board may determine.

"I feel that the problem of radio frequencies will be one of the most important areas for the Board's investigations. I hope that, as a result of its studies, the Board will be able to recommend possible means for conserving frequencies, as well as standards for determining the relative priority of competing claims for frequencies, and possible administrative arrangements within the Government for assuring, on a continuing basis, a sound and equitable allocation of the limited frequency supply.

"I believe that the studies to be undertaken by the Board are of vital importance to the economy of this Nation, to our international relations, and to our national security. I am sure that you will receive the full cooperation and assistance of all parties concerned.

Sincerely yours,

HARRY S. TRUMAN"

The Executive Order referred to in the President's letter reads as follows:

"EXECUTIVE ORDER # 10110

"PRESIDENT'S COMMUNICATIONS POLICY BOARD

"By virtue of the authority vested in me as President of the United States, it is hereby ordered as follows:

"1. There is hereby created a board to be known as the President's Communications Policy Board which shall be composed of a chairman and four other members to be designated by the President.

"2. It shall be the function of the Board to study the present and potential use of radio and wire communications facilities by governmental and non-governmental agencies and to make and present to the President evaluations and recommendations in the national interest concerning (a) policies for the most effective use of radio frequencies by governmental and non-governmental users and alternative administrative arrangements in the Federal Government for the sound effectuation of such policies, (b) policies with respect to international radio and wire communications, (c) the relationship of government communications to non-government communications, and (d) such related policy matters as the Board may determine.

"3. The Board is authorized to hear and consult with representatives of industry and the Federal Government concerned with the subjects under study by the Board. All executive departments and agencies of the Federal Government are authorized and directed to cooperate with the Board in its work and to furnish the Board such information as it may require in the performance of its duties. The Board shall protect the security of any classified information submitted to it.

"4. Each member of the Board shall, while away from his home or regular place of business and engaged in the official business of the Board, receive actual traveling expenses and per diem allowances in lieu of subsistence in accordance with rates established by the Standardized Government Travel Regulations, as amended.

"5. During the fiscal year 1950 the expenditures of the Board and the traveling expenses and per diem allowances of the members thereof shall be paid out of an allotment made by the President from the appropriation appearing under the heading "Emergency Fund for the President" in the Independent Offices Appropriation Act, 1950 (Public Law 266, approved August 24, 1949); and during the fiscal year 1951 the same shall be similarly paid from any corresponding or like appropriation made available for the fiscal year 1951. Such payments shall be made without regard to the provisions of (a) section 3681 of the Revised Statutes (31 U. S. C. 672), (b) section 9 of the act of March 4, 1909, 35 Stat. 1027 (31 U. S. C. 673), and (c) such other laws as the President may hereafter specify.

"The Board shall terminate one year after the date of this order.

HARRY S. TRUMAN

THE WHITE HOUSE,
February 17, 1950."

Chapter I

AN ANSWER IN SUMMARY

> One of the bulwarks of a free society is freedom of communications. Its commerce, its education, its politics, its spiritual integrity, and its security depend upon an unimpeded and unsubservient exchange of information and ideas.
>
> One of the hopes for a peaceful world rests upon the ultimate possibility of extending this same freedom of communications beyond all barriers. War begins in the minds of men, and in the minds of men must be engendered the will for peace. We must therefore strive to facilitate a meeting of the minds of men everywhere, and through the liberating arts of communication to create the attitudes favorable to peace.
>
> These convictions and concepts have provided the background for the conclusions and recommendations reached in the following study of the economic, organizational, and physical aspects of America's telecommunications system.

Our telecommunications system is a great national resource which makes available to the people of the United States a rapid nationwide and worldwide communications service.

All the facilities which make this service possible—telephone, telegraph, radio, and television—utilize electrical energy in some form to convey intelligence from one person to another. Electrical impulses speeding through these facilities carry information of all sorts throughout the country and to other nations of the world.

When wires and cables are used as the media through which they are transmitted, it is not difficult to control these impulses. When the transfer of electrical energy is made by radio through the medium popularly called the "ether," serious problems arise.

Many of these problems stem from the fact that the ether is public property available to all the people of the world, and the further fact that there is a limit to the number of electromagnetic waves which can be received intelligibly without harmful interference.

If interference is to be avoided, it is obvious that both national and international users of the radio spectrum must reach accord on equitable sharing of this limited medium. Consequently, telecommunications must be considered both from a national and from an international point of view.

The telecommunications system of the United States is engaged basically in the transfer of information from one person to another. Yet information about the system is inadequate. As part of our studies, we have gathered facts that fill some of the important gaps. The recognition that there are other gaps and that they too must be filled underlies several of the recommendations of policy and action which we shall make.

In our quest for solutions to the problems of telecommunications, we surveyed the facilities available today and the difficulties encountered in their operation, reviewed the troubles that have caused growing pains in the development of the system, and sought symptoms of future ills.

Both private and public agencies operate in the telecommunications system. We have found inescapable evidence of serious difficulty, not confined to the United States alone, but international in scope, in the management and use of the worldwide but limited resource of the radio frequency spectrum. There is indication of economic danger for some private companies, and of a lack of help on the part of Government agencies in avoiding that danger. There is evidence of confusion of responsibility among Government agencies which from time to time have been established for the regulation of parts of the system. These are principal among the disconcerting facts which our studies have disclosed.

Not all the facts are disconcerting, however. We have also found reason for no small amount of encouragement. There are many—and they are among the largest—areas of the telecommunications system, both public and private, in which standards of efficiency, economy, and performance are superb. There is a spirit of cooperation among the component organizations—public and private. There is in existence an administrative structure which, if properly strengthened, can become an effective central instrument to foster the vigor of the telecommunications system.

Special Problems of Telecommunications

Telecommunications present a special combination of technological, economic, social, and political problems. The telecommunications system as a whole, public and private, depends to an unusual degree upon a technology which is changing and growing with marked rapidity. The task of adjusting organization and practice to take advantage of technological advances and opportunities is complicated, however, by the intimate connection of telecommunications with both the national security and the international relations of the United States. Political considerations may require commercial carriers to maintain unprofitable circuits to certain overseas points. Economic prospects may counsel against heavy investment in the latest and most expensive high-speed cable equipment, yet the requirements of national defense may justify such an outlay.

The radio sector of our telecommunications system is further complicated by the fact that radio operates in the public domain. The possibility of interference necessitates domestic and international efforts to arrive at agreements for the apportionment of radio frequencies. Here again, efforts to take full advantage of new developments must proceed in the short run within the limits of existing agreements, and may be hampered or helped in the long run by the results of efforts to negotiate new ones.

Special economic pressures have borne heavily on some of the nation's telecommunications companies. Air-mail and long-distance telephone service have reduced the potential demand for telegraphic services. American companies engaged in overseas operations have been competing with each other for markets and in dealing with foreign monopolies. In this latter case, American companies have met with a special obstacle: The competition among American firms offers foreign monopolies the opportunity to play American competitors off against each other. The Federal Government's own international telecommunications network, which has grown to vast proportions in recent years, has handled traffic which might have been sent over common carriers.

The merging of private companies engaged in international radio and cable communications has at times been advocated as a way of easing their position. In the domestic field, merger of the telegraph companies has already occurred. It has been further advocated that the merged company acquire the record communications business of the telephone company—its teletypewriter exchange and leased line services.

Continued operation of the privately owned companies is essential to the national security, but nowhere do we find provision within the Government to insure that Government policies do not inadvertently affect the economic well-being of these companies.

We have found that the Federal Government has encountered many difficulties in its efforts to keep up with the growth and increasing complications of the nation's telecommunications structure. Some of these difficulties are suggested in the chapters on domestic and international telecommunications.

Technological progress in telecommunications is so rapid that it could quickly alter the character of the entire structure. This fact requires special vigilance on the part of the regulatory agencies.

Specific Issues

For analysis, we resolve these general problems into five specific issues. They are—

1. How shall the United States formulate policies and plans for guidance in reconciling the conflicting interests and needs of Government and private users of the spectrum space—that is, for guidance in making the best use of its share of the total spectrum?

2. How shall the United States meet the recurrent problem of managing its total telecommunications resources to meet the changing demands of national security?

3. How shall the United States develop a national policy and position for dealing with other nations in seeking international telecommunications agreements?

4. How shall the United States develop policies and plans to foster the soundness and vigor of its telecommunications industry in the face of new technical developments, changing needs, and economic developments?

5. How shall the United States Government strengthen its organization to cope with the four issues stated above?

The first four of these questions require brief explanation.

1. *Reconciling Uses of the Spectrum.* This task—which is known as frequency management—is one of enormous technical complexity. Different portions of the spectrum have radically different propagation characteristics; that is, their range and dependability vary. Some are usable for long-distance and others only for short-haul purposes. Their efficiency also changes from night to day, and from day to day, and is affected by sun spots and by atmospheric conditions.

By better management of the spectrum, much more could be done with frequencies now available. There is opportunity for more effective sharing of frequencies, for more intensive use of individual frequencies, and for increased economy in kilocycles assigned to each circuit.

The assignment of space in the spectrum among private users (including state and local but not Federal Government agencies) is a responsibility of the Federal Communications Commission (FCC). The total amount of such space available for assignment, however, is not determined by the FCC. In effect, it is determined by the President, who is responsible for the assignment and management of those frequencies used by Federal Government agencies. The Interdepartment Radio Advisory Committee (IRAC) is the instrumentality through which frequencies are assigned to Federal users. Thus far, no national policy has existed to clarify this dual control of a single resource and thus to aid in governing the apportionment of space between private users and Government users as groups. No criteria have been established for use in choosing between the conflicting needs of a Government and a non-Government user.

2. *National Security.* In the present period of recurrent crisis, it is likely that we shall be faced with a continuing problem of adjusting the use of telecommunications—especially radio frequencies—to what

may be violent fluctuations in the requirements for national security. Indeed, we may face a situation in which the President's emergency powers to control, take over, or close down communications facilities will have to be invoked, and arrangements for the delegation and exercise of those powers will be essential. We may also be faced with the necessity of creating wholly new telecommunications facilities.

Telecommunications of course play a major role in the economic and cultural life of the Nation. They are the vital nerve system of our modern military establishment. When spectrum space is insufficient to meet both the full needs of national security and the full needs of other affairs, the latter must give way to the former. When the emergency has passed, frequencies and facilities must be restored to civilian use. To create an ad hoc agency to meet each crisis would be a clumsy expedient at best, and indeed, the problems of transfer and retransfer of spectrum space and of facilities for using it are too complex for ad hoc control to be adequate. A continuing mechanism to deal with this situation is needed for the foreseeable future.

3. *International Agreements.* Just as the United States has no clear policy for apportioning its own share of spectrum space, so it has lacked satisfactory means of determining policy as a basis for negotiations with other nations. The United States, in preparing positions for international negotiations, has in effect asked Federal and other claimants to state their needs, and then presented the total as the United States requirement. In those portions of the spectrum where the total of these requirements has been small enough to be accommodated along with the needs of the rest of the world, our delegations to conferences have had a negotiable position. In some cases, however, the total stated requirements have exceeded not merely those which could reasonably be put forward as the proper United States share, but have actually exceeded the total physical content of the bands. Furthermore, there is no permanent mechanism by which the stated requirements of United States users can be adjusted with equity and safety. The imperative need for means of making such adjustments hardly requires elaboration.

4. *Maintaining a Sound Industry.* The private telecommunications industry of the United States is one of the nation's most valuable

assets in peace or in war. The normal life of the country is supported and facilitated by it in numberless ways. In abnormal times, the industry can place at the disposal of the nation a large reserve capacity built up because of its competitive structure. This capacity helps to take up the immediate surge of military requirements. The industry can release radio frequencies, cable capacity, and other communications facilities, when required for Government purposes, without seriously affecting its ability to carry the civilian load.

It is essential that the industry be in sound economic condition. Some of its components, however, have faced serious difficulties. To meet these situations, the companies have from time to time taken individual action, and from time to time Government has been of assistance to them in rate adjustments and other ways.

But there has been no long-range study of the question, no long-range planning. No agency of Government is in a position to take a comprehensive view of this problem. No agency is qualified to advise the President in fields where the interests of private and Government telecommunications users are in conflict. Meanwhile, in the absence of guiding policy, the action of Government agencies could seriously handicap the industry.

Scope of the Study

We have spent nearly a year seeking answers to these four problems and also to the crucial question Number 5—"How shall the United States Government strengthen its organization to cope with these four issues?" In this study we found it necessary to collect a large volume of information—some of which was not readily available in public documents. We were fortunate in securing the services of an extremely competent staff and we received most cordial cooperation from all Government and private agencies whom we consulted. Many agencies went to great lengths to supply detailed data on various phases of the problem.

The most pertinent information which we collected is summarized in the succeeding chapters of this Report, and we have given particular attention to those subjects not adequately covered in existing literature. Yet there are many important phases of the subject which we have covered only summarily, in some cases because there already exists available public information, but in other cases because we did not have time to carry out the extensive research necessary for an adequate treatment. In fact, as our study progressed, we became more and more aware of the great complexity of the problem and of the fact that no temporary or part-time board could do justice to the whole of it.

Critical to this study was an investigation of the nature and extent of the actual pressure for additional space in the radio frequency spectrum. The picture of the situation presented in Chapter II is one of great complexity. In many bands there is extreme congestion. The competition for frequencies for radio broadcasting and for television is well known to all. Less well known but also critical is the situation in the band suitable for very-long-range communication—4 to 27.5 megacycles. In this band not only is there great need for many circuits, but, because of propagation characteristics, two stations thousands of miles apart may still interfere with each other if they operate on the same or adjacent frequencies. The problem immediately becomes one for complex international negotiations.

The degree of spectrum crowding varies enormously in different parts of the spectrum and in different parts of the world. Opinions vary as to how serious the situation now is. But no one denies that it is getting worse and will continue to do so. Only vigilant intelligent management and vigorous pursuit of new technological possibilities can prevent possible future chaos.

In Chapter III we turn attention to an analysis of the United States domestic wire and radio telecommunication facilities, tracing their technological development and the economic problems they face. These facilities are very largely privately owned. The United States Government is a most substantial customer. The great bulk of the facilities available for public message service—telephone and telegraph—are owned by two great regulated but competing monopolies, the American Telephone and Telegraph Company and the Western Union Telegraph Company. These two companies perform an invaluable public service, and it is important for the Government to make sure they are intelligently regulated so that the public and the Government may continue to receive the benefits of the irreplaceable service they supply.

We believe that this service can best be insured by retaining the present system of private ownership.

The field of international telecommunication (Chapter IV) offers far more puzzling problems. Thus, while the United States end of overseas radiotelephone service is operated by a single company (the Bell System), radio and cable telegraph services are offered by several competing companies. Fluctuating international political and economic conditions, the rapidly growing use by the United States Government of international communication facilities (many of which are Government owned), competition for space in the crowded long-range radio communication spectrum, and many other factors have led to serious problems whose nature and extent are only too inadequately outlined in this Report. But they demand urgent attention by the United States Government, and we have recommended policies and mechanisms to help solve these continuing problems.

The nature and functions of the various existing Government agencies concerned with telecommunications have been given detailed examination (Chapter V). We find a complex pattern of such agencies with even more complex interrelations. It is a structure which has functioned smoothly in many ways. But it involves a duality or even multiplicity of control, as well as overlapping interests, and is a structure inadequate to meet the ever-more complex problems of this field. We believe the structure can be rendered coherent by the creation of a new executive agency and we set forth in some detail our proposals for the creation of this agency.

Finally in Chapter VI, we assemble existing and proposed telecommunications policies in the hope that they may serve as a starting point for the development of policies to guide present and future agencies, public or private, which deal with telecommunications.

Conclusions

On the basis of our studies, we have reached the following conclusions.

A. As to the pressures on the radio spectrum—

1. Pressure on the radio frequency spectrum is steadily increasing as a result of the greater use of radio in telecommunications.

2. The means on which we have relied in the past for management of the spectrum are no longer adequate to resolve in the best national interest the problems produced by this increasing pressure. The current difficulty growing out of the search for suitable space for television broadcasting in itself emphasizes this inadequacy.

3. Measured in terms of spectrum space rather than in number of discrete frequency channels, the Federal Government's share of the spectrum, though not so great as is commonly believed, is nevertheless large. While we do not know that it is out of proportion to the Government's responsibilities, it must have the most adequate justification and careful management if the greatest benefit is to be obtained from it.

4. There is need for a continuing determination of the changing requirements of Federal Government users both among themselves and in relation to the requirements of other users.

5. The recent rapid worldwide growth of telecommunications, combined with the needs of the current national emergency, makes the resolution of these problems a matter of great urgency.

6. The resolution of these problems can be secured only through adequate, energetic management, which demands that the Government organize itself to take a comprehensive view of the telecommunications field.

B. As to United States telecommunications at home—

1. The telephone system of the United States is a financially sound, multi-billion dollar industry consisting of the Bell System and 5,000 independent companies. This coordinated system is providing the nation with what is admittedly the best telephone service in the world. It is steadily improving that service by aggressive technological advancement. In view of the healthy condition of the telephone system, we conclude that no changes in Government procedure for insuring adequate service in the national interest are necessary.

2. The telegraph system of the United States has experienced economic difficutlies owed in part to the expansion of other means

of rapid communication. The recent return of the principal telegraph company to profitable operation, in part because of improved management and modernization of its plant and in part because of greater general business activity, is encouraging. This current improvement in the position of the industry affords an opportunity to develop information needed for sound, long-range planning to avoid future difficulties. We believe that sound management and vigorous technological development can contribute further to the stability of the domestic telegraph system.

3. The effects of the administration of the Communications Act of 1934 relative to reductions of telegraph service through the closing of unprofitable offices or through substitution of agencies need further study. Western Union maintains that the restrictive application of present legal provisions places an undue financial burden upon the company which it can ill afford to bear; representatives of labor contend that too great a degradation of service often has followed the substitution of agencies for offices.

4. Rates for the telegraphic services—telegram, teletypewriter exchange service (TWX), and private leased lines—are given regulatory approval without adequate knowledge of the costs of providing such services. Also, in passing upon long-distance telephone rates, the Federal Communications Commission should inform itself of the probable effect of proposed changes upon the position of the telegraph industry, and upon rates for local telephone service.

5. We have looked carefully into the proposal that the telecommunications industry should be divided clearly into two parts, one dealing exclusively with "record" communications, the other with communications by "voice." Our examination of this question has shown that such a dividing line is very difficult to draw, and we have concluded that the attempt to reorganize the telecommunications system on the basis of such a distinction might result in effects on the system going far beyond the initial intention of any such division. The main bone of contention today is the fact that the telephone company offers a form of record communications—TWX and private-line leases—which competes with message-delivery functions of the telegraph company. We note that Congress in 1943 amended the

Communications Act to permit acquisition of this form of service by the telegraph carrier. Thus the companies involved are free to negotiate an agreement to make this change, subject to approval by the Federal Communications Commission. We believe that this matter should be determined by the normal processes of negotiation.

6. The operation of leased domestic telecommunications networks by the Federal Government for the transmission of Federal Government messages is not, strictly speaking, competitive with the operations of commercial telecommunications companies. In its teletype networks, the Government is taking advantage of volume rates offered by the telecommunications companies in the same manner as can any other customer with large volume requirements. The Government should continue to take full advantage of the most efficient and economical rates and conditions of service which are available to any large user. While it is important that the Government seek the most economical means of handling its own communications, it also is of great importance that it continue its present policy of using privately owned facilities rather than building up a Government-owned competing network.

C. As to United States telecommunications abroad—

1. The Government should adopt the policy of maintaining the strength of the private competitive international communications system.

2. There should be a Government agency charged with the responsibility for implementing this policy.

3. Urgent recommendations have been made to Congress that legislation be enacted to permit companies in the international cable and radio field to merge. One of these calls for a single company to handle all United States domestic and international record communications, thus providing an integrated system. We find no imperative reasons calling for an immediate merger of these companies; we conclude, on the contrary, that recent improvements encourage a continuation of their present independent status. Moreover, in our judgment, a period of partial mobilization is not a good time to undertake a reorganization of these important components of our communi-

cations system. Our conclusions in regard to merger are based on conditions as we now find them and can project them. We recognize, however, that the situation can change and that the welfare of the communications system demands constant attention to the condition and stability of these companies. We are mindful of the strong conviction held by informed members of Congress and others that merger is desirable. We have ascertained that interested Government departments are divided in their views on the subject. While we believe that the national interest does not at this time require the repeal of existing prohibitions against merger, we recognize that changing conditions may provide compelling reasons for a merger later on. If so, the anticipation of them by adequate study and legislation will be essential. The kind of merger which might thus be indicated, as well as the timing of it, may be dictated not only by normal economic forces, but by the wisdom of the Government's own policies vis-a-vis the companies and by technological developments. Technological developments may in fact prove to be the conclusive factor in determining the future of these companies.

D. As to Government organization—

1. Fundamental changes in telecommunications require the overhaul of Government machinery for formulating telecommunications policy and for administering certain telecommunications activities in the national interest.

2. The Communications Act of 1934 established a system of dual control of the radio frequency spectrum. This dual control arises largely from the fact that the regulation of private telecommunications is a function of Congress exercised through the Federal Communications Commission, while the operation of Government telecommunications is primarily a function of the Executive. For example, the assignment of frequencies to military services is an exercise of the President's powers as Commander-in-Chief of the Armed Forces.

3. The Federal Communications Commission, though needing further strengthening, should continue as the agency for regulation and control of private users.

4. The President has exercised his power to assign frequencies through the Interdepartment Radio Advisory Committee, made up of representatives of the using Government agencies. While this Committee should continue as a forum to arrange the use of the spectrum in such a way as to avoid interference, it is not an adequate means for keeping in order the large portion of the spectrum occupied by Government agencies.

5. The Telecommunications Coordinating Committee has served a useful function and should continue as a mechanism for interdepartmental discussion of telecommunications matters.

6. The whole Government telecommunications structure is an uncoordinated one and will be even less adequate in the future than it has been in the past to meet the ever-growing complexities of telecommunications. A new agency is needed to give coherence to the structure.

7. There is need for a better determination of the division in the national interest of frequency space between Government and non-Government users. To achieve that end, close cooperation between the Federal Communications Commission and the proposed new agency will be necessary.

Recommendations

1. There should be established in the Executive Office of the President a three-man Telecommunications Advisory Board to advise and assist the President in the execution of his responsibilities in the telecommunications field. This Board should carry out the planning and executive functions required by the President's powers to assign radio frequencies to Government users, and to exercise control over the nation's telecommunications facilities during time of national emergency or war. It should stimulate and correlate the formulation of plans and policies to insure maximum contribution of telecommunications to the national interest, and maximum effectiveness of United States participation in international negotiations. The Board should recommend necessary legislation to the President, and advise him on legislation in the telecommunications field. The Board should

stimulate research on problems in the telecommunications field. It should establish and monitor a system of adequate initial justification and periodic rejustification and reassignment of frequencies assigned to Federal Government users, and, in cooperation with the Federal Communications Commission, supervise the division of frequency spectrum space between Government and non-Government users. While we believe that a three-man board is preferable, we recognize the possibility of appointing one man, a Telecommunications Adviser, to exercise the functions of the proposed board.

2. The Federal Communications Commission should be strengthened in funds and in organizational structure so that it can better carry out its duties under the Communications Act of 1934, and can participate more fully in Government-wide formulation of policy.

3. Appropriate units within the Department of State should be strengthened for the better performance of the functions of the Department relating to telecommunications.

4. Other Federal departments and agencies which have large telecommunications interests also should strengthen their machinery for formulating telecommunications policy, and for relating that policy to the other policies and programs served by telecommunications.

5. The Federal Government should step up its program for conducting and stimulating research in telecommunications, especially in those fields bearing on propagation and frequency utilization. Such studies would make it possible for the Government to take economic or technological changes promptly into account in revising policies for preserving the vigor of our private communications companies.

6. The proposed Telecommunications Advisory Board should give special attention immediately to the stimulation of technological developments which will still further strengthen our overseas communications. It should also formulate policies which would insure that these new technological developments will be used in behalf of the nation as a whole, its industry and commerce, its security, and its cultural exchange.

7. Policy of the United States should be based upon the following fundamental propositions:

a. The radio frequency spectrum is a world resource in the public domain. Our Government must adopt policies and measures to insure that this resource is used in the best interests of the nation, with due regard to the needs and rights of other nations.

b. The United States, almost alone among the nations of the world, relies on privately owned telecommunications companies to play the principal part in the country's telecommunications system. It should continue to be the policy of the United States Government to encourage and promote the health of these privately owned companies as a vital national asset.

c. The United States telecommunications system is essential to the national security, to international relations, and to the business, social, educational, and political life of the country. Hence, Government must remain alert to the problems of this system, and be prepared to support measures necessary to insure the continued strength of the telecommunications system as a whole.

Chapter II

PRESSURES ON THE RADIO SPECTRUM

The use of radio frequencies for communications has expanded tremendously since Marconi first bridged the Atlantic with his historic wireless signal on December 12, 1901. Research and development in the past quarter-century have been responsible for most of the additional utilization of the radio spectrum.

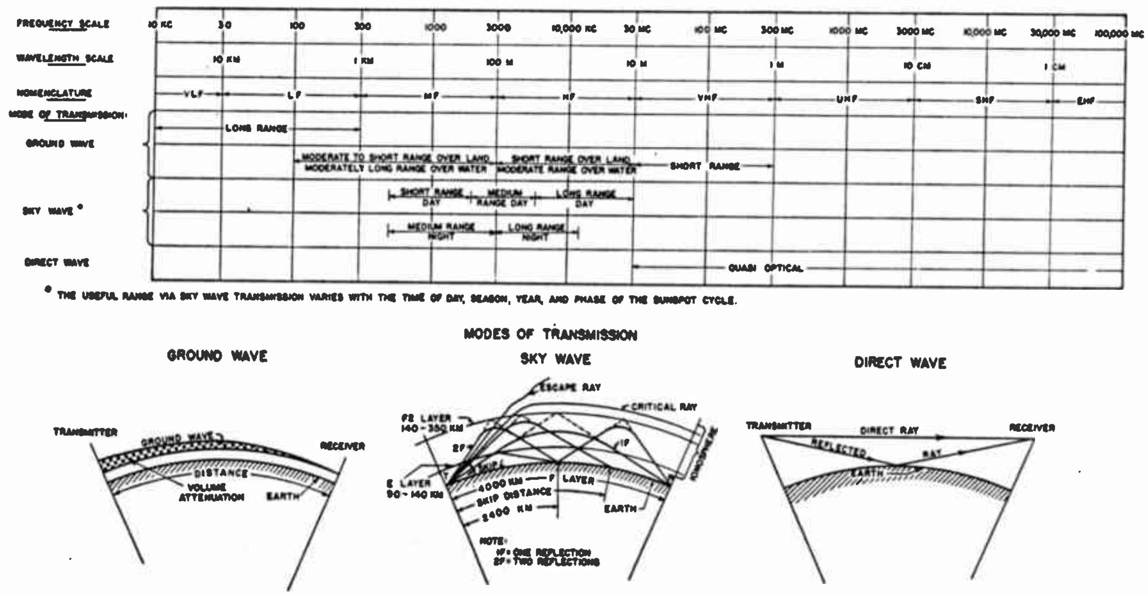
In the years immediately following Marconi's achievement, it was thought that only a few frequencies in the lower portion of the radio spectrum were suitable for communications and that they could be employed only for limited purposes.

The Berlin Radio Conference of 1906, for example, considered but two frequencies—500 kilocycles (kc) and 1,000 kc—and discussed them only for ship-shore telegraphy. By 1912, the time of the London Conference, use of the spectrum had broadened somewhat, ranging from 150 kc to 1,000 kc. In the early 1920's, even after broadcasting had begun, frequencies above 1,500 kc were still considered of little value for communications, but later in the decade new emphasis on high-frequency operations and a general spurt in demand for all communications led to a rapid exploitation of additional portions of the radio spectrum.

The extension of use of the spectrum is summarized chronologically in the following table:

Year	*Incident*	*Usable Radio Spectrum*
1901....	Atlantic bridged.	
1906....	Berlin Radio Conference......	500 kc and 1,000 kc
1912....	London Radio Conference....	150 kc to 1,000 kc
1927....	Washington Radio Conference.	10 kc to 23,000 kc
1932....	Madrid Radio Conference.....	10 kc to 30,000 kc
1938....	Cairo Radio Conference......	10 kc to 200,000 kc
1947....	Atlantic City Radio Conference.	10 kc to above 30,000,000 kc

A GLANCE AT THE RADIO FREQUENCY SPECTRUM SHOWING SOME OF THE BROADER FREQUENCY CHARACTERISTICS



NOMENCLATURE OF FREQUENCIES

FREQUENCY SUBDIVISION	FREQUENCY RANGE	FREQUENCY SUBDIVISION	FREQUENCY RANGE
VLF (VERY LOW FREQUENCY)	BELOW 30 KC	VHF (VERY HIGH FREQUENCY)	30 TO 300 MC
LF (LOW FREQUENCY)	30 TO 300 KC	UHF (ULTRA HIGH FREQUENCY)	300 TO 3,000 MC
MF (MEDIUM FREQUENCY)	300 TO 3,000 KC	SHF (SUPER HIGH FREQUENCY)	3,000 TO 30,000 MC
HF (HIGH FREQUENCY)	3,000 TO 30,000 KC (30 MC)	EHF (EXTREMELY HIGH FREQUENCY)	30,000 TO 300,000 MC

(PRESIDENT'S COMMUNICATIONS POLICY BOARD — FEBRUARY 8, 1951)

The development of so valuable a natural resource as the radio frequency spectrum is a matter of paramount importance. Despite technical and operational improvements the demand for frequencies has steadily crowded the supply within the usable spectrum. The use of this resource should have the most careful planning and administration within the United States and in cooperation with other countries. Unfortunately, guidance and administration often have been inadequate.

The Radio Spectrum

A determination of the possibilities for greater use of the radio spectrum is a very complex undertaking. Each use of it, whether an international broadcast carrying a news report thousands of miles, or the signal of a short-range navigation beacon making flecks of light on the receiver aboard a ship almost within shouting distance, requires the establishment of a channel in the spectrum. Contrary to the layman's opinion, the presently usable spectrum (10 kc to 30,000,000 kc) does not offer an unlimited number of channels. Consider the spectrum as a slice of the North American continent a hundred miles wide running straight from the East to the West Coast. Each channel may be thought of as a highway through that stretch of land. Some of the highways are narrow, some wide, but each must be somewhat wider than the vehicles using it.

Here a major danger to understanding of the problem arises. The radio spectrum embraces nearly 30 billion cycles. Standard practice refers to radio channels in terms of single frequencies. Hence hasty judgment easily assumes millions of frequencies as efficiently available and wonders why there should be any problem. Another glance at the slice of the continent and the highways will make the matter clear. A center line runs along each highway, just as a center frequency lies in each channel. The hundred-mile slice of the continent would accommodate a vast number of white lines—even though that number would have ultimate limits. To think of the white lines rather than of highways leads to confusion. The radio channel occupies more than the center frequency by which it is identified.

Each usable channel thus consists of a relatively small, but a specific, part of the radio spectrum. Depending upon the traffic it is to carry, it may be only a few cycles or several million cycles wide. In the language of engineering, the total channel width (or bandwidth) required for a transmission of energy is the number of cycles embracing 99 per cent of the total radiated power extended to include any discrete frequency on which the power is at least 0.25 per cent of the total radiated power. In double sideband emission (the type generally used in broadcast transmissions of intelligence today), the channel width is twice the departure (tolerance) of the actual operating frequency from the reference or assigned frequency plus twice the bandwidth required to convey the particular intelligence desired. The frequency tolerance is usually specified as a number of cycles which is a percentage of the reference frequency, and thus increases with the number of cycles representing the reference frequency. The specified tolerance usually is the best it is practical for industry to meet in the design of equipment.

If the total United States requirements in terms of channels of various widths were known, reckoning the spectrum possibilities would still be exceedingly difficult because of the complex and varied manner in which radio signals travel from the transmitter to the receiver. In radio propagation, energy fed to the transmitting antenna produces electromagnetic waves in the space surrounding the antenna. The energy radiated into space can be used to convey intelligence.

These waves travel away from the antenna with the velocity of light. There are three principal ways in which they may pass from transmitter to receive: 1. the "sky wave," which travels up to ionized layers in the earth's upper atmosphere (the ionosphere) whence it is reflected back to the earth; 2. the "ground wave," which travels along the earth without influence of the ionosphere; and 3. the "direct wave," which travels as its name implies, on the line of sight. Most long-distance radio transmissions consist of the sky wave and most short-distance transmissions consist of the ground wave. Many are a combination of all three.

Frequencies below about 300 kc (VLF and LF) are used for long-distance ground-wave transmissions, particularly in regions such as

Alaska where physical conditions make blackouts of skywave common. Frequencies from about 100 kc to 3000 kc (LF and MF) generally are used for ground-wave transmissions for moderate distances over water and moderate to short distances over land. During the night, frequencies from approximately 1000 to 3000 kc generally are suitable for sky-wave transmission up to about 200 miles; in daytime, frequencies from about 3 to 8 megacycles (Mc) usually are satisfactory for this distance. Long-distance sky-wave transmission generally is most effective with frequencies from 3 to 12 Mc (HF) during the night and 6 to 25 Mc during the day. Frequencies from 3 to 30 Mc are used for ground-wave transmissions for relatively short distances over land and moderate distances over water. Those from 30 to 300 Mc (VHF) are usually employed for short-distance ground-wave and direct-wave or optical path transmissions. Frequencies above 300 Mc (UHF, SHF, and EHF) are limited in use to distances not greatly exceeding the line of sight. However, there may be transmission to greater distances by way of the troposphere.

Simple arithmetic, obviously, is not alone enough to determine the possibilities of use of the spectrum.

Although the parts of the spectrum are not of equal usefulness for all purposes, each is in sufficient demand to give rise to allocation and assignment problems. Use of the high-frequency portion of the radio spectrum (4 Mc to 27.5 Mc) presents the most serious difficulty, because of the multiple applicability of this portion for medium- and long-distance telecommunications, tropical and long-distance broadcasting, and other services, and because of its international aspects. Further, frequencies outside these limits are in general not suitable substitutes. The possibilities of the high-frequency spectrum have to be measured in terms of possible circuits rather than frequencies since, in general, more than one frequency assignment is required for each circuit. The number of possible circuits which can be carved out of the spectrum depends upon the type of circuit desired (radiotelephone, radiotelegraph, etc.); the geographical location of the terminals; the time of day, season, phase of the sun-spot cycle; the amount of power used; the type of antennas used; atmospheric noise; questions of possible interference; number of circuits operated

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by the agency; efficiency and effectiveness of equipment and operators; availability and correct use of propagational data.

To provide continuous 24-hour-per-day service for the average circuit over a sun-spot cycle, it may be necessary to use five or more frequency assignments for a single circuit in one direction. As the number of circuits operated by an agency increases, the average number of frequency assignments required per circuit may decrease slightly because of greater freedom in changing frequency to avoid interference and multiple use of frequencies at different locations and for different path lengths. On the average, about three high-frequency assignments are required daily for each one-way circuit. Since communication usually is a two-way matter, most communications circuits require two one-way circuits and, consequently, two complements of frequency assignments. This dual need may not be encountered on light traffic circuits.

Further, on the average long-distance circuit requiring three frequency assignments of, for example, 6, 10, and 14 Mc for nighttime, transition, and daytime operation (over the midpoint of the path involved), the circuit cannot be maintained continuously unless a frequency assignment of each order is available. In practice, because of the greater requirements for frequencies below 8 Mc, the supply of channels between 6 and 8 Mc (taking into account possible multiple use of each frequency) determines the maximum possible number of 24-hour long-distance circuits. Fortunately the situation is not so bad as it appears at first glance, because of the propagation characteristics of the high frequencies, which have multiple use possibilities with geographical separation, generally as follows:

Frequency Range	*Possible Number of Duplications*
4 to 7 Mc	5
7 to 12 Mc	4
12 to 15 Mc	3
15 to 27 Mc	2

The actual number of separate and distinct channels available within any particular portion of the spectrum is not static but is fluid, increasing with improvements in equipment, operating techniques, circuit discipline, availability and proper use of propagational data, need, and willingness to accept a poorer grade of circuit. The actual separation between frequencies required to provide the same grade of service has been continually decreasing because of improvements in the stability and selectivity of equipment. It is not expected, however, that there will be much greater improvement in this respect. The allowance of spectrum space necessary between adjacent frequency channels to avoid interference is essentially constant throughout the high-frequency spectrum on a percentage basis but not on a kilocycle basis. Consequently, there are more possible usable channels between, say, 4 and 5 Mc than there are between 13 and 14 Mc.

In the exploitation of a limited entity such as the radio spectrum, it is essential that as the pressure for radio channels increases there must be established alert telecommunications management to assure equitable allocation of these channels. Further, it is essential that this management assure, insofar as is economically practicable, the use of the technical improvements in equipment and operating techniques for increasing the intelligence transmitted per kilocycle of spectrum space.

It is as difficult to evaluate frequency utilization as to determine the possibilities of the radio spectrum. Efficient utilization of radio frequencies can be obtained only if the user and regulatory agencies constantly keep watch over the use of frequencies. Only in this way can the regulatory agencies know which users make full use of their frequency assignments and which have too many frequency assignments. It is estimated that a thorough analysis and control program for the United States and possessions would cost $50 million a year. Such a program would envision the use of United States monitoring stations plus additional stations elsewhere throughout the world. As the demand for frequencies increases, the necessity for better frequency management will become greater.

There is no evidence that the United States has made any serious attempt previously to measure the utilization of radio frequency assignments by either industry or the Federal Government. There is evidence that other countries have done some work along this line.

The nations of the world have met periodically to conclude treaties which regulate the use of the radio spectrum, to obtain standardization of methods and procedures, and to minimize interference. Nearly all countries have imposed additional regulatory measures in their areas of jurisdiction to implement provisions of international treaties, to prevent domestic interference, and to obtain the most equitable distribution of frequencies.

The history of the international agreements through 1938 is summarized in Section 2 of the Federal Communications Commission (FCC) "Special Report on Frequency Allocation to the Communications Subcommittee of the Senate Committee on Interstate and Foreign Commerce, March 29, 1950."

World War II caused cancellation of the international telecommunications conference planned for Rome in 1942. As a result, the conference in Atlantic City in 1947 followed a 9-year period in which the nations did not get together to seek up-to-date agreements on world use of the radio spectrum.

U. S. Control of Frequency Allocation

The United States Congress has passed three major acts and established two commissions specifically to regulate various phases of communications. These acts were the Radio Act of 1912, the Radio Act of 1927, and the Communications Act of 1934, since amended. The commissions were the Federal Radio Commission and the Federal Communications Commission. Interested Federal Government departments and agencies formed the Interdepartment Radio Advisory Committee (IRAC), recognized by several presidents, and the Telecommunications Coordinating Committee (TCC) as voluntary coordinating groups. The effects which these actions have exerted in the assignment and use of radio frequencies are discussed in detail in Chapter V of this Report.

In the armed forces during World War II, frequency allocations were coordinated in the Frequency Allocation Committee (FAC) of the Joint (JCB) and Combined Communications Board (CCB) of the Joint and Combined Chiefs of Staff, respectively, and by organizations within each department. Since the war the JCB has been replaced by the Joint Communications-Electronics Committee (JCEC) within the Joint Chiefs of Staff.

Relationship of International and National Organizations

The international and national organizations concerned with telecommunications problems, plus various ad hoc committees and delegations to conferences, make up a formidable array of groups dealing with one or more phases of the problem. Inevitably, there are overlapping of responsibility and gaps in authority. Few persons understand this hodge podge. The complexity of the subject is indicated by the chart in Chapter V, which shows the international and United States organizations engaged in some phase of radio spectrum management or use.

Weaknesses in Present Organizations and Practices

Statutory Authority. The limitations of the Communications Act of 1934, as amended, and of the Commission created largely for its administration have been the subject of much consideration by Congress in recent years. The law was written when radio was not so highly developed and before the present demand for spectrum space had become acute. It established a dual system of allocations as between Federal Government and non-Government[1] users but provided no umpire. The FCC is empowered to assign radio frequencies to non-Government users and the President is likewise empowered to assign frequencies to Federal Government users, a power he exercises through IRAC. Each agency enjoys coequal authority over the entire spectrum.

Because of this dual authority over the same entity, it is essential that there be full coordination between IRAC and the FCC. As a member of IRAC, the FCC is afforded, on the one hand, an opportunity to comment upon all assignments to Federal Government stations. On the other hand, IRAC has an opportunity to comment upon proposed FCC assignments when the FCC considers it necessary to refer the proposal to IRAC. Final action by FCC does not require approval by IRAC, but the reverse is not true; FCC as an IRAC mem-

[1] Includes State and municipal government and all other than Federal Government users.

ber can veto action desired by other Government agencies. In practice, a spirit of accommodation has generally prevailed. But if there is disagreement between the FCC and IRAC, only the President can resolve the issue. Upon at least one occasion during World War II, he was called upon to do so. The fact that this system has worked at all is a credit to the good will and common sense of the members of both agencies.

National Policy. Both the FCC and IRAC have been and are greatly handicapped by inadequate national policy for the division and use of the radio spectrum. To cite one instance, lack of a clear policy concerning the use of radio for domestic point-to-point telecommunications during the war led to long, bitter arguments in IRAC. Such meager policy as exists and could be collected is included in Chapter VI of this Report. Much of it had not been previously reduced to writing.

Allocation Practices. There are several faults in the present frequency-assignment practice. Contrary to the public impression created by procedures for assigning frequencies for standard broadcasting and TV purposes, the FCC in general does not require rigorous justification for the assignment of frequencies for other services. IRAC does not require sufficient justification for the assignment of frequencies, has no authority to question any Government department's statement of need for a frequency, and is not constituted to do so. Assigning blocks of frequencies to be used by a particular agency on a national basis, without providing for their use by others in areas where the original assignee does not use them or is not likely to use them, is wasteful of frequencies and adds to the crowding of the radio spectrum. For example, there are many areas of the United States, Alaska, and Hawaii where there is little prospect of need or of support for the existing 12 very-high-frequency television channels, much less the greater number of ultra-high-frequency channels where use of these frequencies for other purposes would be in the public interest. Another example is the making of too many assignments for broad band transmission, when the broad band is needed only a very small percentage of the time. Waste also results from the practice of assigning many of a user's frequencies to all of that user's stations, although the frequencies are rarely used at more than one or two stations.

Frequency Assignment Records. It is fundamental that a storage and issuing agency maintain a catalog and adequate records of stock on hand and issued. In its management of the priceless radio spectrum, however, the United States has failed to maintain in one place adequate records of frequency assignments or deletions, or to publish a list of such assignments. The latest list available for public use was prepared by the FCC and reproduced by a private firm in 1949; it does not include the frequency assignments of the Federal Government agencies and is not now complete for the non-Government users. In the event a commercial user wishes to apply for frequency assignment for a circuit, he must search through this non-current public list, the International Telecommunications Union (ITU) Frequency List (even more out of date), come to Washington or retain the services of Washington consulting radio engineers to study the FCC records, and then file a complete application. This application incidentally gives notice to competitors that the requested frequencies are reasonably clear and available for use. The applicant has no opportunity to determine beforehand if a Federal Government department is using a frequency with which interference will result or if such department will raise an objection. If Federal Government objection is forthcoming, he must repeat the whole process.

Existing Situation

The rapid growth of telecommunications in the nine years between the Cairo (1938) and Atlantic City (1947) conferences led to greater pressure for radio frequencies. More and more countries went outside the Cairo service allocation bands, in derogation, to meet the increased requirements. The war, of course, prevented full coordination between countries to avoid and clear interference. This situation was further complicated by the decision of some of the warring nations, including the United States, to withhold international notification of new uses of radio frequencies and to reject any claims of prior rights for any country registering a frequency after 1939.

Recognizing early in 1943 that the end of the war would present many frequency-allocation problems because of withheld notifications, pent-up requirements, continuing large military requirements, and enormously expanding commercial aviation and other new activities, the United States began a consideration of postwar frequency allocations. The United States Atlantic City proposal in 1947 was the outgrowth of this preparatory work, of public hearings held in 1944 by the FCC, and of the discussions in Rio de Janeiro and Bermuda in 1945 and in Moscow in 1946.

The Atlantic City Table of Frequency Allocations was designed to provide essential radio services with adequate spectrum space. Frequency usage within these allocations was to be regulated by an engineered international list of circuit assignments which was designed to make the greatest use practicable of the radio spectrum.

From the point of view of frequency allocation, assignment, and use, the most far-reaching agreements at Atlantic City were: (1) revision of the frequency allocation table to provide, in the main, exclusive bands for the five basic functions—fixed, mobile, broadcasting, amateur, and radiolocation services; (2) changes in the amount of spectrum space allocated to these services; (3) procedure for the preparation of a new international frequency list on the basis of sound engineering principles; and (4) the adoption of the concept of an International Frequency Registration Board (IFRB) to register frequencies on a technical basis.[1]

The Provisional Frequency Board (PFB) was created to prepare in draft form a new international frequency list on a basis of these agreements, for submission to the Extraordinary Administrative Radio Conference scheduled for The Hague on September 1, 1950.

Upon approval of such a list for the Atlantic City Table of Frequency Allocations below 27.5 Mc, the IFRB was to commence its functions and a date was to be agreed upon for implementation. Postponed because of the international situation, the Conference is now scheduled to convene in Geneva on August 16, 1951, if that date is confirmed in April by the Administrative Council of the ITU.

[1] The IFRB and its work are covered in more detail in the "Final Acts" of the Atlantic City Conference.

The United States participated, as did the other nations, in the Atlantic City Conference and the work of the Provisional Frequency Board, performed under the agreements reached at that Conference, for the purpose of improving international telecommunications.

Conditions of unrest, cold war, and continuing international crises generated an atmosphere that was hardly favorable to the efforts of the PFB.

The Table of Frequency Allocations between 4 and 27.5 Mc adopted at Atlantic City in 1947 has not yet been implemented. Tentative plans have been prepared for the aeronautical and maritime services, and partially for the fixed services. The frequency list for the Table of Allocations between 150 and 4000 kc, which are for the most part regional in character, is ready within Regions 1 and 3 for final amendment and adoption. Region 2 (which includes the United States)has no regionally integrated plan as of February 1, 1951, even though it is about 85 percent competed below 2000 kc.

Experience gained from the past three years has highlighted the difficulties of implementation under the procedures envisaged at Atlantic City. Lack of plans and policy plays a major role in the difficulty experienced by all countries concerned to agree upon implementation. It was obvious to the President's Communications Policy Board, in view of the forthcoming meeting of the Administrative Council of the ITU in Geneva in April, 1951, and the impossibility for the Board to complete, in the time available, all the tasks assigned to it, that special steps would have to be taken to overcome this lack.

In view of the extreme importance of this matter, the Board considered it imperative that the United States re-examine the situation to determine:

(1) The current scope and magnitude of the United States interest in the Atlantic City Allocation Table below 27.5 Mc.

(2) The most workable methods by which the Table could be implemented in the light of changed world conditions.

(3) The course which the United States should advocate and pursue in the light of findings under (2).

Accordingly, in October and November of 1950, the Board discussed the problem with the Under Secretary of State, the Deputy

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Secretary of Defense, and the Chairman of the Federal Communications Commission. The Board proposed that these three officials constitute themselves into an ad hoc committee, and take responsibility for reviewing the political and technical difficulties contributing to the impasse, and for recommending workable policies for the Government to follow. The Board further recommended that this ad hoc group enlist the help of a small panel of especially qualified persons, who would make an objective appraisal of the factors of national interest involved, independent of the particular interests of any claimant agency.

The proposal was accepted, the ad hoc group was formed, and the independent panel was set up in January, 1951.

Demand for Radio Frequencies

The basic difficulty of the nations of the world in arriving at a satisfactory frequency list and means of implementing the Atlantic City Table is that of inflated demands for radio frequencies. The apparent shortage of frequencies thus engendered has been aggravated as each nation attempts to provide for future as well as present needs. The United States also has been handicapped, as perhaps have many other nations, by the necessity of remaining on a defense emergency basis which requires radio frequencies far in excess of peacetime needs.

The demand for radio frequencies has been growing steadily since the early 1900's. It was not until the beginning of World War II, however, that pressures became acute. During World War II the increased requirements of the Federal Government, in particular the armed forces, for radio frequencies were offset somewhat by the closure of a number of facilities and the release of the frequencies involved to the armed forces. Upon the termination of hostilities, the borrowed frequencies were returned piecemeal to the FCC, commercial circuits were reopened, and many new circuits were established. At the same time, the armed forces found it necessary to continue many of their overseas circuits, each of which required radio frequency assignments. The tremendous expansion of the use of radio by many countries which formerly had registered few frequency assignments, the expansion of the high-frequency broadcasting service, the expansion of the aeronautical service, and the reluctance to incur the expense of installing more efficient types of equipment have all contributed to the crowding of the high-frequency spectrum. In the ten years between 1939 and 1949, the number of discrete frequency assignments between 4 and 20 Mc made by the United States was doubled. The growth in listings in the ITU Frequency List between 4 and 10 Mc, shown in the table below, is indicative of the increasing demand for frequencies.

Number of Frequency Listings—ITU Frequency List

4-10 Mc

	1929	*1939*	*1949*
U. S. Government	92	377	3, 189
U. S. Non-Government	71	381	929
U. S. Total	163	758	4, 118
World Total	1, 698	6, 658	21, 456

The greatly expanded desires for the high-frequency broadcasting service—in the bands between 5.95 and 18 Mc, where the impact on high-frequency telecommunications is greatest—resulted in an increase in the Atlantic City Table of 450 kc or 43 percent over the Cairo service allocations in those bands.

Pressure on other sections of the radio spectrum also has become heavy. Established radio services such as that for aviation have been expanded rapidly to keep pace with the growth of the activities they support and because of intensified use of communications in those activities. Additional room in the spectrum has had to be found to accommodate these services. At the same time, new services such as television broadcasting have been brought out of the laboratory and have won public acceptance. Many entirely new users—railroads, taxicabs, and trucking companies, for example—have requested frequency channels. When the FCC held a public frequency hearing in 1944, approximately 30 different radio services were represented. Among them were the services concerned with the safety of life and property—the police and fire radio services, the aviation service, the ship service, and the forestry service. The total demands of these groups far exceeded the available spectrum space.

The parts of the radio spectrum where pressure causes the most serious concern are those in which international coordination and agreement are required. Principally, they are the portions having long-range characteristics, 4 to 27.5 Mc frequencies; the portions used by services such as the aeronautical service, where standardization of equipment and procedures is essential; and broadcasting in the standard band, which is of regional concern. Other portions of the spectrum are of national concern primarily and usually do not involve other countries, except to provide common systems.

Within the United States, dissatisfaction with efforts to meet the pressure has often led to statements that Federal Government users are responsible for the difficulty. Statements have been made by some that the Federal Government users get too large a share of the spectrum, to the detriment of industry. There are also contests within the Federal Government for the spectrum space now allocated for Goverment use.

These contentions raise two major questions. First, who are the Federal Government users and second, is the Federal Government's share too large? The first question is easy to answer, whereas the second is extremely difficult and can be answered only after an exhaustive objective study of United States communications, Government functions, and communications needs. Federal Government users are those departments and agencies which require the use of radio, or which can use radio to execute their functions more efficiently and economically. They include the Departments of Defense (Army, Navy, and Air Force), State, Commerce (including the Civil Aeronautics Administration), Treasury (including the Coast Guard), Justice, Interior, Agriculture, the FCC, and other agencies. The armed services, the Department of State, and the CAA are the largest Federal Government users of radio frequencies.

It is basic of course that the armed forces must have communications from the Department of Defense down to the most remote force. These communications may be thought of as command and administrative channels between the Army, Navy, and Air Force and the various field commanders, and combat or tactical channels between field commanders and their forces. Since the armed forces may be engaged in areas where existing communications to Washington are inadequate or unsuitable, they must provide their own. Usually, existing commercial international circuits cannot be used for reasons of control and security. For example, the foreign terminals of commercial companies, in most instances, are operated and controlled by foreign nationals or governments and all traffic handled may be subject to scrutiny and delay. Few if any of the proponents of greater use of commercial facilities for the transmission of Government messages advocate that military messages be routed through the commercial companies.

Where no interference to the flow of military messages results, the communications facilities of the armed forces are used to transmit traffic for other Federal Government departments and agencies and the Red Cross. It has been suggested that this traffic should be sent via commercial companies and that the cost would be less. The stated policy of the armed forces in this matter is that no increase in military facilities, equipment, or personnel shall result from the handling of other department and agency traffic and that such traffic will be accepted only on the basis of an official request by the department or agency concerned. Military systems must be designed with a reasonable amount of spare capacity able to absorb greatly increased traffic loads on short notice. The armed forces therefore feel that the handling of maximum traffic within authorized capacity is an asset to training and general preparedness. Under the conditions stated above, they question whether diversion of this traffic to commercial interests would result in reduction in Government costs or use of frequencies.

The Signal Corps, in addition to its defense functions, is charged with operating telecommunications within Alaska for public correspondence, where the possibility of financial return has not been sufficient to interest a responsible commercial company. Private enterprise furnishes some minor non-competing services. Because of Alaska's strategic position and the radio propagation conditions existing there, the number of frequency assignments required per circuit is much greater than for comparable circuits in other parts of the world. The need for radio in Alaska is also increased by the lack of transportation and of wire communications facilities.

The Corps of Engineers is charged by Congress with certain non-military functions in connection with river and harbor work and flood control, and uses radio in carrying out its mission.

The growing use of radio by the Department of State for broadcasting is the result of the international situation. The Department's use of radio frequencies is stated to be essential to the carrying out of its function under the United States Information and Education Exchange Act of 1948, "to promote the better understanding of the United States among the peoples of the world and to strengthen cooperative relations." International high-frequency broadcasting was selected as one medium to this end.

Under the Communications Act, Navy Department radio stations and apparatus are made available for the reception and transmission of press messages offered by newspapers published in the United States or its territories and possessions or published by citizens of the United States in foreign countries, and by United States press associations. The Act provides also for the use of Navy facilities for reception and transmission of private commercial messages between ships, between ship and shore, between localities in Alaska, and between Alaska and the continental United States. Both these services are subject to certain rate conditions, and it is provided that they shall be discontinued whenever the FCC notifies the Secretary of the Navy that privately owned and operated stations are capable of carrying them on. The Navy also furnishes a general broadcast service of weather, time, and hydrographic information to all shipping.

In addition to its defense functions, the United States Air Force operates weather flying squadrons for the collection of data for weather forecast, collects and broadcasts weather information, and furnishes communications to non-military aircraft in certain areas where civil facilities are not available. These services all require the use of radio frequencies.

Radio frequencies are used by the Department of the Treasury (Coast Guard) in providing marine navigational aids and safety services for shipping. The Coast Guard also operates the radiolocation service known as Loran. Transfer of these operations to commercial facilities could not be expected to decrease the total number of frequency assignments required.

The CAA is charged by Congress with the function of providing navigational aids and communications facilities as a public service for both civil and military aircraft. If these functions were turned over in whole or part to private enterprise, the over-all number of frequency assignments or the spectrum space required could hardly be reduced.

The FCC employs radio to connect certain of its remote monitoring stations. Instantaneous communication to all of these stations is essential at times to identify an unknown transmission or to obtain a "fix" on an aircraft or ship in distress. It is considered impractical to lease the facilities of a commercial company for this work or to turn over the function to a commercial company.

Thus we see that there is a large Federal Government requirement for radio frequency assignments, and that much of it is for services which would use the same amount of the radio spectrum even if they were transferred to private operation. Another substantial portion of it is for services which must for security reasons be operated as they are at present. The question may nevertheless be legitimately raised whether the demands have been kept to a minimum in relation to the tasks to be performed. Non-defense radio traffic of some Federal Government departments might in some instances be carried by commercial facilities.

In 1939 the major international common carriers were operating 138 circuits, whereas in 1950 the international common carriers as a group were operating 219 circuits (many at high word capacity) to more than 100 foreign cities. Since the war the FCC in general has followed a policy of granting competing companies circuits to the same foreign city.

Since but one United States frequency list can be presented to the IFRB, the Federal Government and non-Government frequency requirements should be accommodated within such a list. At present there is no national telecommunications policy under which the relative importance of particular circuits can be determined and the frequency requirements screened. This factor assumes even greater importance when one considers that the pressure on the radio spectrum is continually increasing.

The relative amounts of the spectrum used by the Federal Government and non-Government users are often compared. The question is asked whether the Federal Government has more high frequencies than non-Government users, and whether it has more of the spectrum than it needs. Available comparisons of high-frequency assignments have been made on the basis of the number of discrete frequencies assigned without regard to the band of emission and thus are subject to considerable misinterpretation in many instances. This is evident from the fact that one telephone channel with a band of emission of 10 kc occupies 100 times as much spectrum space as one telegraph channel with a band of emission of but 0.1 kc, yet each assignment counts as one frequency. A fairer method of evaluating the amount of spectrum space used by any agency is to take the sum of the bands of emission assigned to that agency. An analysis of the high-frequency spectrum between 4 and 20 Mc as of May, 1950, reveals that although the Federal Government agencies are allocated 1166 frequencies, they have but 4164 kc of the spectrum; whereas the non-Government users, with 833 frequencies (excluding international broadcasting with 38 frequencies and 380 kc of spectrum space and the amateurs with 700 kc of space), occupy 4324 kc of spectrum space.[1] A comparison of the spectrum space allocated to the Federal Government and the non-Government users for the fixed service by increments of 1 Mc follows, Table I.

Current channeling of the radio spectrum above 30 Mc does not permit a similar analysis. Neither are all the frequencies between 30 and 30,000 Mc equally useful for a specific purpose. Also, since

[1] The fact that the sum (9567.73 kc) of these assignments is considerably less than the 16,000 kc analyzed does not mean there is unassigned spectrum space. The entire spectrum is not available for assignment by the United States, but is shared with other countries. In addition an equally large part of the spectrum is used by the United States for transmission from foreign locations. Above 30 Mc the shorter interference range characteristics permit full use of the spectrum by the United States, except immediately adjacent to Canada or Mexico.

the frequency stability of equipment—its ability to remain on the assigned frequency—may be expressed as a percentage of the assigned frequency, the present channeling at, for example, 1000 Mc must be about 10 times the channeling at 100 Mc. It follows then that 100 Mc of spectrum space in the region of 1000 Mc will not provide as many channels as will 100 Mc of space in the region of 100 Mc. The

TABLE I

Frequencies and spectrum space assigned—Continental United States, Territories and Possessions (as of May, 1950)*

Mc	Federal Government		Non-Government		Shared	
	Number of frequencies	Total spectrum	Number of frequencies	Total spectrum	Number of frequencies	Total spectrum
		Kc		*Kc*		*Kc*
4	167	676.20	74	335.35	4	19.25
5	152	589.42	92	446.15	....	......
6	106	352.65	61	258.05	7	46.00
7	70	236.30	63	325.30	....	......
8	114	389.69	75	272.17	6	24.10
9	69	200.16	31	192.80	....	......
10	52	190.30	76	377.36	....	......
11	64	236.82	41	147.45	....	......
12	84	253.98	33	121.55	....	......
13	54	177.37	57	408.00	....	......
14	30	106.87	27	203.00	....	......
15	32	119.29	59	339.70	....	......
16	69	239.59	40	129.12	....	......
17	64	231.89	39	207.40	....	......
18	26	96.20	40	361.00	....	......
19	13	67.50	25	199.10	....	......
Total	1,166	4,164.23	833	4,323.50	17	89.35

*In the range 4–20 Mc, approximately 380 kc was used for international broadcasting (from the continental U. S. and Hawaii) and 700 kc was allocated to the Amateur Service. These assignments are not included in the preceding table.

relative division of the radio spectrum by megacycles of space between 30 and 30,000 Mc between the Federal Government and non-Government users is shown by Table II.

TABLE II

Relative Division of Radio Spectrum, Federal Government vs. Non-Government, 30 Mc to 30,000 Mc (based upon number of megacycles)

Portion of Spectrum Mc	*Amount of Space* Mc	*Federal Government* Mc	*Non-Government* Mc	*Shared* Mc	*Amateur* Mc
30–300........	270	113.56	119.44	24.00	13.00
300–3000......	2,700	*357.2	1,110.00	967.80	265.00
3000–30,000...	27,000	11,875.00	10,500.00	2,650.00	1,975.00
Total...	29,970	12,345.76	11,729.44	3,641.80	2,253.00

*Part of the space now allocated to the Federal Government is reserved for future use by civil aviation, at which time it will be shared with non-Government.

This table shows that, contrary to general belief, the Federal Government has exclusive use of 42.1 percent of the space between 30 and 300 Mc and but 13.2 percent of the space between 300 and 3000 Mc. The Federal Government has its largest percentage (44 percent) of any decade between 3000 and 30,000 Mc. If the analysis is based on a logarithmic frequency scale, a method more nearly reflecting the actual possibilities for derivation of channels in the spectrum, the relative division of the spectrum is as shown by Table III.

TABLE III

Relative Division of Radio Spectrum in Percentage, Federal Government vs. Non-Government, 30 Mc to 30,000 Mc (based upon logarithmic scale)

Portion of Spectrum Mc	*Federal Government* %	*Non-Government* %	*Shared* %	*Amateur* %
30–300....................	29.7	57.0	8.5	4.8
300–3000..................	18.8	43.6	28.3	9.3
3000–30,000...............	36.0	36.7	18.7	8.6
Total..............	28.2	45.7	18.5	7.6

While Table II shows the Federal Government has about 50 percent of the total spectrum space between 30 and 30,000 Mc, Table III shows that, based on the probable number of useful channels which can be derived, the Federal Government has allocated for its exclusive use less than a third of the probable number of channels which can be derived from the 29,970 Mc between 30 and 30,000 Mc.

The preceding discussion and comparison of the relative division of the spectrum is not considered complete nor final. It does, however, show that while the contention that the Federal Government has 50 percent of the useful radio spectrum is not strictly true, the Government does have a large proportion. This large use of so valuable a national resource demands adequate justification and the most careful management to assure its operation in full accord with national policy and to meet proved need in the best interest of the nation.

A current major problem involving the relative division of the radio spectrum and relative needs of the Federal Government and non-Government users is that of finding adequate space in the spectrum for television. There are now allocated for television broadcasting 12 very-high-frequency (VHF) 6 Mc channels as shown by Table IV.

TABLE IV

VHF Channels

Channel No.	*Megacycles*	*Channel No.*	*Megacycles*
2	54–60	8	180–186
3	60–66	9	186–192
4	66–72	10	192–198
5	76–82	11	198–204
6	82–88	12	204–210
7	174–180	13	210–216

The spectrum space between 470 and 890 Mc or 410 Mc was reserved by the FCC for ultra-high-frequency (UHF) television broadcasting channels. To date, experimental licenses only have been issued in the UHF band.

As the number of television stations in operation increased, it became evident from resultant interference between stations and from field measurements that the theory of optical or line-of-sight transmission was inadequate and that transmission of the television frequencies also took place by way of the troposphere. To assure that the national television allocation plan should be based on the soundest engineering foundation, the Commission released its order of September 30, 1948, suspending action on pending and new applications for permits to construct television stations until the technical phases of television allocation were resolved.

There is now pending the Commission proposal (Dockets Nos. 8736, 8975, 8976, and 9175) to reallocate the television channels to provide greater protection from tropospheric interference and to allocate an additional 42 six-megacycle channels or 252 Mc of space in the UHF band. This proposed plan, if adopted, will reduce the total number of VHF television stations in the United States and the number allocated to some areas. It will, however, provide for additional UHF stations. The proposed plan contemplates the allocation of both VHF and UHF television stations to the same community. There is little possibility that a UHF station can compete successfully with a VHF station. Within practical limits of power, a UHF station cannot serve as large an area as can a VHF station. For a considerable period after the UHF stations commence operation, particularly in cities where there are VHF stations, there will probably be few UHF receivers and consequently a limited audience.

These technical problems and the recent agitation to reserve a number of VHF channels for educational purposes serve to increase the pressure for more VHF channels for the rapidly growing television industry. Television interests are continually pressing for more spectrum space in the VHF band or immediately adjacent thereto. Assuming the validity of the need of television for the 42 additional channels adjacent to the present 12 channels, the problem becomes one of finding 252 Mc of continuous spectrum space between channels Nos. 6 and 7 and above Channel No. 13. Thus the question arises—Can the services now allocated these frequencies move, and if so, where?

An examination of the present allocations in the 86 Mc between 88 and 174 Mc reveals that the Federal Government is allocated 28

Mc; non-Government is allocated 30 Mc; and 24 Mc is shared by Federal Government and non-Government. Of the Federal Government allotment, 16 Mc is within the VHF band which the United States was forced to use to work with its allies in World War II and which is used for essential military purposes. Only the remaining 12 Mc offer any possibility at all for TV channels (2). Twenty of non-Government's 30 Mc are allocated to the culturally and technically important FM broadcasting. Even if all of this space were reallocated to television, it would yield only three channels. The 24 Mc shared by Federal Government and non-Government is used for aeronautical navigation and aircraft control, part of the SC-31 system of instrument landing of aircraft. A great investment of time, money, and development resources has been made in this system and it cannot be changed overnight. At best, then, not more than 5 TV channels could conceivably be allocated between 88 and 174 Mc. This would leave 37 channels or 222 Mc to go above 216 Mc, the present upper limit of VHF-TV.

Until January 1, 1952, when the agreement with the British to use the band 220 to 231 Mc for the British Radar Indicator System at United States gateways terminates, the nearest frequency above 216 Mc where a TV channel could start would be 240 Mc. Provision for 39 additional channels or 222 Mc would extend the TV band up to 462 Mc, well above the upper limit of theVHF band or 300 Mc, and into the present UHF-TV band. Such an allocation would necessitate moving and finding new space for the aeronautical radio navigation "glide path," also part of the SC-31 Instrument Landing System, meteorological aids, amateur, essential military services, and non-Government land mobile services. A number of these allocations and uses, for example, the glide path and meteorological aids, involve agreements and treaties with other nations and could be changed only with great difficulty and delay. Many of these allocations and uses involve great investments in time, money, and development resources which should not be wasted.

The investment in time, money, and development resources is proportionately important to the television industry. At the end of 1948 the estimated investment in tangible property of television stations and in receivers was $403 million. By the end of 1950, even though no new station construction permits were granted after September, 1948, there were 107 stations serving about 10.6 million receivers. Manufacturers have reached large scale production of receivers and during December produced 704,000 receivers. At the end of 1950 the estimated investment in tangible property of television stations and in receivers had grown to about $3.1 billion. Television net time sales for 1950 were estimated at about $84 million, compared with $28 million in 1949. This rapid increase in the number of receivers and investment makes much greater the impact of changes in frequency assignment. Even should additional channels become available between the present Nos. 6 and 7 channels, most of the older receivers would require adapters or converters to receive them. Delay in solving this problem multiples the difficulties and expense of making the necessary changes.

The problem of finding sufficient spectrum space for television has defied solution since the beginning of postwar planning in 1943. It can be solved only after the most careful study and weighing of competing needs of all concerned to arrive at a solution in the best national interest. By no stretch of the imagination could it be resolved by a temporary board. This major problem in itself emphasizes the need for a high-level permanent agency concerned with telecommunications, and with the resolution of conflicting Federal Government and non-Government requirements.

Summary

In the 50 years since its inception, use of the radio spectrum has grown into an enormous, vital, and complex activity connecting all countries with means of rapid communications. The radio communications systems which have developed are of major importance to the United States and to the world in the dissemination of information and maintenance of security and welfare, and in the conduct of business.

With the development and expansion of radio, the need for regulation, both national and international, has grown until the resulting organizations, treaties, and agreements have become as complex as telecommunications itself. Most of these organizations and agreements were devised to meet an existing need and not in anticipation of future needs. Frequently they were not established formally until long after they started to function. Once formalized, legislation and organizations to deal with telecommunications have not been kept current with this dynamic activity. The condition of "too little and too late" has held more often than not.

Existing organization to control use of the spectrum, one of the most valuable natural resources of the United States, is responsible for the establishment or continuance of dual control of this resource. This dual control has led to friction, misunderstanding, waste, and avoidance of responsibility. The organization is lacking in over-all policy guidance, and so complex that few persons understand all its ramifications.

Weaknesses in the present United States telecommunications organizations and lack of high national policy and direction have hindered the United States in the national control of telecommunications and in its international relations on telecommunications. The present telecommunications legislation and organization have failed to produce adequate direction, leadership, administration, and control and have fostered dissension between the Federal Government and industry. Many of these shortcomings could have been mitigated if not avoided.

The United States ratified the Atlantic City 1947 International Convention, including adherence to the Atlantic City Table of Frequency Allocations and associated radio regulations. Over three years later, there has been no acceptable position and plan for the implementation of this Table for more efficient and orderly use of this limited resource.

Experience of the past three years has highlighted the difficulties of implementation under the procedures envisaged at Atlantic City. Lack of plans and policy plays a large part in the inability of all countries concerned to agree upon implementation. It was obvious to the Board, in view of the forthcoming meeting of the Administrative

Council of the ITU in Geneva in April, 1951, that special steps would have to be taken to overcome the lack.

Accordingly, in October and November of 1950, the Board discussed the problem with the Under Secretary of State, the Deputy Secretary of Defense, and the Chairman of the Federal Communications Commission. The Board proposed that these three officials constitute themselves into an ad hoc committee, and take responsibility for reviewing the political and technical difficulties contributing to the impasse, and for recommending workable policies for the Government to follow. The Board further recommended that this ad hoc group enlist the help of a small panel of especially qualified persons, who would make an objective appraisal of the factors of national interest involved, independent of the particular interests of any claimant agency.

The proposal was accepted, the ad hoc group was formed, and the independent panel was set up in January, 1951.

Since the beginning of World War II, the allocation of radio frequencies has been increasingly an engineering and executive matter and not merely a record-keeping problem. However, the United States has failed even to maintain adequate records of frequency assignments. Sound frequency management could find ways of greatly reducing the pressure of the demand for radio frequencies, bringing it more into keeping with the supply. Under present management and policy, that pressure has grown to dangerous proportions. In the ten years between 1939 and 1949, the number of discrete frequency assignments between 4 and 20 Mc used by the United States was doubled. The growth of United States international long-distance broadcasting has greatly increased the demand for frequency assignments. In the critical world situation, there is little chance that the pressure will be reduced. The only solution is improved policy for the use of radio and better management of the radio spectrum.

Most of the differences of opinion between the Federal Government and industry users of the radio spectrum spring from lack of information concerning the relative needs of Government and industry for radio and the relative division of the spectrum. Previous estimates of the relative division of the spectrum have been based on non-representative methods of evaluation. Measured in terms of spectrum space rather than number of discrete frequency assignments, the Federal Government's share, though not so great as is commonly believed, is nevertheless large. While we do not know whether this use is out of proportion to the Government's responsibilities, it is apparent that it must have the most adequate justification and careful management if the greatest benefit is to be obtained from this resource.

Pressures for additional, suitable channels in the VHF region for television broadcasting pose a major immediate problem. By the end of 1950 the estimated investment in tangible property alone of 107 television stations and 10.6 million receivers amounted to about $3 billion. Television net time sales for 1950 were estimated at about $84 million. Most of the existing receivers will have to be modified or provided with adapters to receive additional channels regardless of their location in the radio spectrum. The great growth of television broadcasting, agitation for the reservation of VHF channels for educational purposes, and the discovery of tropospheric interference have demonstrated that 12 VHF channels are insufficient to meet the stated needs. The space desired for television is now used for essential services of the Federal Government and non-Government users with great investments in time, money, and development resources which should not be jeopardized by the peremptory moving of these services. In addition, the entire VHF band of 270 Mc is insufficient to accommodate the apparent desire for a total of at least 324 Mc.

This Board is of the opinion that a $3 billion, rapidly growing industry and a multi-billion dollar Federal Government investment for defense, civil aviation, and other essential non-Government services cannot long be left in this uncertain situation. Because of the rapid increase in the number of new, individually owned receivers—over 700,000 in December 1950—frequency allocations cannot be changed easily and mistakes reach far into the future. This major problem alone emphasizes the need for a high-level permanent agency concerned with telecommunications and with the resolution of problems involving the interest of both the Federal Government and non-Government users. No temporary Board could hope to resolve them.

The high-frequency portion of the spectrum between 4 and 27.5 Mc presents the gravest problem because of its multiple use for medium- and long-distance telecommunications, tropical and long-distance broadcasting, and other services, and because of its international aspects. Better and more far-sighted management and regulation might have averted some of these difficulties. The full possibilities of the radio spectrum have not yet been realized, but are being approached. Exploitation of the spectrum is not static but is fluid, increasing with the cooperation and good will of users, improvements in equipment, operating techniques, circuit discipline, need, and willingness to accept a poorer grade of service where necessary. It is not likely that the improvements derived from these measures will keep pace with the demands unless energetic steps are taken to establish an agency competent to assure the best circuit discipline, equitable allocation of frequency channels, and full use of technical developments.

Conclusions

1. Pressure on the radio frequency spectrum is steadily increasing as a result of the greater use of radio in telecommunications.

2. The means on which we have relied in the past for management of the spectrum are no longer adequate to resolve in the best national interest the problems produced by this increasing pressure. The current difficulty growing out of the search for suitable space for television broadcasting in itself emphasizes this inadequacy.

3. Measured in terms of spectrum space rather than in number of discrete frequency channels, the Federal Government's share of the spectrum, though not so great as is commonly believed, is nevertheless large. While we do not know that it is out of proportion to the Government's responsibilities, it must have the most adequate justification and careful management if the greatest benefit is to be obtained from it.

4. There is need for a continuing determination of the changing requirements of Federal Government users both among themselves and in relation to the requirements of other users.

5. The recent rapid worldwide growth of telecommunications, combined with the needs of the current national emergency, makes the resolution of these problems a matter of great urgency.

6. The resolution of these problems can be secured only through adequate, energetic management, which demands that the Government organize itself to take a comprehensive view of the telecommunications field.

Chapter III

UNITED STATES TELECOMMUNICATIONS AT HOME

Our normal industrial and commercial life is dependent upon the transmission of millions of messages and conversations each day. A rapid flow of information is necessary to the operations of Government. Public health and safety require rapid telecommunications. Quick transmission of communications in storms, floods, fires, epidemics, and strikes facilitates control, rescue, remedy, and restoration. In keeping with our traditions of a free press and public enlightenment, millions of words are transmitted annually for publication in print and by radio broadcast.

The persistence of the demand for telecommunications is shown by what happens when either of the two basic systems—the telephone and the telegraph—is unable to maintain service.

Between April 7 and May 20, 1947, a large number of telephone company employees were on strike. The public telegraph load in the month of April jumped more than 8 million messages above the previous month and produced additional revenues estimated at $7.4 million. Conversely, during a telegraph strike in New York City from January 8 to February 10, 1946, telegraph revenues dropped almost $3 million; a substantial portion of that amount went into abnormal telephone receipts.

National Defense. The country's telephone and telegraph resources provide the backbone of military telecommunications in time of emergency. The dependence of the armed forces upon the domestic telecommunications facilities of the United States is indicated by the following statement made to the Board by the Department of Defense:

"The nerve system of National Defense is the sum total of all communication systems that are available, operationally and potentially, for the prosecution of any emergency or war effort. The operational existence of nation-wide systems of rapid voice and record communications in peacetime is indispensable from the standpoint of meeting the wartime requirements of both the military services and the civil economy. As the intensity and complexity of warfare continues to increase, correspondingly greater demands will be placed on the communication systems of the nation from the standpoint of both circuit capacity and flexibility of operation. It is, therefore, considered in the vital interest of National Defense that there be maintained within the United States to meet that need as many nation-wide commercial communication systems as are economically feasible."

Civil Defense. Since the outbreak of the Korean action in June, 1950, the attention of the people and Government—Federal, State, and city—has been drawn to the need to plan and organize for civil defense.

For the over-all national interest there must be sound, modern, efficient nation wide systems for the rapid handling of telecommunications. From the standpoint of national security and civil defense, and in view of the possibility of sabotage, strikes, and catastrophe, duplicate systems should be maintained. Circuits between key points should not be concentrated in one cable, on one pole line, nor on one radio beam route. Nor should all terminal equipment serving key points be housed in one building. The dispersion and duplication of facilities should be considered in all telecommunications planning for the future. In planning the defense of our cities against bombing, we need to be sure that communication can be maintained both within and between cities, and that emergency means are available for communication with the populace by radio.

The Two Basic Systems. Although the telephone and telegraph systems do not offer precisely the same kind of service, each can and does serve at least as a partial substitute or replacement for the other for emergency telecommunication. Much of their outside plant facilities can be used interchangeably.

To provide the nation with an adequate system for both peace and war, these two basic networks for telecommunications should be developed and maintained. Practical considerations will limit the extent to which alternate routings will be feasible; but within these limits, each network should maintain separate inside and outside plant facilities with alternate circuit routes and terminals.

In the discussion which follows, the soundness of the nation's telephone system is apparent. On the contrary, the telegraph industry has passed through a succession of crises which probably are not over. Current improvements in the position of the industry afford an opportunity to develop information needed for sound, long-range planning to avoid future difficulties. We believe that sound management and vigorous technological development can contribute further to the stability of the domestic telegraph system.

THE TELEPHONE SYSTEM

The nation's telephone system consists of the Bell System with approximately 34 million telephones, together with some 5,000 independent telephone companies operating an additional 8 million telephones.

Units of the Bell System are the American Telephone and Telegraph Company, its general departments and its long lines department, 20 associated Bell operating companies, Western Electric Company, and the Bell Telephone Laboratories. The independent companies are served by a healthy manufacturing industry which has pioneered many important technical advances such as the use of dial telephones.

Description of the Bell System

The Bell System's primary undertaking is the furnishing of telephone service. Through interconnecting arrangements with the independent companies, it provides domestic local and long-distance telephone service to the 42 million United States telephones, and international telephone service with nearly all of the balance of the estimated 72 million world telephones.

The Bell System also leases to its clients telephone and telegraph circuits for various domestic services, maintains a teletypewriter exchange service (TWX), a telephone service to land mobile units and to aircraft, and telephone service to overseas points and to ships at sea, the latter divided into two categories, coastal harbor and high seas.

The Bell System in 1949 had total assets of nearly $11 billion and a gross annual revenue of nearly $3 billion. It owns or controls about 80 percent of the telephones and receives about 90 percent of the revenues of the domestic telephone systems.[1]

General reliance upon telephone service is so widespread in the nation that to itemize uses of it would be to labor the obvious. Its public acceptance is evidenced by the fact that there is now a telephone for every 4 persons in the country. For the present purpose, this over-all contribution of the telephone industry to the national interest is taken for granted, and other individual contributions are discussed specifically.

The Bell System and National Security

The national security requires that there be available, to expand or supplement the military communications system, a nationwide efficient, integrated, and diversified domestic telephone system operated by persons loyal to the United States. Defense planning should also include multiple automatic communications systems on a national grid to insure continuous operation if key points are destroyed. Further, we must plan for essential expansion, and stock critical materials.

Efficient, fully functioning civil operations which support the military operations are also necessary to a successful war effort. To function properly, civil activities such as commerce, manufacturing, transportation, exercise of Government, civil defense, fire protection, and public information must have adequate rapid communication.

In time of national emergency, the communications networks must be expanded to include many new manufacturing plants and military posts. Communications must be provided for fire protection and guard systems for these plants and posts. Convenient telephone pay stations must be furnished for workmen and military personnel. Frequently, trunklines as well as local facilities must be expanded.

[1] Attachment III–A gives selected Bell System statistics which reflect the size, growth, and importance of the Bell System and some comparative data with the totals for all telephone carriers for 1949.

In World War II the Bell System provided 400,000 miles of inter-city leased circuits and 2,600 teletypewriter stations, built new facilities for over 3,000 military establishments, and provided 600,000 telephones for them. Aircraft warning service was provided for 58 Information and Filter Centers, handling Army Flash Calls at a peak rate of 30 million annually.

During World War II public telephones were installed at 201 camps housing over 5,000 men each, at 376 attended locations involving about 3,000 attendants and nearly 19,000 telephones. Telephone facilities were also provided for 88 hospitals with 1,000 or more beds, with 102 attended locations, 584 attendants, and over 4,600 telephones. The demands of World War II increased the telephone calls per month from 2.8 million in 1940 to 3.3 million in 1945, an increase of 18 percent. To meet these requirements, the Bell System expanded from 17 million telephones, 89 million miles of wire, and $4.7 billion invested in plant in 1940 to 22 million telephones, 99 million miles of wire, and $5.7 billion invested in plant in 1945.

The Bell System provides trained telecommunications personnel. In World War I, 14 telegraph battalions were formed with men from the Bell System. In World War II, communications specialists cadres were designated to provide a nucleus of experienced telephone men within each of 380 Signal Corps units. For these units 4,250 officers and enlisted men came from the Bell System. Over 400 additional Bell System specialists volunteered under this plan for designated commissioned staff positions in the Signal Corps. In all, nearly 70,000 men and women from the Bell System entered the military services during the war. Four affiliated units were ordered to active duty in 1950 after the start of the fighting in Korea. In addition, many trained civilian telephone operators replaced military operators.

During World War II the Bell System operated 26 plant schools, training 7,235 men for the armed forces.

The system's laboratories helped materially in the development of new tools of war. Telephone research conducted in peacetime proved to be valuable in many military problems, enabling the Bell laboratories to make major contributions to such projects as gun directors, rockets, torpedoes, guided aerial missiles, detection of submarines and magnetic mines, airplane crew trainers, propagation of microwaves, and microwave relay equipment. In all, over 1,200 military research projects were carried through to completion.

The extensive resources of the Bell System also meant that large quantities of critical items of materials and equipment could be stored for war emergency use.

The extensive manufacturing facilities of the Western Electric Company, a Bell System subsidiary, made it possible to produce large quantities of urgently needed equipment for communications and military purposes.

The Bell System and the National Economy

The Bell System in 1949 received for its domestic communications services nearly $3 billion. It paid out about $2 billion in wages and salaries to some 600,000 employees, and about $346 million in taxes, and collected for the Federal Government about $444 million in excise taxes. Operating disbursements of about $500 million, in addition to wages and taxes, were made to other companies and individuals. Dividends of about $216 million were paid to nearly a million stockholders. Capital expenditures of over $1 billion were made for expansion. The system's major contribution to the national economy, difficult to measure in dollars but nonetheless real, is the increase in business attributable to the convenience of rapid communication.

The network of the Bell System and the connecting companies provides widespread facilities for distribution of international wire and radiotelephone messages. These facilities connect the nearly 42 million telephones in the United States with nearly 30 million telephones in 86 other countries of the world. In 1949 about 620,000 overseas and highseas telephone calls were completed, producing about $7 million in revenue.

Trends in the Bell System

Technological Trends

The domestic telephone communications systems have made many mechanical and technical advances which have improved the quality and speed of service. The "hearability" of the telephone has been improved about four-fold in the past 20 years through the use of newly developed equipment and techniques. Greater use of automatic equipment has reduced the average time of completing toll and long-distance calls from 1.8 minutes in 1948 to 1.5 minutes in 1949, with 95 out of every 100 being completed while the calling party was holding the line.

Dial telephones have been increased to 73 percent of the total. New type toll switching systems enable customers in large areas to dial their own calls directly to other cities beyong their local calling areas.

The provision of the teletypewriter exchange has made it possible for any one teletypewriter to be connected to any other of the 25,000 teletypewriters in the system.

Coaxial cable and microwave relay have appreciably increased the available channel capacity and improved in great measure the quality of electrical transmissions.

Manual switching or relaying has been greatly reduced through the use of improved automatic switching systems. Toll dialing equipment is now in operation to permit operators to dial toll calls straight through on 25,000 toll circuits to over 600 cities or towns.

Economic Trends

Since 1939 average hourly earnings in the telephone industry have increased 70 percent and costs of materials have increased more than proportionally. For instance, in 1949, electrolytic copper was 2.2 times its 1939 cost, zinc 3.3 times the 1939 cost, and lead 3.38 times the 1939 cost. These rising costs have been offset in part by operating economies and by local rate increases.

From the early days of the telephone, revenues from local service have generally followed business conditions, lagging behind somewhat and fluctuating to a lesser extent. Through the years there has been an increase in the number of local calls that can be made without increasing the subscriber's monthly bill.

World War II started another cycle of rising costs which the company has sought to offset by requesting increased local rates. With earnings below the average of the previous 25 years, the Bell telephone companies, faced with rising costs and wages and the need to expand plant facilities, in 1946 secured local rate increases in 8 states and requested rate increases in 16 others. By 1949 increases in local rates had become effective in, or had been requested in, practically every state. Though increases in local telephone rates have varied for different classes of service in different places, the increases requested (including those already granted) averaged about 20 percent of the Bell System revenues.

The United States Treasury Department 1947 study entitled "Excise Taxes on Communications" summarized the subject of rates as follows:

> "Rates charged on local telephone service vary among localities and are subject to differences in State regulatory practices. Following increases made after World War I, there were no important changes in basic rates until 1946. There was a slight decline between 1935 and 1941, but no change in prices to consumers during the war except for the increase in excise tax. Although basic rates remained substantially unchanged for a long period, the rate of return permitted to be earned has shown a long-term decline. Rates probably were not reduced during the period between the wars because the increase in the demand for local telephone service apparently leads to higher unit costs which the companies have only been able to offset by technological developments and increased employee work loads. Because of higher costs, rates are now being increased."

Since 1919 interstate long-distance rates have been periodically reduced, under the jurisdiction of both the Interstate Commerce Commission and the FCC. Over the period, 14 reductions have been made. Most recent action was taken on January 19, 1951, when the FCC directed that A. T. & T. and its 20 affiliates in the United States file a statement before March 23 on the basis of which decision would be taken on a possible interim reduction of long-distance rates. Hearings to determine whether existing rates are unjust, unreasonable and burdensome were scheduled to begin April 16.

The Commission's order was taken as occasion by the National Association of Railroad and Utilities Commissioners (NARUC)—representative of the state commissions whose responsibility is for intrastate rates as distinguished from the interstate toll rates with which FCC is concerned—to petition to intervene and seek enlargement of the issues. The NARUC move was strongly endorsed by Senator Ernest W. McFarland of Arizona, Chairman of the Communications Subcommittee of the Senate Interstate and Foreign Commerce Committee. In a letter to the Commissioners, January 30, 1951, Senator McFarland said in part:

"The problem of disparity in telephone rates has disturbed me for a long time although I appreciate that it is commendable on the part of the Federal regulatory agency to be vigilant in attempting to avoid an inordinately high return to the American company on its plant investment. The trouble is that the general public does not realize that every move that is made to reduce long distance toll rates results directly or indirectly in an eventual increase in local exchange rates and in intrastate toll telephone rates. . . .

"Some of the examples . . . of differences between an interstate toll rate and an intrastate rate for an identical or nearly identical mileage are almost fantastic. For instance, the three minute station-to-station rate between Florence and Yuma, Arizona, is $1.05 while the rate for the same service between Yuma and Winterhaven, California, is 80¢ although the telephone route mileage is identical, namely 197 miles. . . .

"We all know that the nationwide telephone plant is a complex and closely integrated structure and that over the years no separation formula has been wholly fair or wholly satisfactory either to the American company and the associated companies or to the 48 state commissions. But one thing is clear to all of us—there would be no long distance toll business without the local plant and the local telephone instrument in each home and business. . . .

"The fact remains that while the Commission (FCC) has ordered long distance rates lowered, local exchange and intrastate rates have steadily increased. Moreover, while wages and other general expenses of doing business have increased tremendously, those who use the long distance actually get cheaper service. In my judgment, this anomaly cannot be explained away by merely insisting that greater volume of long distance business has brought this about since it is clear without any question that the basic volume increase is due largely to the tremendous expansion of local facilities."

The Western Union Telegraph Company also filed a petition to intervene, on the ground that a substantial reduction of long-distance rates might adversely affect its financial stability. The General Services Administration of the Federal Government also petitioned to intervene, citing that the Government is among the largest single customers of the Bell System.

Total taxes on the Bell System's telephone service in 1949 aggregated nearly $800 million—an increase of about $100 million over 1948.

Since the early days of the telephone, the gross revenues of the telephone systems and in particular the Bell System have increased rapidly except for a temporary regression following 1930. By about 1940 the Bell System had again reached the revenue level of 1930, and the impetus of World War II increased its earnings even more rapidly until in 1949 its gross revenues were nearly $3 billion.

The capital investment, operating expenses, and taxes showed the same general rise from 1925 to 1950, increasing more rapidly since World War II. As a result the percent return on capital of the Bell System (including Western Electric) showed a steady decline from a high of 8.7 percent in 1927 and 1928 to 4.3 percent in 1933, then fluctuated between a high of 7 percent in 1940 and a low of 4.5 percent in 1947, reaching 4.9 percent in 1949. The average return for the 25-year period was 6.26 percent.

Through 1931 the A. T. & T. never failed to earn its dividend. In the next 17 years, there were 9 years when the dividend was not earned but was paid partly out of the surplus accumulated over the years. The Bell System at the end of 1949 had a surplus applicable to A. T. & T. stock of over $340 million.

With minor exceptions there has been for some years a monopoly of telephone service in each area. Rates and services, instead of being controlled by competition, are now regulated by state commissions and the Federal Communications Commission. Although there are more than 5,000 telephone companies in the United States, the Bell System is the dominant unit in the domestic telephone communications field. Actual ownership of the Bell System is now in the hands of nearly 1 million stockholders.

General Trends

The growth of the Bell System reflects the importance of the telephone to United States industry and social life.

The requirements of the public for rapid, flexible record communications led to the expansion of the Bell System's private line service, begun before 1890, and its teletypewriter exchange service (TWX), started in 1931. Together these total nearly 48,000 stations, with revenues of $46 million in 1949.

Mobile radiotelephone service for ships and small craft has existed for a number of years. State and city police have used private mobile radiotelephones since the early 1930's. The second world war increased the demand for communications in all circumstances. In response to this requirement, the Bell System in 1946 inaugurated the new domestic public land mobile radiotelephone service, providing for connection via radio and wire with any other telephone in the nation. By the end of 1949 it was available in 144 areas, and on certain railroad trains.

Influences Affecting the Bell System

Public demand is a powerful instrument in shaping the policy and operations of the Bell System. Demands for better quality and faster and cheaper service, and the company's pride of performance, have led to many technical and operational improvements. Subscriber objection to delays in completion of toll calls and the ever-increasing volume of calls stimulated the establishment of the toll dialing system. Demands for long-distance telephone service beyond the capacity of existing plant facilities led to the development of the carrier system, the coaxial cable, and the microwave radio relay.

Through arrangements between Western Union and the telephone company, a telephone subscriber may dictate a telegram to the Western Union operator and have the cost charged to the monthly telephone bill. The telephone company collects the charge, deducts its commission for the work performed, and pays Western Union. Conversely, Western Union frequently makes delivery of telegrams by telephone. In addition to the normal telephone service furnished to Western Union, the telephone company also leases considerable circuit mileage to Western Union for its use. At the same time, the Bell System competes with Western Union for record communication business through its teletypewriter exchange service, private line teletypewriter, and some telegraph service.

The Bell System is closely related to other domestic telecommunication systems such as are used by broadcasting, airlines, and other companies, because it leases to them the circuits which make these systems possible.

THE TELEGRAPH SYSTEM

Rapid record delivered telegram service in the United States is provided principally by the Western Union Telegraph Company. The service involves the carrier's taking possession of a message, charging for it on a word-count basis, and conveying it by rapid means to the addressee. The business came into being something over a century ago, displacing the Pony Express familiar in American legend. During the past twenty years, the telegraph business has undergone a number of economic vicissitudes. In an effort to overcome these, the Congress in 1943 permitted merger of the Postal Telegraph Company with the Western Union Telegraph Company. As the company neared the start of its second century, increased business and industrial activity in the United States and increased alertness and aggressiveness on the part of Western Union's management combined in April 1950 to change the earning status of the company for the better. Western Union in 1950 showed an encouraging net income after several years of deficit operation.

The troubles of the telegraph industry gave concern to Congress as many as fifteen or sixteen years ago. The 1943 merger action stemmed from those troubles. Recommendation has been made from time to time that a thoroughgoing long-range study of the problems of telegraph communication should be made by appropriate Government authority. The most recent such recommendation was that of the Federal Communications Commission in 1946, but the necessary funds were not made available by Congress. Present performance and immediate prospects, however encouraging, do not eliminate the need for such a study.

Description of Western Union Telegraph Company

Since its incorporation in 1851, Western Union has gradually developed into an integrated nationwide telegraph system through purchase, lease, or stock ownership of more than 500 telegraph properties. The merger of the Postal Telegraph Company with Western Union in 1943 virtually completed this process. The system operates as a regulated monopoly under the provisions of the Communications Act, which places regulation of interstate and foreign communications by telephone and telegraph, both wire and radio, in the hands of the Federal Communications Commission. Purely intrastate wire communication does not fall within Commission jurisdiction.

The provisions of the Act require that common carriers subject thereto furnish service at reasonable charges upon reasonable request. Without Commission approval, carriers may not construct or acquire interstate lines or curtail or discontinue service. All charges, practices, classifications, and regulations must be just, reasonable and non-discriminatory. Common carriers file with the Commission tariff schedules for regulatory purposes.

Western Union as it operates today under this public sanction webs the nation with more than a million miles of open wire and almost 380,000 miles of wire in underground and overhead cables. This outside plant, directly or through tributary lines of telephone companies, serves almost 30,000 public telegraph agencies and offices and 22,000 private customer offices scattered over the nation. In addition, 42 million telephones in the United States are available to the subscribers for the filing or receipt of telegrams.

Over 41,000 employees received more than $125 million in 1949 for operating and maintaining this system. More than 174 million domestic telegram messages were handled in 1949, producing revenues of $141 million at the average toll of about 82 cents per message. Net investment in this communication plant runs over $172 million.

The largest customer of Western Union is the United States Government, which as a single user, provides more than 3 percent of the total domestic operating revenues of the company.

Western Union offers a number of telegraph services, including straight telegram, serial, day letter, night letter, telegraphic money order, telemeter service, leased wire, custom-built telegraph systems, commercial news service, and illustrated telegram service. In addition, it handles correct time service, messenger errand service, messenger distribution service, collection and remittance service, and American Express money orders and travelers' checks.

While, historically, Western Union has been and still is a wire system, it has recently begun to utilize radio in several applications. One of these is the use of microwaves (radio beam) to replace wire for trunkline channels. Another is the "telecar service" which involves pickup and delivery of telegrams by cruising automobiles connected by radio with the central office. Still another is the marine reporting service, involving the reporting of vessels to the central office by radio from pilot vessels.

By far the bulk of the traffic today is recorded on automatic typewriters called "teleprinters" or on typing reperforators. The old-fashioned manual Morse system is disappearing, while the facsimile method may emerge as a fully automatic device requiring little operating labor. As the name implies, this method aims to reproduce at the receiving end the material as offered for transmission—written, printed, typed, or drawn matter.

With the United States today a leader in world affairs, the need for efficient international communications is obvious. International telegraph communications originate at or are destined to places all over the United States. Hence a pickup and delivery facility is necessary. This facility is provided for the general public by the Western Union's nationwide system of wires and offices. The system serves not only Western Union's overseas cable service but those of other overseas cable and radiotelegraph companies. However, in gateway cities most of the commercial overseas companies handle a large percentage of their own pickups and deliveries.

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With a few exceptions, the armed forces of the United States do not construct or own domestic wire telegraph networks. Their domestic telegraph requirements are met by normal telegram service provided by Western Union and by lease of facilities from the telegraph and telephone companies.

Potential demand for telegraph services in any future war may be gauged by the demands made upon the telegraph industry in World War II. Federal Government domestic messages rose from 8.5 million in 1937 to more than 15.5 million at the war period peak in 1943, or almost double. In addition, the armed forces began to lease telegraph lines from Western Union in significant volume in 1938 and these facilities reached a war peak of 1,800 miles in 1944. The growth of such service has been accelerated in the postwar period and had reached 78,000 miles in September 1950.

The telegraph industry also provides an immediate source of "know-how" and facilities to meet special communications requirements of the military. In World War II, Western Union was called upon to handle more than 7,000 special telegraph projects for war purposes. These included development of special equipment to meet military requirements, adaptation of existing equipment, and many research assignments.

In peacetime the telegraph industry provides a ready reservoir of trained communications personnel. More than 10,000 employees of Western Union and Postal entered military service during World War II. Assuming that the bulk of these performed military duty for which they were already trained, the military was thus relieved of much training effort. The industry not only had to train additional personnel to handle increasing war business, but also had to train replacements for those who entered the armed forces.

Well over $5 million was expended by the telegraph companies to set up and operate training organizations. Taking advantage of the school facilities, the military fitted hundreds of members of the armed forces into these groups, in order to reduce its own mammoth training job.

Apart from huge increases in the carriage of messages, special circuit facilities and equipment were supplied to the Department of State, the Federal Bureau of Investigation, the Maritime Commission, the Office of Strategic Services, the Office of War Information, Army, Navy, Army Anti-submarine Control, British Admiralty, British Air Commission, other governmental agencies, and many large basic war industries. Special telegram services were created, including the casualty message procedure, the Expeditionary Force Message, the Homeward Bound Message, and the reduced rate telegraph money order.

Telegraphic communication "know-how," research, and development contributed to the solution of many military communications problems. Special automatic equipment and circuits were involved, such as radio multiplex, telekrypton, telefax, varioplex on ocean cables, multiple film scene selector, reperforator switching, means for generation of additional channels from existing wire line plant, etc. While some of these activities produced results applicable in peacetime, others tended to defer the normal long-range program of modernization.

Western Union and the National Economy

Significant measures of Western Union's participation in the domestic economy are the following rounded figures for 1949:

Total net investment in communication plant	$172,000,000
Operating revenues	$171,000,000
Total telegraph offices	29,400
Telegraph revenue messages handled	174,000,000
Number of employees (October 31, 1949)	41,600
Total employee compensation	$125,900,000
Total interest charges (domestic and overseas)	$3,150,000
Federal and State taxes paid by company	$5,775,000
Federal excise taxes paid by customers	$36,500,000

Trends in Western Union

Technological Trends

Transmission of domestic telegraph messages for many years was accomplished almost wholly by the manual method, employing the Morse "dot-dash" code.

In 1915 Western Union began a series of technological improvements with the introduction of the "automatic multiplex telegraph system" on its trunkline network. In this system the circuit is "multiplexed" into two or more channels, each of which can carry a message in two directions simultaneously. The system is "automatic" in that the sending operator, by operating a keyboard, punches a tape which is automatically fed into the system and the transmission is automatically received on an electric typewriter at the receiving end of the channel. The new system improved accuracy and speed of service, raised the productivity of operators, and obviated large capital expenditures which would otherwise have been necessary to carry increasing volumes of traffic with equal or improved quality of service.

In 1926 a modified version of the automatic system, known as the "simplex printing telegraph system," was applied to circuits connecting main offices to branch offices and to smaller independent offices in other communities. By 1928 most of the telegraph companies' branch offices had been so equipped. At this point, to round out the automatic system, the telegraph companies began making installations of this type in the offices of larger customers.

Because, with little instruction, an ordinary typist could send and receive telegrams on them, these electric telegraph "typewriters" were well received by the larger users of the telegraph service. The installation of simplex printers made it unnecessary for a customer who wanted a rapid service to employ a Morse operator. The telegraph companies were also interested in avoiding the delay and expense of messenger pickup and delivery. Today more than 20,000 such printers are in customers' service and many thousands more are in use in telegraph offices operated directly or indirectly by Western Union itself.

Even with the automatic system, a telegram moving across the country had to be typed manually from two to six or even seven times en route. To eliminate such labor-consuming, delaying, and error-producing manual re-transmissions, the company initiated a limited program of reperforator switching at its larger relay offices. By 1943 several of its larger offices had been converted to this type of operation, but, because of war conditions, the program was more or less suspended. Following the merger of Postal with Western Union in the fall of 1943, an extensive program to modernize and mechanize the combined operation and plant and to improve telegraph service was planned.

So far as reperforator relay switching is concerned, the program, originally scheduled to be completed in seven years, was speeded up in January 1946. The dire necessity for reducing costs and improving handling methods accelerated the reperforator switching plan to the extent that the objectives sought at the time of merger are today practically realized. In this system each area relay center has direct circuit connections with every other area relay center, thus avoiding relays through intermediate centers.

In the early 1930's Western Union undertook to investigate the possibilities of facsimile to transmit and record reproductions of printed, typed, and hand-written copy. The system was tried on both intercity trunk circuits and on short lines between the customers' and branch offices and main offices. By 1934 it was determined that, in its then state of development, fascimile had a speed in words per minute far below that of other systems in use at the time. Nevertheless, developmental work continued and some installations were made until the project had to be suspended during the war.

Emerging after the war was the "desk-fax," a small and relatively inexpensive machine capable of sending and receiving messages. The operation requires no skill. It is fully automatic once the message blank is placed in the machine and the starting button depressed. As part of Western Union's postwar program, more than 2,000 desk-fax units have been installed in customers' offices. The company's management believes that the desk-fax promises to solve, in part at least, the perplexing problem of quick and economical pickup and delivery of telegrams.

To assist in the solution of the pickup and delivery problem at branch and "agency" offices, installation of transmitting and recording facsimile equipment designed to handle a substantial volume of telegrams is part of Western Union's current program of plant improvement.

One of the heavy expense burdens borne by the communications industry is the construction and maintenance of its trunk circuit plant. Over the years, Western Union has continued the erection of stronger and better pole lines, replacing the less desirable and less efficient iron wire with copper, and substituting underground cable for aerial lines in congested areas.

In 1934 Western Union commenced the use of carrier current telegraphy in its network of trunk facilities. Carrier operation permits the derivation of a multiplicity of circuits from a smaller number of wires. Even when the cost of the terminal equipment necessary to derive the additional circuits is deducted, the savings over the construction of new wire lines are high.

By 1944 carrier current telegraph had developed to the extent that installations between New York and Washington provided 36 high-speed two-way telegraph circuits on two physical wires. By this time, it was clear to Western Union that carrier operation was a vast improvement over the "ground return" single wire trunk circuit operation then in general use.

Western Union's wire plant in 1930 comprised 219,000 miles of pole line and over 1.5 million miles of open wire. The merger of Postal with Western Union in 1943 added 31,000 miles of Postal line and 334,000 miles of wire, but, because of its physical condition, most of this equipment was dismantled after World War II.

By 1950 Western Union's wire plant had contracted to 205,000 miles of pole line (of which 98,000 miles are railroad lines shared by Western Union) and to a little over 1 million miles of wire.

In addition to this plant, the company installed and operates more than 800 miles of multi-channel radio beam, and leases from the telephone companies 1.25 million miles of carrier channels.

The demands of World War II accelerated research and development in the use of radio, particularly on frequencies above 30 million cycles. Much was learned about the behavior and use of frequencies from 30 million to 10 billion cycles. From this research it has become possible to adapt radio beams to the transmission of record communications.

Radio beam (microwave) relay involves the construction of a series of towered radio stations along the desired route, spaced about 30 miles apart. The beam system obviates the otherwise necessary continuous rights of way, pole lines, cross arms, and wires.

As a result of the mechanization program, Western Union states that its modernized telegraph plant is capable of handling more than double the present telegraph volume. Percentage utilization of plant available for message business as of October 1950 was as follows:

Daily peak period (one-half hour)	32%
Over 24-hour weekday	11%
Over Saturday-Sunday weekend	4%

The company declares that it recognizes the vital importance of maintaining separate trunking systems as between oral and record communications. Asked what its intentions were as between leasing of trunk-line facilities from the Bell System and the continued construction of its radio beam system, Western Union told the President's Communications Policy Board on November 6, 1950:

> "Contrary to the impression that may have been created by Western Union's increasing use of facilities leased from telephone companies in recent years, Western Union has at the present time and intends to retain in the future a comprehensive network of physical facilities entirely independent of telephone facilities. . . .
>
> "Western Union has substantially completed large-scale rebuilding of its circuit facilities on an FM carrier basis. This has involved the transposition and loading of physical wires on which FM carrier was imposed, the addition of FM carrier on radio beam voice bands and as required, on leased voice bands. Its radio beam system linking New York, Philadelphia, Washington, and Pittsburgh, is in operation, and in connection with the expansion of this system the Company has planned routes across the nation and has acquired tower sites as far west and south as Minneapolis, Kansas City, Dallas, and Atlanta.
>
> "These plans reflect Western Union's recognition of the advisability, in the interest of national security, that a nation-wide network of telegraph trunking circuits be for reasons of physical security separate from the circuits carrying voice communications. Given favorable economic conditions and the high level of demand for circuits that makes radio beam systems economically justifiable,

we envisage over a period of time a radio beam system providing trunk facilities between major cities, replacing leased facilities and some parts of Western Union's existing wire plant.

"The speed and extent of the expansion of the radio beam system are necessarily dependent, however, upon the establishment of National Policy. Western Union's ability to obtain necessary capital funds for the expansion will be influenced in major degree by the establishment of National Policy strengthening its financial position; and the expansion can be justified as a matter of economics only if National Policy is formulated to the end that telegraph traffic which has been diverted from Western Union be returned to it."

As of December 31, 1949, Western Union's outside plant facilities were:

Miles of Line

Facility	*Owned*	*Jointly Owned*	*Leased*	*Per cent Leased*
Pole Line............	88, 169	13, 272	6, 359	5.90
Wire................	1, 030, 000	11, 040	25, 750	2.41
Aerial Cable..........	72, 758	19, 308	257	.2
Underground Cable....	260, 012	15, 057	1, 992	7.20

Carrier System Miles

Channel	*On Owned Wires*	*On Owned Radio Beam*	*Leased Voice Frequency* *	*Per cent Leased* *
300 cycles............	72, 908	6, 908	36, 531	31.4
150 cycles............	212, 641	75, 216	1, 206, 240	80.7
Other................	7, 898	....	....	....

*Almost wholly from A. T. & T. and associated companies.

The relative costs per telegraph channel mile, assuming the actual assignments made to the various types of service, were stated by Western Union in October 1950 as:

1. For Western Union lines.................................. $19.70
2. For lines leased from telephone company...................... 5.30
3. For microwave.. 6.30

In summary, basic technological developments in Western Union have been directed not only toward economy in investment, reduction in operating expense, and improvements in existing services, but also toward new services. Some of these are telemeter service and private automatic telegram systems, and currently, a private telegraph network involving automatic switching centers located in Western Union offices and operated by Western Union personnel.

Service Trends

Western Union's basic service is the transmission of telegraph messages; this is supplemented, as has been explained, by a number of allied services including the leasing of circuits. Discussion of service trends hence involves message business, which can be measured by the number of telegrams transmitted and by the revenues they produce, and non-transmission business, the most convenient measure of which is revenues.

Message Business. About 80 percent of Western Union's income is produced by telegrams, the most important of which is the full-rate so-called "day message," which brings in almost 75 percent of the company's total public message service revenues. Business messages—those concerned with commercial transactions as distinguished from personal and social matters—account for about 75 percent of the total message volume.

The general trend of Western Union's message volume between 1927 and 1949 was downward. The reduced rate serial service, after a fast build-up in 1934, had steadied down to about 7.5 million messages in 1949. Money order messages, on the other hand, show a rather healthy long-range growth.

The reduced rate "timed wire service" classification, which had reached a peak of 8.6 million messages in 1942, was ordered discontinued by the Federal Communications Commission because it was found to be unjustly discriminatory.

The reduced rate greeting message—a "social" rather than "business" service—had reached a record volume of 22 million in 1941. This service and other non-essential activities of Western Union were ordered discontinued by the Board of War Communications in 1942 in order to clear the lines for essential war traffic. They were not restored after the war.

The number of Government transmission messages averaged around 7.5 million per annum between 1926 and 1941, rose to a peak of over 14.5 million per annum during the war years, then fell off to an average of about 3 million, standing at less than 2.5 million in 1949. The trend is similar for non-Government messages but not so pronounced. These messages totaled 189 million in 1926 and dropped erratically thereafter. They numbered 151 million in 1949.

With these changes in the character and quantity of transmission messages, the total of all messages dropped by 30 million or 14 percent between 1927 and 1949; because of rate increases, however, revenues rose by $11 million or 8 percent over the same period.[1]

Western Union's message volume is sensitive in two ways to the marked increase in the number of telephones in the United States. The total of telephones of the Bell System, which serves over 80 percent of the country's telephone subscribers, stood at about 12 million in 1925, 17.5 million in 1940, 22.5 million in 1945, and over 33 million in 1949. The telephone has probably taken over social and personal business from the telegraph. The increase in the number of telephones has increased the number of direct avenues to telegraph service, since Western Union receives messages by telephone for transmission, through cooperative billing arrangements with telephone companies.

Growth of air-mail service is another factor taken into account in analyses of reasons for the decline in telegraph message business. The question of dependability of delivery—a major consideration in business transactions such as supply 75 percent of Western Union's message volume—here has to be balanced against savings in cost.

Non-Transmission Business. Non-transmission service revenues increased from about $8 million in 1927 to almost $20 million in 1949, a rise of 150 percent. Leased services and money order charges show almost a steady climb during the same period. Measured service (telemeter), for which the customer who is on a fixed connection with another customer pays a rate based on the monthly accumulative number of words transmitted, has grown from $36,000 in 1936, when the service was established, to almost $2.5 million in 1949.[2] Altogether, non-transmission revenues, which represented about 5.5 percent of all operating revenues in 1927, had risen to 11 percent of the total in 1949.

[1] Attachments III–B and III–C.

[2] Attachment III–D.

A substantial portion of the increase in non-transmission business came from the increase in leased circuits. These in 1927 had produced revenues of slightly more than $2 million; by 1949 the figure had risen to $7.5 million. An illustration of the growth of leased facilities in the latter part of the period is given by data from Western Union on facilities leased to Government agencies:

Year	*Revenues*	*Miles of Circuits*	*Number of Western Union-owned Printers*
1937	4,800	100	4
1944	790,500	57,300	250
1949	1,421,200	106,000	470
1950	1,726,300*	135,000	600

*Estimated on basis of first eight months actual.

Some organizations operating leased facilities estimate that they are saving from 20 percent to 40 percent of what their telegraph expenses would otherwise be; it is likely that the increased use of leased circuits has contributed to the decline in message business. An isolated case cited by Western Union is a drop of 50 percent in monthly public message revenue at its main office in Schenectady, New York, which is explained as "caused mainly by the conversion of the file of our largest customer there (General Electric) to a leased wire system set up by Western Union for that company."

Need for thorough study of the situation is indicated by the fact that though the leasing of circuits is growing, is regarded as saving money for lessees, and is probably reducing Western Union's message business, the question whether leasing gives Western Union any profit cannot be firmly answered. In response to an inquiry from the Board as to the profitability of leased wire service, Western Union reported:

1. The factors involved in a study of the over-all economics of private wire systems are exceedingly complex, so that several months would be required for completion of a study in process, and a direct answer to the question could not be given.

2. The profit margin, if any, as indicated by the study thus far, is small. The rental of out-station equipment and switching center equipment is almost certainly done at a loss.

In its response, Western Union took occasion to comment that:

> "In the operation of private wire service Western Union has been faced with the Hobson's choice of meeting the rates of the Bell System, in which private telegraph and TWX systems are an insignificant part of the total revenues and upon which a profit is relatively unimportant to the well-being of the telephone system, or go out of the business and see an ever increasing proportion of the volume record business diverted to the Bell System. Until there is an over-all integration of rates for communications service in accord with a national policy of fostering sound economic conditions in the industry it seems that the kind of chaotic situation that now exists in this field will continue."

Influence of TWX. Revenues of the teletypewriter exchange service (TWX) to which Western Union referred have shown a significant increase. In this service, the carrier provides the necessary terminal teletypewriter equipment at the subscriber's location and the desired circuit for operation by the subscriber in the same manner as in public telephone service. Time rather than words serves as the base for the tolls.

In 1931, the first year TWX service was offered to the public, revenues amounted to only $7,000. They climbed steadily to a peak of $23 million in 1943, fell to $13 million in 1946 and again climbed to almost $18 million in 1949. Private line teletypewriter service, without the exchange feature, brought the telephone companies $25.5 million in revenues in 1949, as against $9.5 million in 1935.

But here again there is need of knowledge. In October 1949 the Chairman of the Communications Subcommittee of the Senate Committee on Interstate and Foreign Commerce requested the Federal Communications Commission to furnish information on the TWX service of the Bell System. This subcommittee wanted data particularly on the TWX rate structure, on whether the present rates would be compensatory if that service were an independently operated organization, and also on the extent to which TWX is servicing all business or only the lucrative part thereof.

The Federal Communications Commission, in responding to this request, regretted "that it is not in a position at this time [March 1950] to furnish your committee with reliable data which would provide the basis for some determination as to the extent to which current rates for TWX service rendered by the Bell System Companies are compensatory to those companies," pointing out that Bell System representatives estimated that a current study would cost between $400,000 and $500,000 and require on their part from four to six months, and that no study had been made since one in 1935, which is not considered reliable for application to the situation today.

The Commission also made the following points:

1. On March 1, 1944, overtime rates for TWX service were reduced from about one-third of the initial period rates to about one-quarter, resulting in estimated annual savings of $2.4 million to users.

2. On February 1, 1946, the initial period rates for connections in excess of 350 miles were reduced by amounts ranging from 5 cents to 65 cents, depending on the distance, with the overtime rate and report charges being reduced proportionately. These reductions resulted in estimated annual savings to users of $1 million.

Production. The value and trend of operator productivity at Western Union central offices in terms of equated messages per hour worked are shown in Attachment III-E. From an average figure of about 61 messages per hour in 1941, production fell off during the war years to a low of about 55 in 1944. With the postwar introduction of reperforator switching, production has climbed steadily to a high of 113.2 equated messages per hour worked in June 1950.

The average number of revenue messages per man-hour in 1929 was 1.54. The current series shows an almost steady climb from 1.71 to 2.13 for this measure and indicates in effect improved efficiency in the amount of labor time applied to the handling of each message unit.

The figures are:

Year	*Average Number Revenue Message Transmission Units* * *(thousands)*	*Aggregate Hours Paid For* † *(thousands)*	*Average Number Revenue Message Transmission Units Per Hour Paid For*
1944	233,192	136,297	1.71
1945	245,162	132,476	1.85
1946	221,248	120,518	1.84
1947	224,629	107,917	2.08
1948	202,317	100,911	2.00
1949	186,031	87,205	2.13
1950 (7 months)	(‡)	45,064	(‡)

*Western Union Annual Report to FCC, 1949.
†Western Union Commercial Department Wage and Hour Reports.
‡Not available December 1950.

Speed of service performance and the trends for periods for which data were readily available are given in Attachment III-F. These data represent the quality of service at the 25 largest traffic offices in the United States.

The relay drag figure represents the interval between the time a message is received at a relay office and the time it is sent to another office. The figure for reperforator-switching offices averages about 8 minutes less than for manual offices, standing at 8.8 minutes in June 1948, and 7 minutes in August 1950.

The trend of the manual figure is likewise downward since September 1948. The combined figure dropped from a high in 1943 of 14.8 minutes to 9.6 minutes in August 1950.

The average origin-to-destination speed of service is shown by the lower graph indicating an improvement from the rates in September 1948 to January 1950. From then, the trend is upward again, standing in August 1950 at 40 minutes for tie-line deliveries, 44 minutes for telephone deliveries, and 48 minutes for messenger delivery.

As the foregoing figures suggest, perhaps the oldest and most perplexing operational problem in the telegram service is the terminal handling problem. Today a telegram may be economically speeded across the country in a few minutes, but to get it to the transmitting office and to deliver it from the receiving office economically and speedily is another question.

While the terminal handling problem is not yet solved—and indeed may not ever be fully solved—data on Western Union terminal and originating handlings show the following trends in percentage distribution of its load for the methods indicated:

Year	*Messenger*		*Counter*		*Telephone*		*Tie-Line*	
	Terminating	*Originating*	*Terminating*	*Originating*	*Terminating*	*Originating*	*Terminating*	*Originating*
1928	80	50	1	26	13	18	6	6
1934	74	50	3	17	9	19	14	14
1940	66	40	2	16	15	26	17	18
1946	56	26	3	25	20	26	21	23
1950*	53	25	3	13	17	31	27	31

* February study.

Discounting any changes in the ratio of business to social telegrams, it is clear that the trend is toward terminal handling by wire—

principally by teleprinter, telephone, Morse, or facsimile as against the costly messenger handling. Because telephone calls cost money to Western Union and often result in handling confirmation of telephoned telegrams, and, because teleprinters cost more than newly developed facsimile equipment, Western Union has embarked on a postwar program to install in large numbers of patrons' offices facsimile equipments such as the desk-fax earlier mentioned.

Economic Trends

During the past 20 years, powerful economic forces, realignments, and developments have had impact upon the rapid record communications industry in the United States. Among the more important are rising price levels, rising labor costs, increased taxation, new direct and indirect competition, technological advances, and Government regulation.

All these factors, with the possible exception of Government regulation, have had telling effects, in one way or another, upon practically all business enterprises. But the high ratio of fixed plant investment to revenues peculiar to public utility operation, together with the active interest of State and Federal Government in that operation, has restricted to some extent the ability of the telegraph industry to adjust to changing conditions in the same way, to the same extent, and with the same rapidity, as an unregulated private enterprise.

These factors were a challenge to management and a hazard to corporate survival. They ultimately led to the inability of the Postal Telegraph Company to operate at a profit so that in 1943 it was permitted to merge with Western Union. This development leaves the Western Union practically alone in the domestic record telegram field.

Fiscal Performance. Western Union's favorable earnings in 1950 reversed a trend of losses or slight returns on investment.

The company credits reduction of operating costs as the principal reason for the upturn. Major factors contributing to the reduction are cited as stringent control of expenses, modernized plant, and improved operating methods.

The improvement in operating revenues that began in April 1950 is attributed by the company management to intensified sales effort, a rationalized rate structure, and later to the increased business activity that followed the outbreak of fighting in Korea. Reductions in mail delivery also may have had some effect on revenues.

This shift in fiscal performance during 1950 is obviously too recent to give assurance that the economic problems of the company have been solved. But there are indications of better financial weather ahead.

The Board retained a firm of consulting engineers to look into the future prospects of the telegraph industry. After a customer survey, the engineers concluded that "the pattern of use of the various types of communications in the domestic field has reached a stable condition." Combining that finding with economic studies, the engineers reported to the Board that there is likely to be a continuing demand for telegraph service and that Western Union should be able to earn a profit in the near-term future.

In spite of that outlook, there is much to be gained by Government authorities—those responsible for regulation and those interested in the industry for its national security value—in studying the financial history and prospects of Western Union. One fact that stands out immediately is the absence of adequate data on which to base fair conclusions. Review of the company's difficulties should help to indicate where these gaps need to be filled, as well as to provide valuable lessons for the future when new economic problems are encountered.

An analysis of rapid record communications in relation to all rapid domestic communications was made for the Board by Dr. Bonnar Brown of the Stanford Research Institute. He found that total intercity communication revenues (including telephone, telegraph, and air mail) fluctuated very closely with the country's gross national product, but that record intercity revenues (of both telegraph and telephone companies) have lagged behind. He prepared the table on page 81 to illustrate these trends.

Commenting on the trends disclosed by his analysis, Dr. Brown declared:

"Both of the series—column 4 and column 5—show a rise in percentage in the late 20's, but the rise for record communications is less, and, consequently, its proportion of the total communications revenues had already started to fall. Whether the early 30's saw the culmination of a growth period, or whether the data simply reflect the effects of cyclical boom and depression is uncertain, but the retrogression in the position of record communications stands out.

Gross National Product and Domestic Communication Revenues

	1 *Gross Nat'l Product (Billions)*	2 *Total Communi. Revenues (Millions)*	3 *Record Communi. Revenues (Millions)*	4 *Percent Col. 2 of Col. 1*	5 *Percent Col. 3 of Col. 1*	6 *Percent Col. 3 of Col. 2*
1926	99.5	413	166	0.41	0.17	40.2
1927	97.6	437	165	.45	.17	37.9
1928	99.8	482	174	.48	.17	35.0
1929	103.8	538	187	.52	.18	34.8
1930	90.9	518	173	.57	.19	33.5
1931	75.9	474	150	.62	.20	31.8
1932	58.3	378	118	.65	.20	31.3
1933	55.8	350	114	.63	.20	32.7
1934	64.9	361	121	.56	.19	33.4
1935	72.2	392	125	.54	.17	32.8
1936	82.5	440	137	.53	.17	31.2
1937	90.2	460	140	.51	.16	30.5
1938	84.7	441	128	.52	.15	29.0
1939	91.3	467	131	.51	.14	27.0
1940	101.4	497	135	.49	.13	27.2
1941	126.4	586	153	.46	.12	26.1
1942	161.6	740	178	.46	.11	24.0
1943	194.3	915	204	.47	.10	21.3
1944	213.7	1010	210	.47	.10	20.8
1945	215.2	1127	217	.52	.10	19.3
1946	211.1	1118	204	.53	.10	18.3
1947	233.3	1161	230	.50	.10	19.8
1948	259.1	1286	219	.50	.08	17.1
1949	255.6	1347	211	.53	.08	15.6

"Considering that semi-monopolies exist in this field, that the services included differ and are offered in a multitude of forms, that rates are subject to control, that subsidies are involved in some cases, that rates may reflect only 'extra costs' of a particular service, and many other special conditions, the use of total revenue figures may appear to be hazardous, but two sets of considerations tend to support the above conclusions. In the first place, the very regularity of the relationships displayed tends to suggest that the special conditions are not so controlling as might be supposed. Dollarwise, the economy has been able to take just so much communications service, and has gradually changed as to the dollars spent in different forms. Secondly, any examination of the physical quantities of the services provided over the years leads to similar results. Here the lack of complete data and the difficulty of aggregating dissimilar types of services together presents many problems, but without carrying the analysis as far as is done in the revenue figures, it is still clear that record communication is losing out.

"In this period of declining relative position, record communication has had some long-run rise in dollar revenues. For 1926, revenues were 166 million dollars, and for 1948 they were 219 million dollars. In the interval, however, prices had risen so the 219 million dollars in 1948 could actually buy a slightly lower volume of goods than the 166 million dollars in 1926. Record communication is, therefore, in the position of selling about the same volume of services as it did in the late 20's.

"In a growing economy, the industry that is not keeping in step has many difficulties. Compared with a growing industry, it is not so attractive to capital, to managerial ability, to technical skills, or to the general run of employees, because it does not appear to offer the opportunities to be found elsewhere. Little in the way of new funds will be available, so improvements to lower costs must come slowly out of depreciation allowances. Refundings of existing loans meet with resistance. Yet costs and rates must be continually lowered in real terms (goods, not dollars), in order to match the growth in productivity taking place in the economy as a whole.

"How much the failure of record communications to keep pace is due to a simple preference of the public for other forms, and how much to nonexploitation by record communication companies of potential demand cannot easily be judged. The consistency of the figures in the table suggests that the first cause is predominant, but there also seems to be a general public feeling questioning the efficiency of telegraph operations. Some improvement in volume could possibly result from better service and from exploration of untapped sources of business.

"The present international situation is one which appears to assure a high and growing physical volume of business for the nation as a whole for some years to come. This means communications activity at a high level, and there is even some indication from the history of World War II that the relative decline in record communications revenues is checked in a period of international tension. Nevertheless, our economy in recent years has been operating close to capacity, so that physical volume either in business as a whole or in record communication cannot be expected to increase very rapidly. Prices are rising, and it is doubtful that they will be kept fully in check, so that revenues can also rise from rate increases, but it is to be remembered that rate changes are sluggish and follow price-level changes only with considerable lag."

Influences on Revenues.—Trends in the use of rapid communications services at five-year intervals over a quarter century are shown in the following carrier revenue figures:

Year	*Air Mail* [a]	*Toll Telephone* [b]	*Telegraph Operations of Telephone Companies* [c]	*Landline Operations of Western Union (and Postal)* [d]	*Total*
		(In thousands)			
1926......	$996	$245,704	$15,881	$150,112	$412,693
1929......	4,762	345,935	23,918	163,358	537,973
1934......	5,316	235,093	17,987	102,557	360,953
1939......	17,656	318,573	20,867	109,899	466,995
1944......	79,734	720,014	36,641	173,207	1,009,596
1949......	[e] 71,627	[f] 1,064,521	39,135	171,393	1,346,676

[a] Air mail—Includes domestic air-mail letter, card, and parcel post postage revenue. Until 1949 the portion of domestic air-mail revenue attributable to parcel post was not available. Estimates for 1949 indicate it to have been about $11 million or 15.4 percent of total 1949 air-mail revenues used in this series.

[b] Toll telephone—Includes public message tolls, private toll line revenue and miscellaneous toll telephone revenue. Data are partially estimated.

[c] Telegraph operations of telephone companies—Includes TWX, private line telegraph, and message telegram services. Data are partially estimated.

[d] Western Union and Postal Telegraph—Includes domestic transmission and non-transmission revenues. [e] Preliminary. [f] Preliminary, and based on incomplete coverage.

The total revenues of the communications industry as a whole, including air mail, thus in a quarter century increased some 220 percent. The absolute increases in the revenues of the components of the industry in that period are striking: air mail 7,000 percent, toll telephone 300 percent, telegraph operations of telephone companies 160 percent, landline operations of Western Union 14 percent. The relative percentages of total revenues enjoyed over the period by the components of the industry also indicate that the major trend has been away from telegraphic communication. The figures follow:

Year	*Air Mail**	*Toll Telephone**	*Telegraph Operations of Telephone Companies**	*Landline Operations of Western Union (and Postal)**
1926	0.3	59.9	3.8	36.4
1929	.9	64.3	4.4	30.4
1934	1.5	65.1	5.0	28.4
1939	3.8	68.2	4.5	23.5
1944	7.9	71.3	3.6	17.2
1949	*5.3	*79.1	2.9	12.7

*Same footnotes as for previous table.

Long lines telephone message tolls of the A. T. & T. in 1949 amounted to $439,371,000—something less than half the total toll telephone income of the entire Bell System. Because of its characteristics, however, the long lines message affords illuminating comparison with the telegraph message; when the two are used as criteria, the economic trends affecting the telegraph industry are again emphasized. Figures for representative years between 1927 and 1949 were:

Year	*Interstate Toll Messages* *Revenues* [a] (in thousands)	*Volume* [b]	*Western Union Transmission Messages* *Revenues*	*Volume*
1927	$62,029	35,646	$140,345	215,816
1929	94,421	49,313	154,435	234,050
1934	75,232	37,459	94,653	155,215
1939	102,896	59,218	98,091	189,055
1944	346,884	175,793	158,032	232,712
1949	439,371	225,806	151,740	185,673

[a] Gross revenues (before uncollectibles) from telephone message tolls in which the Long Lines Department of the A. T. & T. Co. has participated. Does not include toll message revenue from calls handled without Long Lines participation or from private line telephone.

[b] Number of telephone messages in which the Long Lines Department of A. T. & T. has participated. Does not include toll messages handled without Long Lines participation or from private line telephone.

Attachment III–G, derived from Attachments III–H and III–I, shows the average revenue per interstate toll telephone message and per telegraph message.

Rates. The full-rate telegram, which is the major source of Western Union's transmission revenues and which is the principal medium for the business or commercial messages constituting about 75 percent of the company's message volume, is carried at rates which, in a typical example, compare thus with other means of rapid communications:

Charges between Washington and Chicago (Federal excise tax excluded)

Ten-word full-rate telegram	$0.75
Three-minute TWX telegraph call	.95
Three-minute nighttime and Sunday station-to-station telephone call	1.00
Three-minute daytime station-to-station telephone call	1.40
Three-minute nighttime person-to-person telephone call	1.55
Three-minute daytime person-to-person telephone call	1.95

Western Union's present rates incorporate increases which were granted by the Federal Communications Commission in 1946 and 1947 because the company was then operating at a deficit estimated at $12 million for 1946. The Commission's action included:

(*a*) An initial flat over-all increase of 10 percent in domestic interstate message rates; Western Union estimated that this increase, coupled to other adjustments, would produce $18.5 million additional annual revenues.

(*b*) Elimination of certain low "exceptional" or "special" rates, which would produce an estimated additional $3.7 million annual revenue.

(*c*) A flat over-all increase of 20 percent in 1947, replacing the 1946 increase of 10 percent in the domestic interstate message rate. It was estimated that this increase would produce an additional $8.5 million annually.

(*d*) Elimination of a 20 percent preferential rate on certain Government messages, which would produce an estimated additional $692,000 per annum.

What influence these rate adjustments may have had on the volume of transmission business cannot be precisely measured; some effects are suggested in Attachments III–B, III–C, III–D, and III–K.

It appeared likely that expansion of leased circuits was accelerated. Thus the total number of Government messages, for example, dropped progressively from almost 5.5 million in 1946 to less than 2.5 million in 1949, and the mileage of lines leased from Western Union by the armed forces rose from the war peak of 1,800 miles in 1944 to 78,000 miles in the fall of 1950. The leased circuit revenues of the company afford another indication; these rose from $3.6 million in 1946 to more than $7.5 million in 1949. Private line teletypewriter revenues of the Bell System, which rose from $18.5 million in 1946 to $25.5 million in 1949, and its TWX revenues, which went from $12.9 million in 1946 to almost $18 million in 1949, may also have benefited by diversion of telegram messages.

Excise Taxes. Early in the second World War, excise taxes were increased to 25 percent on interstate telegrams and on telephone toll conversations costing over 24 cents. Long-distance telephone communication has continued to increase, the tax apparently being taken as a matter of course. Western Union, averaging estimates, found that "it is indicated that an increase in revenues of about $10 million might be expected from the elimination of the tax," although "there is no formula by which a precise determination can be made as to the effect of the elimination of this tax upon the volume of domestic telegraph traffic."

Air Mail. Air mail has experienced a long steady increase in revenues. This growth may have affected Western Union night letter traffic. Attachment III–B shows that night letter (overnight message) volume stood at almost 39 million in 1926, dropped to a little over 19 million in 1933, climbed to over 35.5 million during the war peak in 1945, and since has fallen to 26.5 million in 1949. Total airmail subsidy or deficit payments to airlines for 1950 have been estimated at $125 million.

Influences on Expenses. By far the largest share of the telegraph industry's gross income dollar has gone to payments to and for employees. The trend has been upward. The wage portion of the income dollar fluctuated between the narrow limits of 54 cents and 60 cents from 1926 through 1944. From 1944 to 1946 it rose from 60 cents to over 72 cents of the income dollar. For 1947, however, it fell back to 64 cents and for 1948 and 1949 leveled off to about 68 cents.

During the same period 1926 to 1949, total Western Union and Postal landline employees declined from 76,000 in 1926 to 57,000 in 1938, rose again to 65,000 in 1941, and receded to 41,500 in 1949.

Western Union reports that the average weekly earnings of landline local field employees, excluding messengers, rose from $37.99 in 1945 to $62.78 in 1949. Related data from the Department of Commerce show the following:

	Telephone		*Telegraph*	
	May 1949	*April 1950*	*May 1949*	*April 1950*
Average weekly hours per worker	38.6	38.7	45.2	44.6
Average weekly earnings	$51.84	$53.44	$63.69	$64.13
Average hourly earnings	$1.343	$1.381	$1.409	$1.438

Note.—The normal weekday average hourly earnings for both services are essentially the same, if the overtime rate is eliminated from these data.

The National War Labor Board on December 29, 1945, granted Western Union employees wage increases amounting to $31 million in retroactive pay and $25 million in recurring annual wages. In its decision, the Labor Board pointed out that the telegraph industry was a low-paying industry with an inequitable wage structure, that no general wage increases had been made by Western Union since those ordered by the NWLB in 1943, and that over one-third of the adult employees were receiving less than 55 cents per hour. One reason for the fact that no increases were made between 1943 and this NWLB award was that the National Labor Relations Board for about a year had been holding hearings on representation of Western Union employees.

The sharp increase in wage rates no doubt was the main stimulus for the introduction of labor-saving devices in the telegraph service. One example is automatic reperforator switching, which contributed largely to making possible the reduction in the number of employees in the postwar period from 57,500 in 1946 to 41,500 in 1949.

Reduction of Service. Closing and reduction of telegraph offices and agencies of Western Union have been a knotty probem to both

Western Union and the Federal Communications Commission since the merger legislation of 1943.

When the Communications Act was amended to permit merger, Section 214 was also amended to read as follows:

> "No carrier shall discontinue, reduce, or impair service to a community, or part of a community, unless and until there shall first have been obtained from the Commission a certificate that neither the present nor future public convenience and necessity will be adversely affected thereby; except that the Commission may, upon appropriate request being made, authorize temporary or emergency discontinuance, reduction, or impairment of service, or partial discontinuance, reduction, or impairment of service, wthout regard to the provisions of this section."

Additionally, Section 214 (d), which authorizes the Commission, after hearing, to require a carrier to extend its lines and to provide itself with adequate facilities for performing its services as a common carrier, was amended to give the Commission specific authority to require a carrier "to establish a public office" and to provide itself with adequate facilities "for the expeditious and efficient performance of its service as a common carrier."

Studies made by Western Union indicate that company-operated offices and tributary agency offices at which the message revenues average less than $1,500 a month are operated at a deficit. As of January 1950, there were 1,300 such offices. From the test study, Western Union estimated that these offices incur an annual operating deficit estimated at over $3.25 million.

The minuteness of the revenues obtained by a large proportion of the telegraph offices Western Union operates can be seen from Attachment III–L. In addition to the 13,000 offices represented therein, Western Union operates an additional 12,000 agency or commission offices not included in these data.

Attachment III–L reveals that for the classes shown .85 percent of Western Union's offices (118 communities in number with revenues over $10,000 per month) produce over 71 percent of its public message revenues. It also shows that 5.25 percent of the company's offices (727 communities in number with revenues between $1,000 and $9,999 per month) produce 20.79 percent of its public message revenues. The remaining 93.9 percent of the offices (12,997 in number) produce only 7.57 percent of the public message revenue, and 2,045 joint railroad offices (Class 4) reported no public message revenue for January 1950.

The President of Western Union in his "Report to Annual Meeting of Stockholders," April 12, 1950, stated: " . . . While recognizing the necessity for reasonable governmental regulation of public service companies, the fact remains that, under present governmental and public service policies, the company is required to maintain hundreds of unprofitable offices."

On its own motion the Federal Communications Commission adopted an order on December 30, 1946, providing for an investigation of and public hearing on the over-all plans of Western Union, with respect to the discontinuance, reduction, and impairment of service.

As a result of this investigation, the Federal Communications Commission established a figure of 46 sent and received messages a day as a general guide in determining whether the Commission will authorize conversion of a company-operated office to a teleprinter agency office.

At the hearings in this investigation, Western Union representatives gave testimony and submitted numerous exhibits with respect to company policy, standards, and plans relating to discontinuance, reduction, and impairment of service.

The company's basic policy, expressed at a previous hearing, was reiterated as follows:

> ". . . It was our [Western Union] policy to serve, as far as we could, within our means, as many people in the United States as possible; that we must operate as efficiently as we can, first, in the public interest, so that the telegraph users are not asked to bear unnecessary cost; secondly, in the interests of the employees; and thirdly, in the interests of the stockholders."

Western Union representatives testified that three principal factors made it necessary to reappraise the existing (1947) telegraph coverages:

"(1) The need for normal postwar contraction of facilities following expansion made necessary by increased use of telegraph during the war;

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"(2) The desirability of changes in the facilities for accepting and delivering telegraph traffic growing out of technological improvements;

"(3) The need of economy and greater efficiency of operation arising from deficit operations."

The company also told the FCC that "it is not possible to follow a mathematical formula in selecting offices for consolidation. The requirements of the public for telegraph service, volume of traffic, revenue, operating expense, distance from the nearest office, all vary so widely that each consolidation must be considered on its own merits."

Conversion from company-operated offices to agency operation is not "usually considered by the Company unless the load and revenue fit both of two standards." These are: (1) that the average revenue (collections made from all incoming and outgoing messages) at the particular office does not exceed approximately $750 per month; and (2) that the ratio of local operating expense to revenue is 50 percent or more.

The standards used for determining at which offices hours should be reduced are contained in FCC Rules and Regulations for informal requests for reduction authority. For other situations, formal application is submitted to the Commission with a detailed showing of need so that each case may be judged on its own merits.

With respect to closures and reduction of service, the Federal Communications Commission concluded that no general policy could be formulated to govern its consideration of such action.

In addition to the closing of a large number of duplicate offices resulting from the merger of Postal with Western Union, curtailments since 1947 have been appreciable. During 1947, 1948, 1949, and the first six months of 1950, Western Union reports, the FCC authorized a total of 2,324 branch office consolidations, conversions, and reductions in office hours, from which annual savings are estimated to be over $3.1 million.

Interest Charges. Western Union in recent years has been reducing and adjusting its debt structure in order to save on interest payments. In 1942 the company paid out more than $3.9 million in interest (chiefly on funded debt). By 1948 these charges had been reduced to a little over $3.2 million, and in 1949 they were $3.1 million.

Further actions along this line were taken in 1950 by liquidation of the company's outstanding $7.8 million of 4.5 percent funding and real estate bonds, prepayment of installments on remaining obligations to the Reconstruction Finance Corporation, and calling for redemption of $15.3 million of 5 percent bonds due December 1, 1951. The latter call was made possible by a $12 million loan from a group of New York banks at 3.5 percent interest.

The Current Status of Western Union

The encouragement of competition in the telegraph field was embodied in the Communications Act of 1934 as a matter of policy. In the next year, however, the Federal Communications Commission evidenced its doubt of the wisdom of that policy by recommending enactment of legislation empowering it to authorize and approve consolidations of telegraph companies. This recommendation was not acted upon. But as the condition of the telegraph companies worsened, the idea of consolidation was revived in 1939. The Senate in June of that year authorized an investigation of the telegraph industry by a subcommittee of the Interstate Commerce Committee. No legislation resulted. In 1943, however, Congress amended the Communications Act to permit merger of domestic telegraph companies and to permit Western Union to buy the telephone system's TWX and private line telegraph services. Merger of the Postal Telegraph Company with Western Union followed. The idea of regulated monopoly rather than competition as a means of strength came to the fore.

Concern for the most effective use of the opportunities offered by merger then became the keynote. Reporting its decision of September 27, 1943, authorizing the Postal-Western Union consolidation, the Federal Communications Commission gave expression to it thus:

> "We have found that merger may be expected to place the domestic telegraph industry on a sounder financial basis than heretofore, and to furnish opportunities for the elimination of obstacles to improved telegraph service at reasonable cost to the public;

but we cannot pass over the obvious failure of the management of the proposed merged company to address itself to any specific plans for meeting the demands of users for a record communications service having speed and price standards to which the public is entitled and which will effectively meet the competition of the telephone and the airmail. Attainment of these service objectives, and a generally sound condition, will require radical modifications in Western Union's managerial and fiscal policies and practices, and in its facilities and operating practices.

"The Commission is seriously concerned with the failure of the management to direct its plans and aims to such service objectives. In the interests of providing a completely adequate telegraph service in keeping with the technical accomplishments and public requirements of the present and of the future, vigilant regulatory action will be necessary. The Commission will expect that within 1 year from the effective date of the merger, the merged company will have developed completely and submitted to the Commission, a comprehensive plan for converting, within the shortest possible time, its existing facilities into a modern, efficient, and Nationwide communications system capable of effectively competing with other communications services. A continued disposition to ignore such service objectives will call for such action on the part of the Commission as may be needful and appropriate to assure to the public the rapid, efficient, and Nationwide record communication service with adequate facilities at reasonable charges which it is the stated duty of the Commission, under the Communications Act, to make available.

"The future changes in facilities and services available to the public require special attention. In order to avoid any future misunderstanding upon this matter, which is vitally connected with the maintenance of proper service in the domestic telegraph industry, we deem it important to state before concluding, that we will not sanction any ill-considered elimination of facilities or services whether or not they are a result of merger. We will expect that abandonment of facilities, closure of offices, reductions, impairments, or discontinuances of service will be carried out only pursuant to considered rational plans in which factors of public need and convenience will be controlling."

In response to the Commission's request the merged company submitted on October 7, 1944, a "Plan for the Improvement of Telegraph Service." In general terms the plan mentioned the terminal handling problem, transmission of messages between telegraph offices, leased telegraph systems, training program, carrier and reperforator switching program, telefax (facsimile), telemeter, public information, rates, research, and railroad contracts. After the war, implementation of the plan was begun and was pressed to virtual completion by the end of 1950, some three years in advance of the original target date. During the postwar years, however, financial problems continued to plague the company and the Commission.

Actions on Telegraph Rates

On petition of Western Union in March 1946, the Commission granted a flat over-all increase of 10 percent in domestic interstate rates but denied the requested elimination of the 20 percent differential on Government messages. Summing up the case in its annual report, the Commission stated:

> "It found that Western Union was currently operating at a deficit and anticipated a loss of about $12,000,000 in 1946 if its rates were not raised. The Commission concluded that Western Union would need substantially more revenue than it requested 'if it is to continue in operation as a solvent enterprise and provide satisfactory service on a comprehensive Nation-wide basis.' It pointed out, in particular, that Western Union was faced with increasing competition from telephone and teletypewriter exchange services and airmail services, besides being affected by increased wage costs and reductions in international telegraph rates. The Commission is not satisfied that the modernization program is the answer to Western Union's problems. However, in view of prevailing economic conditions and Western Union's dire need for additional revenue, the Commission granted the rate increase for 1 year pending developments."

In granting the increase, the Commission pointed out that such a temporary expedient did not meet the basic difficulty, emphasized the need of a comprehensive investigation into all phases of the company's operations, and sharply criticized the lack of comprehensive and dependable data in the company's petition for the increase. In

June the Commission issued an order calling for the investigation, but noted that such an inquiry was beyond the limitations of Commission funds and personnel and would necessitate a request to Congress for additional funds.

Before that request could be made, two further actions were taken from which betterment of Western Union's financial situation was expected. Elimination of "exceptional" or "special" city-to-city and city-to-state rates as discriminatory was ordered in October. Since these rates were lower than Western Union's standard rates, it was estimated that their elimination would produce additional revenue from interstate service of $3.7 million. In December the Commission's earlier view that the March rate increase of 10 percent was an expedient only was substantiated as Western Union petitioned for a further advance in interstate message rates. After public hearings, the Commission on December 27 replaced the March increase with a flat 20 percent increase with no time limitation. The effect of this substitution was to increase current rates by 9.1 percent, as against the 15 percent desired by Western Union. This rate revision action was estimated to produce $8.5 million additional annual interstate revenues. In its report on this case, the Commission concluded, in part, as follows:

> "Western Union faces a real emergency and the sound course for it to follow in the immediate future is not clear. There is no question, however, about the urgency of Western Union's need for additional revenues. We are firmly in agreement with the testimony of Western Union's president that rate increases are not the ultimate answer to the company's situation. At the present time, however, it appears that some rate increase may offer immediate revenue relief to the company. The availability of a Reconstruction Finance Corporation loan was characterized by Western Union's treasurer as 'an anchor to windward, which may be of some help in the immediate situation.' Further general rate increases by Western Union will, of course, worsen its position in relation to the competitive means of communication provided by the telephone companies and the airmail, and may fall short of meeting the company's revenue needs."

Seeking an appropriation of $375,000 to conduct the investigation proposed in its June 1946 order, the Commission in testimony before the House Interstate Commerce Committee on February 25, 1947, expressed doubt "whether the modernization program proposed by Western Union, or any program which can be devised can save Western Union and, if so, whether it can be put in operation in time;" stressed the need for determination of national policy; and explained that, broadly speaking,

> " . . . five alternative policy solutions are apparent. If a comprehensive record communications system is not a necessary part of our national economy, then nature may be permitted to take its course with respect to the disposition of Western Union's facilities. If such a system *is* necessary, but need not be independent, then consideration may be given to the possibilities that the telegraph system may be consolidated with either the telephone industry or the post office. If it is determined that an *independent,* record communications system is necessary, then the whole issue resolves itself into the means by which this is to be accomplished and the issue of subsidy is involved.
>
> "A fifth possibility would permit Western Union to concentrate its business only between cities with large volumes of traffic—to skim the cream of traffic—abandoning all other communities, but this would be far from the 'nationwide . . . communication service with adequate facilities' enjoined by the Communications Act."

The requested appropriation was not granted. During the period since the hearings, the 80th (1947–1948) and the 81st (1949–1950) Congresses made studies of the communications problems of the country, including the domestic telegraph situation, but neither enacted legislation pertinent here. The modernization program of Western Union was expedited, and the company's management took a more aggressive leadership. Rounding out the modernization effort a program was announced by the company in 1949 including:

(1) Installation and operation of new high-speed message centers in Detroit, Los Angeles, and New Orleans.
(2) Installation of hundreds of desk-fax (facsimile) machines in customers' offices in eight major cities.
(3) Installation and expansion of private telegraph networks for large industrial users.
(4) Continued operation (made possible through legislation exempting them from the wage and hour provisions of the Fair Labor Standards Act) of 12,500 telegraph agencies.

(5) Consolidation of major operating departments of the company for greater operating efficiency and economy, and the establishment of a separate sales and advertising division.
(6) Further reduction of the company's debt.

The company went into broader matters in a special report issued in October 1949, proposing the adoption of a coordinated national communications policy and advocating substantial changes in the telecommunications industry. The report recommended:

(1) Repeal of the 25 percent Federal excise tax.
(2) Purchase by Western Union of the teletypewriter exchange service (TWX) and telegraph services of the telephone company.
(3) Legislative permission for purchase by Western Union of the cable and radio facilities of American companies operating in the international field.
(4) Provision by Western Union of an integrated system of domestic communications geared to military requirements and available in normal times to the public and the Government.
(5) Long-term Government financing, as may be necessary, to achieve the above objectives.

Negotiations With the Bell System

Negotiations were carried on in 1943–1945 between Western Union and the A. T. & T. looking toward the acquisition of TWX and allied services by Western Union under the permissive legislation of 1943, but without result. Resumed late in 1949, they had not been concluded at the time of this Report. On July 1, 1948, Western Union, the A. T. & T., and certain companies of the Bell System had entered a contractual agreement in which Western Union would sell and transfer to the Bell System its public telephone business and property for $2.4 million cash and the public message telegram business of the Pacific Telephone and Telegraph Company and a subsidiary. This agreement was subject to approval of the FCC, and of state or other regulatory agencies.

Accordingly, a joint application was filed with the FCC on February 1, 1949, for certificates under Sections 214 and 221 (a) of the Communications Act of 1934 as amended. In late 1949 and early

1950, an FCC examiner held hearings, during which two state commissioners sat as representatives of the National Association of Railroad and Utilities Commissioners. These hearings resulted in an order for the issuance of a certificate, which in effect approved the application.

However, on September 8, 1950, the Chief of the Common Carrier Bureau of the FCC excepted to the initial decision on the grounds that the acquisition of the telephone facilities of Western Union by the Bell System companies under the proposed conditions would deprive Western Union subscribers of "personalized service and of the advantages of an auxiliary or standby service," and would require them "to pay higher charges for their message toll telephone service." As for the discontinuance of public message telegram service by the Pacific companies, the Bureau excepted to the decision on the grounds that the service proposed to be provided by Western Union would generally be less stable in character than the service rendered by Pacific, that speed of service on a large percentage of traffic would be adversely affected, and that "the proposed transaction will result in the elimination of all competition between Western Union and the Pacific Companies in the offering of message telegram service." The Bureau submitted that an order should be entered denying the joint application.

Also on September 8, 1950, on behalf of the Attorney General of the United States, exceptions were submitted to the Examiner's findings, conclusions, and initial decision.

The applicants have filed a reply brief to the exceptions, but the FCC decision had not been rendered at the time of this Report.

Increase in Revenues

April 1950 saw a reversal of the decline in Western Union's operating revenues. The modernization program, rigid economies, improved operating methods, and greater sales efforts are regarded by the management as the company actions which contributed to the change, and rate adjustments, the Korean situation, and increased general business activity as the salient non-company factors. Commenting on the upturn, the Federal Communications Commission in a report dated August 31, 1950, to Senator McFarland of the Committee on Interstate and Foreign Commerce, said in part:

"The Western Union Telegraph Company has reported a net income of $2,687,000 before Federal income taxes for the first six months of 1950. Assuming that revenues and expenses will continue at the March through June level (Western Union reported net losses in January and February), Western Union may realize a net income of $7,000,000 for 1950 as compared with an assumed loss of $5,000,000 in the above-mentioned report. The principal reason for the difference in assumptions is the substantial savings that the company has been able to effect, principally through force reductions as a result of the company's mechanization and economy programs. Landline expenses in the first six months of 1950 were $7,578,000 less than the same period of 1949 of which $6,312,000 represented savings in labor expenses.

"Assuming that Western Union will be able to maintain its earnings in 1951 at the level assumed for 1950, and after adjusting for the sale of buildings subsequent to the date of our earlier letter and further assuming that the once suggested cut in Federal excise taxes on telegrams will not materialize, Western Union may be expected to have cash balances on December 31, 1950 and 1951 of $34.4 million and $22.6 million, respectively. If the application now pending before the Commission for authority to sell the former Postal Telegraph Company's toll telephone system to the Bell System companies should be approved by the Commission, the cash balance for 1951 would be increased by $2.4 million.

"Western Union's improved financial situation bolsters the Commission's conclusions . . . that the Commission 'would prefer to give Western Union a further opportunity to extricate itself from its financial difficulties, rather than to propose the enactment of drastic legislation at this time which might result in, or lead to, Government ownership or operation of Western Union, or which might result in one huge monopoly of practically the entire communications industry of the United States.' "

Summary

The over-all national demand for telegraph facilities and services, as well as for telephone and air-mail services, has been growing almost steadily since 1926. During that period, however, the relative demand for telegram service has lessened. This shift in the character of the demand for telegraph service has seriously threatened the continued existence of the Western Union system as a private enterprise. Remedial measures applied by the company and by regulatory authority in recent years, following a longer period of Government concern over the prospects of the industry, resulted in a return to profitable operation in April 1950. The long-range prospect is indeterminate.

DOMESTIC TELECOMMUNICATION SYSTEMS OF THE FEDERAL GOVERNMENT

Federal Government agencies during the year 1949 operated nationwide leased wire teletype networks, the size of which is indicated by the following estimated figures:

Miles of leased teletype wire, including weather services	325,931
Miles of leased teletype wire, excluding weather services	167,824
Cost of leased wire, including weather services	$8,053,877
Cost of leased wire, excluding weather services	$3,501,796
Originated words transmitted, including weather services	16,347,342,986
Originated words transmitted, excluding weather services	5,835,071,689

A more detailed presentation of these estimated figures appears in Attachment III–M.

No attempt has been made in this study to include any statistics concerning extensive telephonic communications of the Federal Government agencies, the bulk of attention being devoted to statistics relating to wire record communications, largely teletype. Such commercial message statistics as were available, however, are included.

Domestic radio communications such as aeronautical mobile, military land-mobile, radar, etc., are considered to have no particular significance in this study and therefore have been excluded. No figures embracing costs of operation (other than the costs of leasing facilities and equipment) are shown. The development of such figures was considered to be too great a study to make in the time available, since many agencies do not keep adequate cost records.

A brief description of the agency operations listed in Attachment III–M follows:

Department of Agriculture

The Department of Agriculture leased 17,630 miles of teletype network during 1949. Of this total, 15,835 miles were primarily used to transmit market news and related information for national dissemination to the public by radio broadcast and newspapers. Among the other functions of the Department utilizing leased teletype facilities is the service offered in connection with the foot and mouth disease program.

Department of Commerce

Two agencies in the Department of Commerce, the Civil Aeronautics Administration (CAA) and the Weather Bureau, have extensive domestic wire networks totaling 115,659 miles. Attachment III–M shows these two agencies separately and further divides the CAA communications data into two categories, "weather" and "other than weather." Communications involved in weather flight control, weather forecast, and operational weather control, some of which are leased telephone lines, have been included under the caption "weather." General administration, air traffic control, and communications operation are included under the caption "other than weather."

The Weather Bureau network, operating separately although in connection with CAA, carries weather data used exclusively in weather reports and forecasting.

The Weather Bureau, like the Air Force and CAA, uses symbols which are not generally available in commercial telegraph operation. To translate such weather data for transmission by commercial telegraph service would increase the wordage by approximately 40 percent.

Department of Defense

The Departments of the Army, Navy, and Air Force operate individual wire networks throughout the continental United States which total 149,529 miles, primarily for the conduct of rapid record communications between military establishments or between military establishments and other appropriate points in the nation.

Though communications originated by other agencies of the Government are transmitted over the facilities of the defense establishment to the degree indicated in Attachment III–M such transmissions are made under the general assumption that no additional facilities or personnel will be required. There is also some interchange of messages originated by the 3 military services for transmission over each other's networks.

The Air Force networks accommodate weather, facsimile weather maps, military flight service, aircraft control and warning system, and military air transport services. They also serve some needs of the Departments of the Army and Navy, and all 3 of the defense departments make use of the weather services of the Department of Commerce (CAA and Weather Bureau).

As in the case of the CAA, the Air Force statistics have been shown in two parts, "weather" and "other than weather." Again, as in the case of the CAA, the weather wordage figures have been excluded from the grand total of leased line words because they embrace special forms of transmission involving special teletype symbols and telephonic wordage.

General Services Administration

The General Services Administration (GSA) operates a leased wire teletype network, which totalled 14,392 miles, supplemented by TWX service for Government agencies, for the year 1949.

This service, available to all Government agencies, operates from 8:00 A. M. to 11:00 P. M., E. S. T., Mondays through Fridays, and offers direct message service between 54 major United States cities, in addition to the possibility of refile via other media to other United States cities, or to foreign countries.

Pickup and delivery are done by telephone (with mail confirmation), messenger, or by local teletype line when and if the message volume warrants. The Administration estimates that, by acting as a clearing house for Government domestic rapid communications, it reduces domestic telegraph costs to the Government 35 percent to 40 percent. The cost of this service, exclusive of overhead, is prorated to the users on the basis of the cost of the facilities.

Veterans' Administration

The Veterans' Administration maintains a leased wire network of 8,658 miles, supplementing the leased facilities of other Government agencies, to connect its offices in every State for the conduct of its business. West of the Mississippi River, it uses a great amount of TWX service.

Other Federal Government Agencies

Certain other agencies (listed by footnote in Attachment III–M), while free to use facilities maintained by GSA, also lease teletype wire lines or otherwise contribute to the total figures, as indicated in the Attachment.

The degree of radio transmission involved in the figures presented for "Other Federal Government Agencies" is negligible, being for the most part the result of secondary operation, as in the case of the FCC and Department of Justice, which use radio frequencies for emergency purposes when wire lines fail, or to the few points that normally are not served by wire.

Trends in Federal Government Use of Communications

The policy of using military systems for the transmission of record communications of the Federal Government agencies is one of long standing. The volume of Government messages, both military and non-military, gradually increased, and the military systems were expanded. Domestic radio circuits within the continental limits were introduced around the year 1921. These, however, were not comprehensive enough to furnish service to all points in the United States, and the Federal agencies, including the military, relied in great measure upon the domestic commercial companies for service.

There was a gradual transition, starting in 1930, in which wire circuits leased from commercial companies replaced radio circuits for the transmission of Government domestic messages. This transition was the natural outcome of the knowledge that radio frequencies could be employed to better advantage in overseas communications.

At present the use of radio frequencies for domestic communication has been reduced to almost nothing.

Commercial landline rates for Government messages were fixed in 1886, under the authority of the Post Roads Act, at 40 percent of the existing commercial rates. From that time on, the commercial operating companies made continued efforts to have Government rates equalized. Finally, by a gradual process which started in 1935, Government message rates and public rates were equalized in 1947.

As Government rates rose and volume increased, Federal agencies turned more and more to the use of leased wire lines. The saving possible from leased line operation roughly approximates the increased cost that would have resulted from the equalized rates, given the same volume.

The use of leased wire lines by Federal Government agencies became so extensive that the Public Buildings Administration (later transferred to the General Services Administration) was authorized in 1946 to coordinate leased line operations and to provide means of raising the efficiency of such operations.

At the present time the GSA has made some progress toward the more efficient use of lines leased by the Federal Government.

A strong influence which has accelerated the leasing of teletype wires by Federal Government agencies is their cost advantage over message service, given sufficient volume of messages between specific points. The two main sources of leased teletype wires are the A. T. & T. and the Western Union Telegraph Company.

Legislation

Public Law #413, 79th Congress, approved June 14, 1946, gave the Public Buildings Administration authority (with certain restrictions) to operate public utility services, including telecommunications, serving one or more Government agencies.

Public Law #152, 81st Congress, approved June 30, 1949, transferred this authority to the General Services Administration.

In addition, this later law gives broad powers to the GSA in the operation and management of public utility services for the convenience and economy of the Government. GSA claims power under this law to eliminate or consolidate leases of communication circuits operated by various Federal Government agencies.

Interrelationships

Interrelationships between Federal Government systems are not particularly complicated and continue to incline toward a "community" system of operation wherein messages originated by one agency may, by arrangement, be transmitted over the facilities controlled by one of the others.

Relationships between Government systems and domestic commercial systems are more complicated. All the Federal Government networks depend upon the commercial companies for wires and maintenance, and, in some cases, for equipment.

Generally, all the Federal agencies that have communications operations rely upon the commercial domestic organizations to round out their systems, either by telegram service or TWX. This "rounding out" takes the form of deliveries to desired cities or points to which the Federal Government systems do not extend. The Government in almost all cases carries the message as far as possible over its own system.

The Government's domestic teletype systems are estimated to have transmitted in 1949 (excluding weather data) more than 5.8 billion words. Government payments to the A. T. & T. and Western Union for the facilities used in these transmissions were roughly $3.5 million, of which $1.4 million was paid to Western Union. An additional $4.5 million was paid for facilities used predominantly for the transmission of weather data amounting to the equivalent of roughly 11 billion words.

What it costs the Government to operate its domestic leased facilities, and what is saved through leasing facilities rather than paying regular message transmission charges is not actually known. However, an approximation of these charges over commercial circuits can be estimated through the use of calculations made by the GSA in a study for 1949 based upon about 28 million words transmitted domestically. GSA estimated that the Government saved 38.6 per cent by using leased wires, the percentage of saving being based on the assumption that charges for commercial message service would average over 6 cents per word. This assumption indicates that the GSA calculations are based on the straight day message rate for telegram service. The Board estimates the average message cost to be about 5 cents per word. At this average cost per word, the percentage of saving, adjusted from the GSA estimate, would be 32.1 percent.

Summarized estimates for the year 1949, using this average cost figure of 5 cents per word and the savings percentage adjusted from the GSA estimate, follow:

FEDERAL GOVERNMENT LEASED WIRE OPERATIONS, EXCLUDING WEATHER DATA

Rental of facilities	$3,501,796
Total words transmitted	5,835,071,689
Cost at 5 cents per word	$291,753,584
Saving by use of leased lines indicated by 32.1 percent saving adjusted from GSA estimate	$93,652,900
Resultant estimated cost of Federal Government operation of leased facilities	$198,100,684

We have not attempted to determine whether it is necessary for the Federal Government to transmit almost 6 billion words yearly for its domestic business.

OTHER DOMESTIC TELECOMMUNICATIONS SYSTEMS

There are a great number of rapid telecommunications systems within the United States other than those which have been described above. These systems include networks interconnecting broadcast and television stations; airline and railroad telecommunications systems; marine telecommunications on the Great Lakes, rivers, and harbors; land mobile services (autos, trains, trucks); press association networks; private wire networks of large corporations; and the amateur radio networks. Many of these systems are nationwide, and collectively they interconnect all of our major cities and most of the minor ones many times over. These networks are mainly dependent upon the physical facilities provided by the American Telephone and Telegraph Company or Western Union, and during the year 1949 spent some $50 million for leased line service.[1]

In addition to these systems within the continental United States, Alaska, Hawaii, and Puerto Rico all maintain domestic telecommunications systems which serve their particular areas.

A brief description of the most important of these systems follows.

Networks Interconnecting Broadcast and Television Stations

The broadcast industry uses extensive telephone facilities for the transmission of programs to stations, and teletype circuits for planning and coordination of network operations. In 1948, 3 regional networks, 4 nationwide networks, and 11 key stations spent $1 million for wire services. A total of 1,824 other standard broadcasting stations paid $5.8 million for like services. FCC reports indicate that the commercial broadcasting industry spent in 1949 in excess of $15 million for interstate private line services. Television broadcasting has necessitated construction of extensive coaxial cables and microwave links, the use of which increased considerably during 1949 and 1950.

Airline Domestic Telecommunication Systems

Scheduled airlines lease extensive telephone and teletype networks for use in their domestic operations. Some 500 aeronautical ground stations were served in 1949 at an approximate cost of $6 million, divided as follows:

A. T. & T.:	
Teletypewriter Exchange Service	$73,000
Private Line Telephone	1,400,000
Private Line Telegraph	3,500,000
Western Union:	
Private Line Telegraph	629,000
Telegram Tolls	336,000

Growth in the use of leased private line services by the commercial airlines is shown by the following figures from the Long Lines Department of A. T. & T.

[1] Estimate made from statistics supplied by A. T. & T., Western Union, and FCC Reports.

Year	*Expenditure*	*Year*	*Expenditure*
1938	$69,000	1945	$1,190,000
1940	198,000	1947	2,919,000
1942	582,000	1949	4,225,000

Railroad Telecommunication Systems

During the year 1949, Class I railroads (gross revenues over $1 million) had in service 522,000 miles of telegraph wire, 873,000 miles of telephone wire, and 215,000 miles of pole line. This telecommunication network, which extends throughout the nation following the railroad lines, is used for train dispatching, matters relating to passengers and freight, and various other forms of company business. Employees chargeable to the railroad communication service totaled 39,121 and their yearly compensation was $145,248,935.

Domestic Wire Networks of the Press Associations

The Associated Press, United Press, International News Service, and Transradio News Service operate large national teletype networks for the distribution of news. The collective cost of these leased circuits for the year 1949 was $450,000.

Domestic Systems of Large Corporations

A number of the large corporations in the United States, especially those which have nationwide interests and branch offices, maintain their own domestic leased wire teletype systems. Corporations such as United States Steel, General Motors, Ford Motor Company, and General Electric, and many smaller ones, have volumes of domestic telecommunications that enable them to lease and operate wire systems on a national basis and to effect appreciable savings in costs by comparison with telephone toll rates and domestic telegraph message rates. It is estimated that from 20 percent to 40 percent can be saved by private line teletype operation, depending upon volume, under current Western Union message rates.

On the Great Lakes and Rivers

On the Great Lakes, the Mississippi River, and connecting inland waterways, communication is carried on between ships and between ship and shore by radiotelephone. Certain shore stations have a "public coastal service" which will permit calls from ships to be completed through landline connections. Operational messages are also relayed or forwarded as requested by the company or captain. Charges for this service are regulated by law, and established long-distance rates apply on shore connections. Revenues as reported by the Class A and B telephone carriers in 1948 for such services were $575,000 on a basis of 400,000 calls.

Land Mobile Telecommunication Services

These services provide communication between mobile stations and base stations which tie in with public landline telephone facilities. The telephone companies in many locations operate the base stations. In general, trucking firms and automotive emergency road services make extensive use of such systems. A. T. & T. revenues from this service totaled $1.6 million in 1948 on 1.4 million calls handled.

Taxicabs are making extensive use on a nationwide basis of very-high-frequency radiotelephone for dispatching. In 1949 radio was used in nearly 3,000 separate taxicab communication systems covering about 54,000 mobile units.

In Hawaii

The 6 islands of the Territory of Hawaii are provided with telephone and telegraph service by the Mutual Telephone Company. Long-distance operation between the islands is made possible through operation of multi-channel radio microwave equipment incorporating the further use of radio dialing and radioteletype. Mutual also furnishes coastal harbor and mobile radiotelephone service in Honolulu. Assets of the company totaled $28.5 million in 1949, with operating revenues of $7.5 million. The net earnings were $829,000 after Federal and Territorial taxes of $974,000. Plant equipment consisted of 280,000 miles of wire, 95 percent in cable. Telephones in service were 90,000 or 17 phones per 100 population in the islands. Employees totaled 1,400 with compensation of $4.3 million.

In Puerto Rico

Telephone communications on the Island of Puerto Rico are operated by the Puerto Rico Telephone Company, a subsidiary of the International Telephone and Telegraph Company.

While earnings have declined steadily, the Company has been able to install over the last 5 years 19,000 telephones, a net gain of 12,000. This was made possible by the policy of the International Telephone and Telegraph Corporation, the principal stockholder, which has received no dividends since October 1944, yet has permitted its subsidiary, International Standard Electric Corporation, to advance equipment and materials worth $3 million.

The company's rates have not been increased for over 22 years, and in the meantime all costs of doing business have materially increased. Several petitions for increases in rates have been filed, and the company has filed a motion for temporary relief to help it continue to give satisfactory service, and to permit small additions to plant equipment pending the approval of a new rate schedule.

Present plant investment approximates $9 million, with other current assets of about $1 million. Total operating revenues in 1949 were $2.5 million with net earnings of $254,000 after tax deductions but before interest charges of $196,000. Thirty-five thousand telephones were in service and the company had 80,000 miles of wire, 90 percent of which was in cable. Compensation to 675 employees was $965,000 in 1948.

In Alaska

Alaska is provided with telecommunication facilities by the Alaska Communications System (ACS), a branch of the United States Army Signal Corps. Since its authorization by act of Congress in 1900, the system has operated the only long-line communication channels within the Territory and between the Territory and the United States. The ACS now has 32 telecommunication stations serving the Federal and Territorial Government agencies, and the general public, by wire and radio. The latter includes service to and from ships at sea, press services to newspapers, broadcast programs to radio stations, and general commercial messages. Regular telephone service is provided in the larger cities by 14 exchanges with a total of approximately 12,000 telephones in service. In 1948 the telegraph service provided by ACS to 58 Government agencies had an estimated commercial value of $480,000 and military telegraph messages of $3 million. Telephone service to the agencies approximated $54,000 and that to the military $173,000.

Supplementing the ACS, mainly to serve isolated communities, is a 60-station radiotelephone system maintained by the Alaska Communications Commission, an agency of the Territorial Government. The Alaska Native Service also operates a total of 102 radiotelephone stations, the majority of which are located in Arctic and sub-Arctic regions. The stations are used to conduct the routine business of the service, as well as for emergency purposes.

The Civil Aeronautics Administration maintains an extensive network of 42 radio stations, operated by 625 employees, used primarily for aircraft navigation and for weather information. Routine weather reports from outlying stations are also relayed to a common point for forwarding. The CAA is also the largest Government agency user of Alaska Communications System facilities, receiving services valued at $80,000 in 1948 and $76,000 in 1949.

Recent Trends

The outstanding trend apparent in the development of the domestic systems described in this section is that of relatively rapid and substantial growth. For example, the broadcasting industry served 12 million homes with 618 radio stations in 1930. In 1949 it served 42 million homes with 3,067 radio stations. The aviation industry in 1930 maintained 170 ground radio stations and 293 aircraft stations. In 1949, 1,572 radio transmitters were licensed to commercial aircraft operating with 1,409 ground radio stations.

The growth of television has increased the estimated tangible investment in stations and sets from a 1948 total of $403 million to more than $3 billion at the end of 1950. In 1947 there were only 12 stations serving 210,000 receivers. In January of 1951 (even though no new television station construction permits were issued after September 1948), a total of 107 stations were serving an estimated 10.6 million receivers. From Omaha east there are 47 interconnected cities having 80 television stations serving 9 million receivers. Of the total stations, New York has 7, with Chicago and Washington 4 each. Sixteen other non-interconnected cities have 27 stations serving 1.6 million receivers. These figures indicate that about 40 percent of the homes in TV areas now have receivers. During the month of December 1950 alone 704,000 were placed in use. Los Angeles' 7 stations placed that city first in estimated television investment.

The accelerated growth of television has hastened the construction of coaxial cables, bringing the Nation's total to 7,600 miles in 1949. This over-all program has been modified somewhat because of planned installation of microwave radio relay systems between various cities.

Conclusions

1. The telephone system of the United States is a financially sound, multi-billion dollar industry consisting of the Bell System and 5,000 independent companies. This coordinated system is providing the Nation with what is admittedly the best telephone service in the world. It is steadily improving that service by aggressive technological advancement. In view of the healthy condition of the telephone system, we conclude that no changes in Government procedure for insuring adequate service in the national interest are necessary.

2. The telegraph system of the United States has experienced economic difficulties owed in part to the expansion of other means of rapid communication. The recent return of the principal telegraph company to profitable operation, in part because of improved management and modernization of its plant and in part because of greater general business activity, is encouraging. This current improvement in the position of the industry affords an opportunity to develop information needed for sound, long-range planning to avoid future difficulties. We believe that sound management and vigorous technological development can contribute further to the stability of the domestic telegraph system.

3. The effects of the administration of the Communications Act of 1934 relative to reductions of telegraph service through the closing of unprofitable offices or through substitution of agencies need further study. Western Union maintains that the restrictive application of present legal provisions places an undue financial burden upon the company which it can ill afford to bear; representatives of labor contend that too great a degradation of service often has followed the substitution of agencies for offices.

4. Rates for the telegraphic services—telegram, TWX, and private leased lines—are given regulatory approval without adequate knowledge of the costs of providing such services. Also, in passing upon long-distance telephone rates, the Federal Communications Commission should inform itself of the probable effect of proposed changes upon the position of the telegraph industry, and upon rates for local telephone service.

5. We have looked carefully into the proposal that the telecommunications industry should be divided clearly into two parts, one dealing exclusively with "record" communications, the other with communications by "voice." Our examination of this question has shown that such a dividing line is very difficult to draw, and we have concluded that the attempt to reorganize the telecommunications system on the basis of such a distinction might result in effects on the system going far beyond the initial intention of any such division. The main bone of contention today is the fact that the telephone company offers a form of record communications—TWX and private-line leases—which competes with message-delivery functions of the telegraph company. We note that Congress in 1943 amended the Communications Act to permit acquisition of this form of service by the telegraph carrier. Thus the companies involved are free to negotiate an agreement to make this change, subject to approval by the FCC. We believe that this matter should be determined by the normal processes of negotiation.

6. The operation of leased domestic telecommunications networks by the Federal Government for the transmission of Federal Government messages is not, strictly speaking, competitive with the operations of commercial telecommunications companies. In its teletype

networks, the Government is taking advantage of volume rates offered by the telecommunications companies in the same manner as can any other customer with large volume requirements. The Government should continue to take full advantage of the most efficient and economical rates and conditions of service which are available to any large user. While it is important that the Government seek the most economical means of handling its own communications, it also is of great importance that it continue its present policy of using privately owned facilities rather than building up a Government-owned competing network.

Attachment III-A

Bell System Selected Statistics and Some Comparative Data for all Telephone Carriers

	Dec. 31, 1925	*Dec. 31, 1930*	*Dec. 31, 1935*	*Dec. 31, 1940*	*Dec. 31, 1945*	*Dec. 31, 1949*	*All Carriers Dec. 31, 1949*	*% Bell System*
Number of Telephones	11, 909, 578	15, 187, 296	13, 573, 025	17, 483, 981	22, 445, 519	33, 388, 258	[f] 40,709,398	82
Number of Central Offices	6, 147	6, 639	6, 896	7, 052	7, 374	8, 224	[f] 19,342	43
Miles of Pole Lines [a]	394, 529	428, 212	407, 454	399, 838	420, 009	483, 777	....	....
Miles of wire: [a]								
In Underground cable	27, 769, 000	45, 116, 000	47, 639, 000	54, 339, 000	60, 759, 000	81, 865, 000	....	....
In Aerial Cable	12, 835, 000	23, 777, 000	26, 425, 000	30, 307, 000	33, 966, 000	44, 813, 000	....	....
Open Wire	4, 339, 000	5, 231, 000	4, 562, 000	4, 660, 000	5, 034, 000	6, 411, 000	....	....
Total	44, 943, 000	74, 124, 000	78, 626, 000	89, 306, 000	99, 759, 000	133, 089, 000	147,300,000	90. 3
Miles Coaxial [b]	....	....	....	....	....	58, 768	....	....
Miles Microwave Relay [c]	....	....	....	....	....	750	....	....
Number of Telegraph Stations:								
Private Line	....	....	....	....	....	23, 823	....	....
TWX Exchange	....	....	....	....	....	25, 077	....	....
Total	....	....	....	....	....	48, 900	....	....
Average Daily Telephone Conversations	50, 141, 000	64, 034, 000	60, 290, 000	79, 303, 000	90, 548, 000	132, 023, 000	160,000,000	82. 5
Total Plant Investment (thousands)	$2, 566, 809	$4, 041, 237	$4, 187, 790	$4, 747, 674	$5, 702, 057	$9, 432, 750	[g] $10,510,000	87. 7
Operating Revenues (thousands)	$737, 560	$1, 077, 300	$919, 116	$1, 174, 322	$1, 930, 889	$2, 893, 273	[g] $3,180,000	90. 8
Number of Employees [d]	335, 858	391, 746	268, 754	323, 701	474, 527	593, 869	....	....
Number of A. T. & T. Stockholders	362, 179	567, 694	657, 465	630, 902	683, 897	829, 498	....	....
Taxes (thousands)	$58, 113	$84, 732	$94, 507	$184, 770	$399, 917	$346, 144	....	....

[a] Carrier is used on some open wire and cable pairs. When carrier is used the maximum capacity of an open wire pair is 16 telephone channels and the maximum capacity of two cable pairs is 12 telephone channels.

[b] A pair of coaxials can provide 600 telephone channels.

[c] Provides 2,000 one way broad band channel miles.

[d] Includes employees of Western Electric Company and Bell Telephone Laboratories.

[f] U. S. Census by Bell System (41,790,000 telephones as of June 30, 1950).

[g] Estimate by A. T. & T. Co.

(Source: A. T. & T.).

Attachment III–B

Western Union and Postal Telegraph (Landline) Number of Transmission Messages by Class of Message 1926–1949

[Thousands]

Year	*Full Rate* (1)	*Day Letter* (2)	*Night Letter and Night Message* (3)	*Serials* (4)	*Total Public Messages* (5)	*Government* (6)	*Press* (7)	*Money Orders* (8)	*Timed Wire* (9)	*Greetings* (10)	*Cable and Radio*[b] (11)	*Other Transmission Messages*[c] (12)	*Grand Total* (13)
1926	132, 472	17, 724	38, 784	......	188, 980	6, 522	17, 952	4, 077	......	......	......	......	217, 531
1927	131, 153	18, 344	37, 388	......	186, 885	6, 681	18, 148	4, 102	......	......	......	......	215, 816
1928	135, 318	19, 900	37, 748	......	192, 966	7, 655	19, 678	4, 272	......	......	......	......	224, 571
1929	138, 641	22, 260	38, 851	......	199, 752	8, 159	21, 287	4, 852	......	......	......	......	234, 050
1930	123, 535	21, 897	33, 659	......	179, 091	8, 806	19, 417	4, 657	......	......	......	......	211, 971
1931	106, 797	20, 414	27, 518	550	155, 279	8, 993	15, 054	4, 044	3	......	......	......	183, 373
1932	80, 342	16, 612	19, 921	2, 556	119, 431	8, 728	11, 678	3, 148	90	......	......	......	143, 075
1933	78, 007	18, 463	19, 208	4, 903	120, 581	8, 916	10, 999	2, 864	193	......	......	......	143, 553
1934	81, 269	19, 563	19, 875	7, 908	128, 615	9, 763	12, 065	3, 079	1, 693	......	......	......	155, 215
1935	87, 578	20, 811	20, 124	7, 774	136, 287	7, 656	14, 749	3, 414	2, 607	2, 117	4, 356	5, 064	176, 250
1936	93, 605	22, 249	20, 019	9, 369	145, 242	8, 078	14, 842	3, 757	3, 474	8, 714	4, 693	4, 766	193, 566
1937	92, 279	19, 590	23, 043	9, 267	144, 179	8, 495	14, 279	4, 207	3, 389	15, 013	6, 403	4, 746	200, 711
1938	85, 190	18, 574	19, 641	8, 550	131, 955	8, 622	11, 788	4, 003	2, 900	16, 360	5, 678	4, 333	185, 639
1939	87, 811	18, 641	19, 661	9, 086	135, 199	7, 648	11, 400	3, 892	3, 109	17, 534	6, 178	4, 095	189, 055
1940	93, 812	15, 631	20, 220	8, 580	138, 243	5, 882	11, 143	4, 072	4, 093	18, 766	5, 804	3, 642	191, 645
1941	105, 690	13, 917	22, 736	8, 608	150, 951	5, 751	11, 288	5, 269	6, 003	22, 329	6, 174	3, 163	210, 928
1942	113, 242	11, 657	25, 126	6, 723	156, 748	13, 040	8, 361	8, 609	8, 603	18, 300	5, 783	3, 704	223, 148
1943	118, 286	16, 883	30, 544	5, 909	171, 622	15, 453	7, 401	13, 359	[a] 928	9, 654	9, 033	4, 242	231, 692
1944	116, 926	15, 791	33, 086	6, 531	172, 334	12, 743	8, 484	15, 898	......	9, 623	9, 614	4, 016	232, 712
1945	123, 537	15, 949	35, 578	7, 156	182, 220	10, 593	9, 903	15, 748	......	11, 627	10, 698	3, 840	244, 629
1946	124, 945	13, 362	32, 401	5, 924	176, 632	5, 474	10, 104	11, 192	......	3, 832	9, 656	3, 814	220, 704
1947	134, 733	12, 309	31, 405	8, 050	186, 497	3, 107	11, 596	8, 512	......	......	9, 852	4, 523	224, 087
1948	117, 748	10, 087	29, 181	7, 967	164, 983	2, 799	12, 254	8, 577	......	......	8, 897	4, 368	201, 878
1949	108, 014	9, 281	26, 511	7, 670	151, 476	2, 422	11, 638	8, 308	......	......	7, 998	3, 831	185, 673

See footnotes on page 116.

Attachment III-B—Continued

[a] Timed wire service discontinued in February 1943 by order of the Commission and a new service, Longrams and Serial Longrams, was introduced. The number of Longram messages was included with day letters, serial longrams with serials. Longrams and serial longrams were discontinued in 1946.

[b] Cable and radio messages represent the domestic haul of international traffic handled by Western Union and Postal Telegraph. Data not available 1926–1934.

[c] Other transmission messages include Commercial News department, contract (principally railroad) messages and facsimile. Data not available 1926–1934.

Sources: For the period 1926 to 1934, inclusive, the data are based on responses from the Western Union Telegraph Company (landline system) and the Postal Telegraph Company to Telegraph Division Order No. 12. Data for subsequent years are based on annual reports to the Commission. For the years 1930–1936 Postal Telegraph data were reported for the month of January only; annual data were estimated on the basis of the relationship of January transmission revenues to the transmission revenues for the year.

Attachment III–C

Western Union and Postal Telegraph (Landline) Composition of Transmission Revenues 1927–49

[Thousands of dollars]

Year	Message											
	Full Rate (1)	Day Letters (2)	Night Letters (3)	Money Order Messages (4)	Government (5)	Press (6)	Serials (7)	Timed Wire (8)	Greeting (9)	Total (10)	Other (11)	Total (12)
1927	$83, 471	$18, 262	$25, 000	$3, 333	$806	$3, 490	......	......	......	$134, 362	$5, 983	$140, 345
1928	85, 478	19, 848	24, 924	3, 388	874	3, 780	......	......	......	138, 292	7, 241	145, 533
1929	89, 437	22, 400	26, 019	3, 765	981	4, 005	......	......	......	146, 607	7, 828	154, 435
1930	79, 027	21, 980	22, 476	3, 708	1, 061	3, 789	......	......	......	132, 041	7, 305	139, 346
1931	65, 880	20, 262	17, 570	3, 183	1, 085	3, 164	$315	$4	......	111, 463	6, 895	118, 358
1932	48, 526	16, 548	12, 750	2, 443	1, 021	2, 484	1, 295	156	......	85, 223	5, 034	90, 257
1933	45, 781	17, 922	12, 062	2, 169	1, 262	2, 248	2, 370	248	......	84, 062	4, 963	89, 025
1934	46, 908	18, 885	12, 237	2, 354	1, 607	2, 551	3, 678	1, 693	......	89, 913	4, 740	94, 653
1935	48, 291	18, 866	12, 029	2, 485	1, 441	2, 548	3, 912	2, 608	$596	92, 776	4, 792	97, 568
1936	51, 720	20, 033	11, 907	2, 627	1, 470	2, 694	4, 611	3, 324	2, 563	100, 949	4, 849	105, 798
1937	50, 747	19, 069	11, 010	2, 755	1, 536	2, 630	4, 539	3, 261	4, 501	100, 048	6, 220	106, 268
1938	46, 673	16, 559	9, 139	2, 552	1, 607	2, 245	4, 158	2, 856	4, 708	90, 497	5, 146	95, 643
1939	48, 230	16, 561	9, 066	2, 551	1, 601	2, 208	4, 421	3, 009	5, 004	92, 651	5, 440	98, 091
1940	53, 043	14, 060	9, 205	2, 681	2, 097	2, 251	4, 115	3, 871	5, 347	96, 670	5, 328	101, 998
1941	62, 156	12, 708	10, 459	3, 532	3, 314	2, 256	4, 053	5, 648	6, 451	110, 577	4, 992	115, 569
1942	69, 650	11, 379	12, 221	6, 025	8, 087	1, 771	3, 331	8, 131	5, 630	126, 225	4, 179	130, 404
1943	82, 742	16, 617	15, 138	9, 150	10, 819	1, 423	3, 118	813	3, 332	143, 152	9, 876	153, 028
1944	85, 073	15, 746	16, 493	11, 322	10, 298	1, 619	3, 669	......	3, 356	147, 576	10, 456	158, 032
1945	91, 422	15, 863	17, 641	11, 059	8, 912	1, 889	3, 938	......	3, 861	154, 585	11, 960	166, 545
1946	95, 694	14, 420	18, 188	8, 631	4, 627	2, 421	3, 424	......	1, 273	148, 678	11, 564	160, 242
1947	115, 824	15, 100	20, 852	7, 849	3, 202	2, 907	5, 469	......	......	171, 203	12, 631	183, 834
1948	102, 165	12, 833	18, 839	7, 818	3, 362	3, 171	5, 504	......	......	153, 692	11, 904	165, 596
1949	93, 713	11, 562	16, 957	7, 651	2, 914	3, 007	5, 296	......	......	141, 100	10, 640	151, 740

Source: Responses of carriers to FCC Order No. 12 and annual reports to FCC.

Attachment III–D

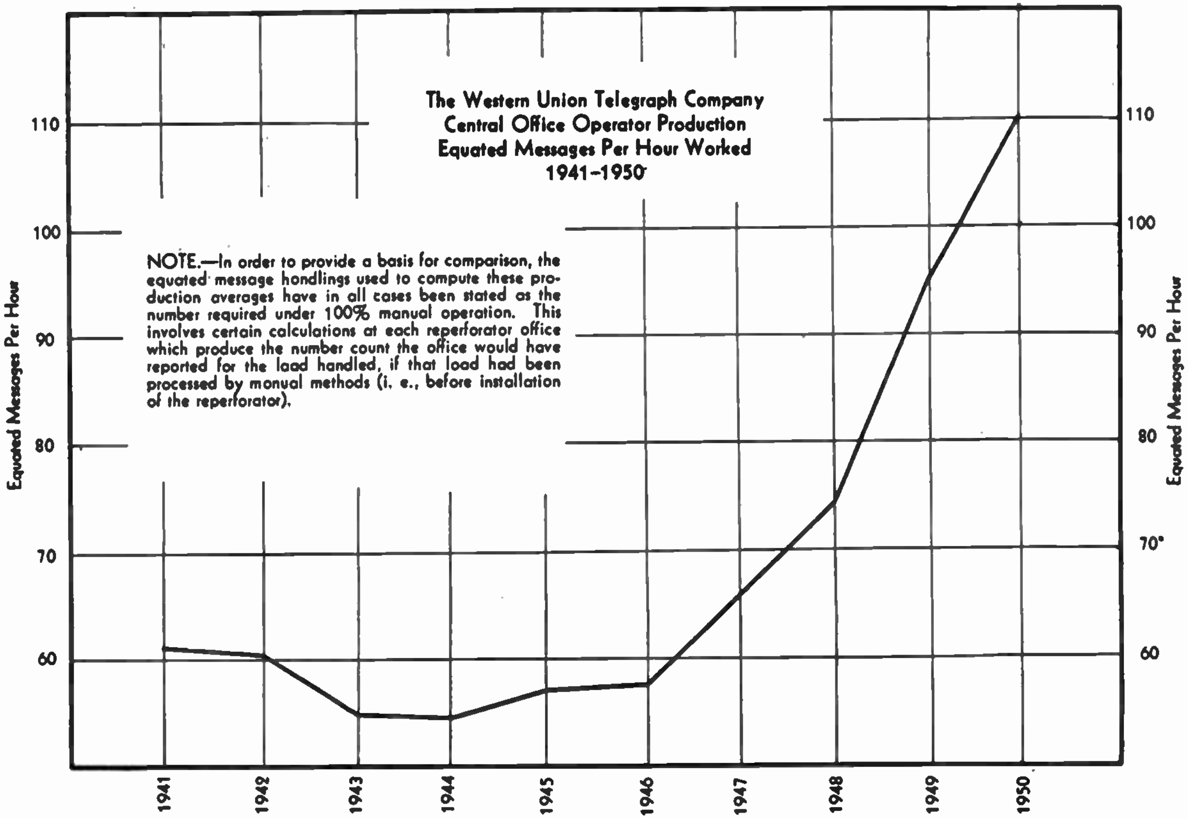
Western Union and Postal Telegraph (Landline) Composition of Nontransmission Revenues, 1927–1949

[Thousands of dollars]

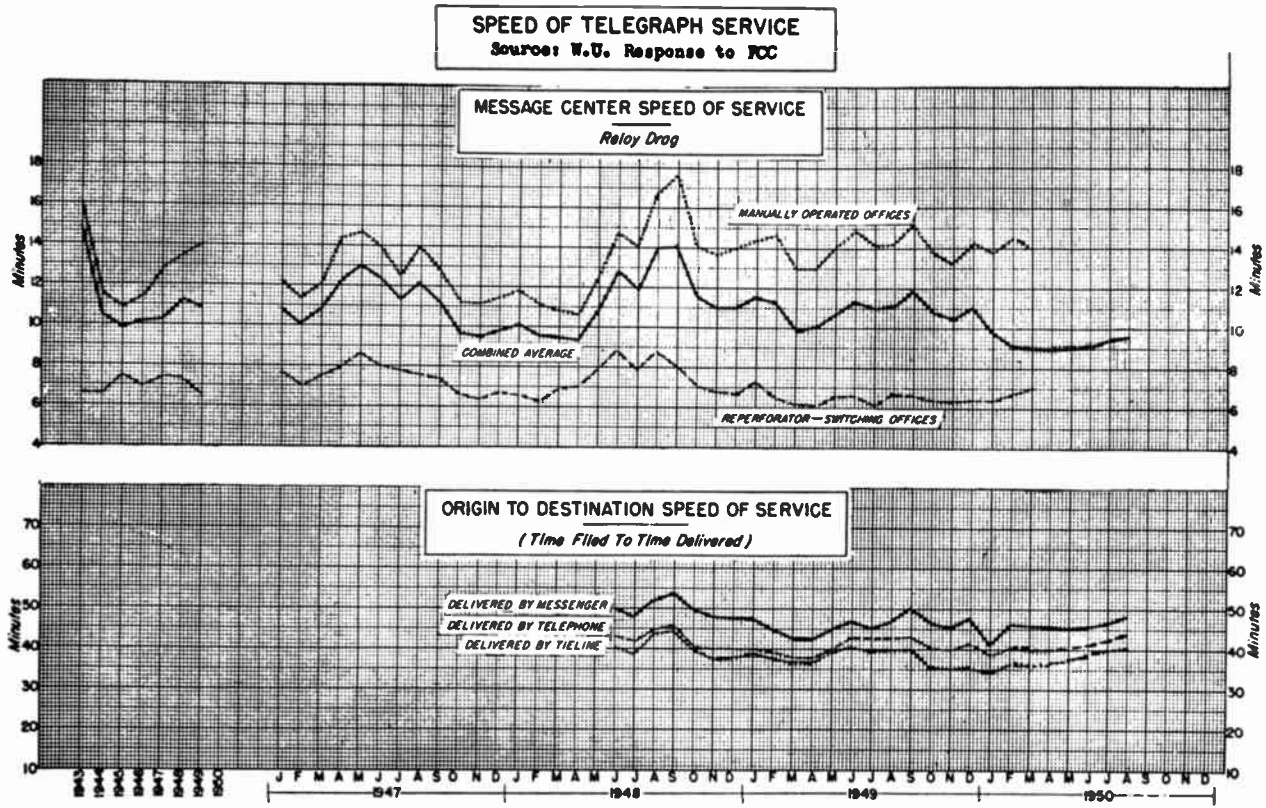
Year	Leased Circuit (1)	Measured Service (2)	Other Leased Plant (3)	Code Registration (4)	Errand Service (5)	Money Order Charges (6)	Time Service (7)	Other (8)	Total (9)
1927	$2, 143	....	$864	....	$1, 466	$1, 892	$1, 359	$206	$7, 930
1928	2, 072	....	892	....	1, 723	1, 956	1, 349	225	8, 217
1929	2, 338	....	814	....	2, 058	2, 196	1, 319	198	8, 923
1930	2, 324	....	954	....	2, 031	2, 079	1, 285	204	8, 877
1931	2, 228	....	973	....	1, 961	1, 779	1, 116	282	8, 339
1932	2, 269	....	963	....	1, 934	1, 356	854	269	7, 645
1933	2, 301	....	976	....	2, 140	1, 235	646	290	7, 588
1934	2, 194	....	1, 018	....	2, 598	1, 325	528	241	7, 904
1935	2, 227	....	1, 035	....	3, 219	1, 408	539	266	8, 694
1936	2, 342	$36	1, 053	....	4, 112	1, 520	556	355	9, 974
1937	2, 426	188	1, 082	....	4, 550	1, 643	595	476	10, 960
1938	2, 500	456	1, 142	....	4, 336	1, 517	609	610	11, 170
1939	2, 631	794	1, 140	....	4, 418	1, 510	603	712	11, 808
1940	2, 615	1, 125	1, 144	....	4, 653	1, 558	604	890	12, 589
1941	3, 524	1, 465	1, 199	....	5, 016	1, 953	614	1, 179	14, 950
1942	4, 292	1, 843	1, 241	....	3, 081	3, 103	621	1, 204	15, 385
1943	3, 689	2, 088	1, 415	$6	61	5, 100	612	954	13, 925
1944	3, 655	2, 275	1, 502	5	51	6, 306	626	755	15, 175
1945	3, 572	2, 395	1, 493	28	55	6, 537	653	770	15, 503
1946	3, 681	2, 251	1, 599	45	298	5, 920	741	759	15, 294
1947	4, 319	2, 154	1, 617	59	699	5, 394	928	650	15, 820
1948	5, 696	2, 316	1, 621	60	1, 033	5, 406	941	760	17, 833
1949	7, 528	2, 405	1, 593	64	1, 234	5, 122	938	769	19, 653

Source: Responses of carriers to FCC Order No. 12 and annual reports to FCC.

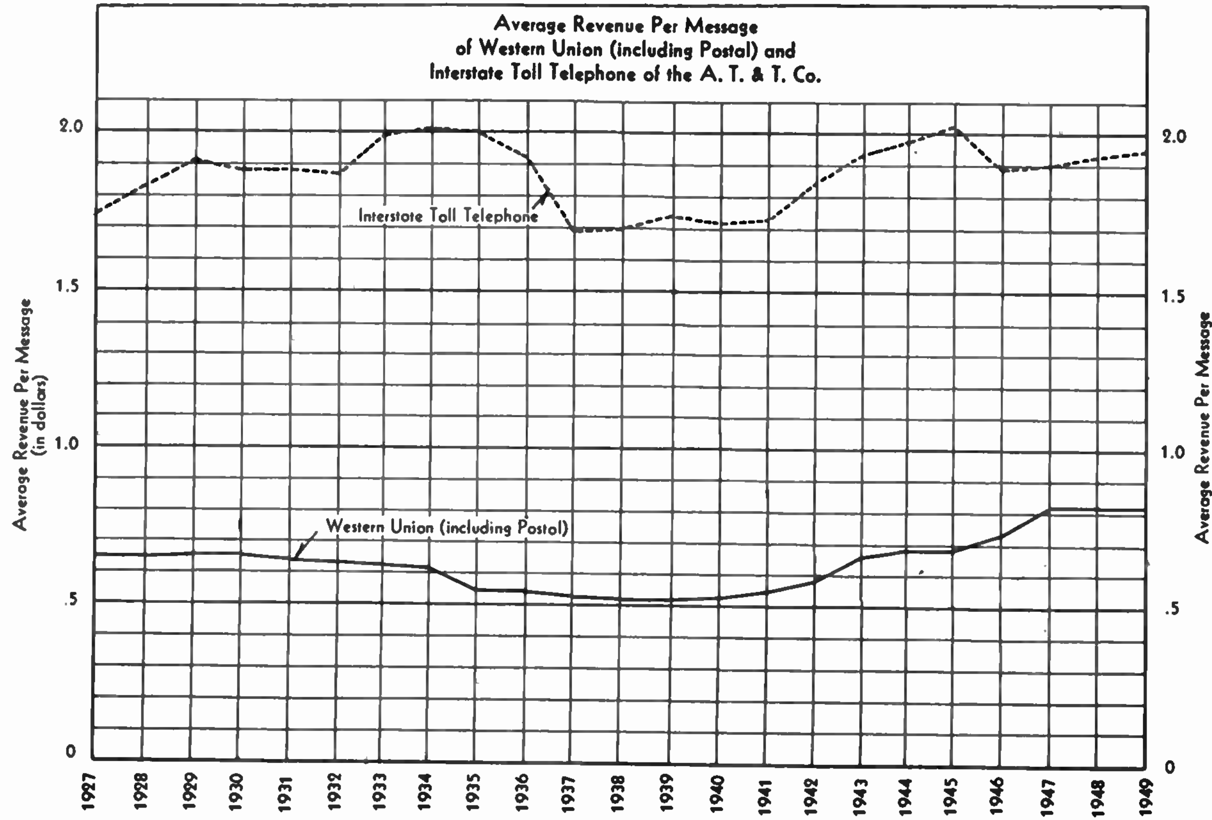
Attachment III–E



Attachment III–F



Attachment III–G



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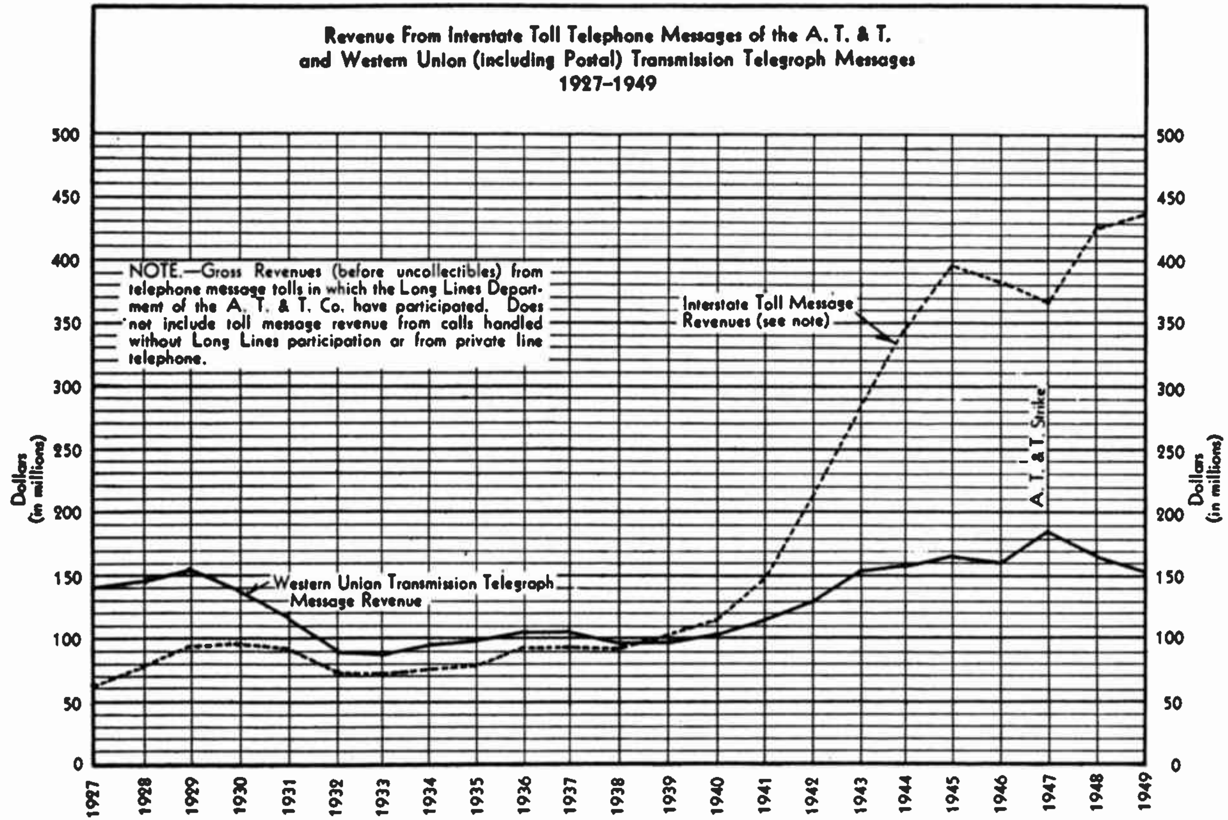
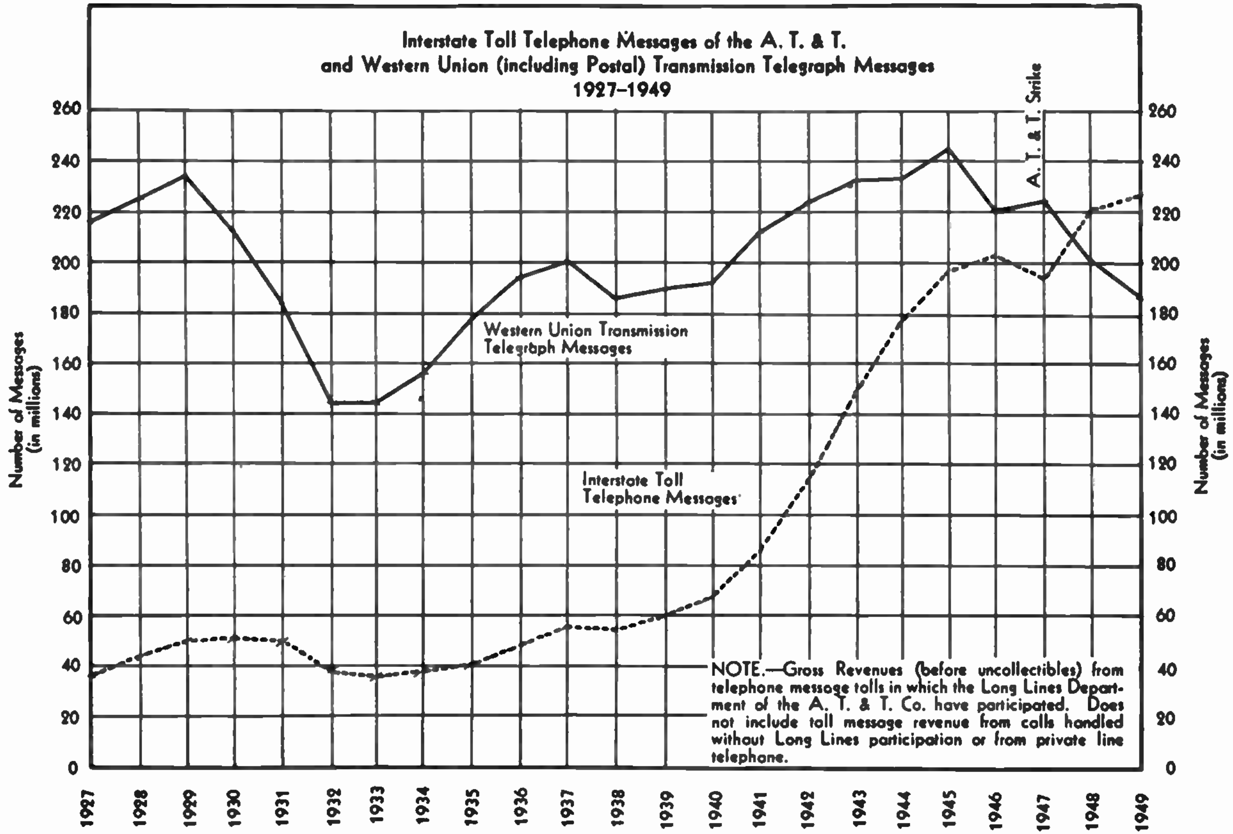
Attachment III–H



Attachment III–I



Attachment III-K

Revenues from Telegraph Operations of Large Telephone Companies, 1926–1949

Year	Total [a]	Private line Morse	Private line teletype-writer	Private line telephoto-graph	TWX	Other [b]	Total [a]	Private line Morse	Private line teletype-writer	Private line telephoto-graph	TWX	Other [b]
	(Thousands of dollars)						(Percent of total)					
1926	$16,580	......	....	....	0	......	100.0	......	....	....	.0	....
1927	18,016	......	....	....	0	......	100.0	......	....	....	.0	....
1928	21,057	......	....	....	0	......	100.0	......	....	....	.0	....
1929	25,197	......	....	....	0	......	100.0	......	....	....	.0	....
1930	27,034	......	....	....	0	......	100.0	......	....	....	.0	....
1931	25,252	......	....	....	7	......	100.0	......	....	....	(c)	....
1932	21,798	......	....	....	514	......	100.0	......	....	....	2.4	....
1933	21,018	......	....	....	995	......	100.0	......	....	....	4.7	....
1934	21,407	......	....	....	2,276	......	100.0	......	....	....	10.6	....
1935	20,684	6,836	9,575	460	3,813	......	100.0	33.0	46.3	2.3	18.4	....
1936	24,166	7,201	10,733	467	5,645	120	100.0	29.8	44.4	1.9	23.4	.5
1937	26,178	6,961	11,592	475	6,792	358	100.0	26.6	44.2	1.8	25.9	1.5
1938	23,963	5,493	10,755	494	6,824	397	100.0	22.9	44.9	2.1	28.5	1.6
1939	23,804	4,641	10,455	480	7,789	439	100.0	19.5	43.9	2.0	32.7	1.9
1940	23,344	3,630	10,326	471	8,440	477	100.0	15.6	44.2	2.0	36.2	2.0
1941	25,320	2,872	11,282	473	10,183	510	100.0	11.3	44.6	1.9	40.2	2.0
1942	35,942	2,206	16,466	474	16,255	541	100.0	6.1	45.8	1.4	45.2	1.5
1943	41,407	1,344	15,724	412	23,485	442	100.0	3.2	38.0	1.0	56.7	1.1
1944	41,693	1,401	18,826	366	20,642	458	100.0	3.4	45.1	.9	49.5	1.1
1945	40,818	1,539	21,573	366	16,827	513	100.0	3.8	52.9	.9	41.2	1.2
1946	34,065	1,508	18,537	550	12,963	507	100.0	4.4	54.4	1.6	38.1	1.5
1947	35,876	1,285	19,601	776	13,757	457	100.0	3.6	54.6	2.2	38.3	1.3
1948	41,830	1,081	22,766	1,182	16,323	478	100.0	2.6	54.4	2.8	39.0	1.2
1949	46,219	879	25,562	1,369	17,965	444	100.0	1.9	55.3	3.0	38.9	0.9

[a] Coverage of total revenue figures:

1926–1930—Private line revenues of Bell System, Cincinnati Suburban Bell Telephone Company and Southern New England Telephone Company.

1931–1934—Private line and TWX revenue of Bell System, Cincinnati Suburban Bell Telephone Company, and Southern New England Telephone Company.

1935–1949—Bell and other Class A and B carriers reporting to FCC.

[b] Includes message telegram service and miscellaneous private and non-private line revenue.

[c] Less than 0.1 per cent.

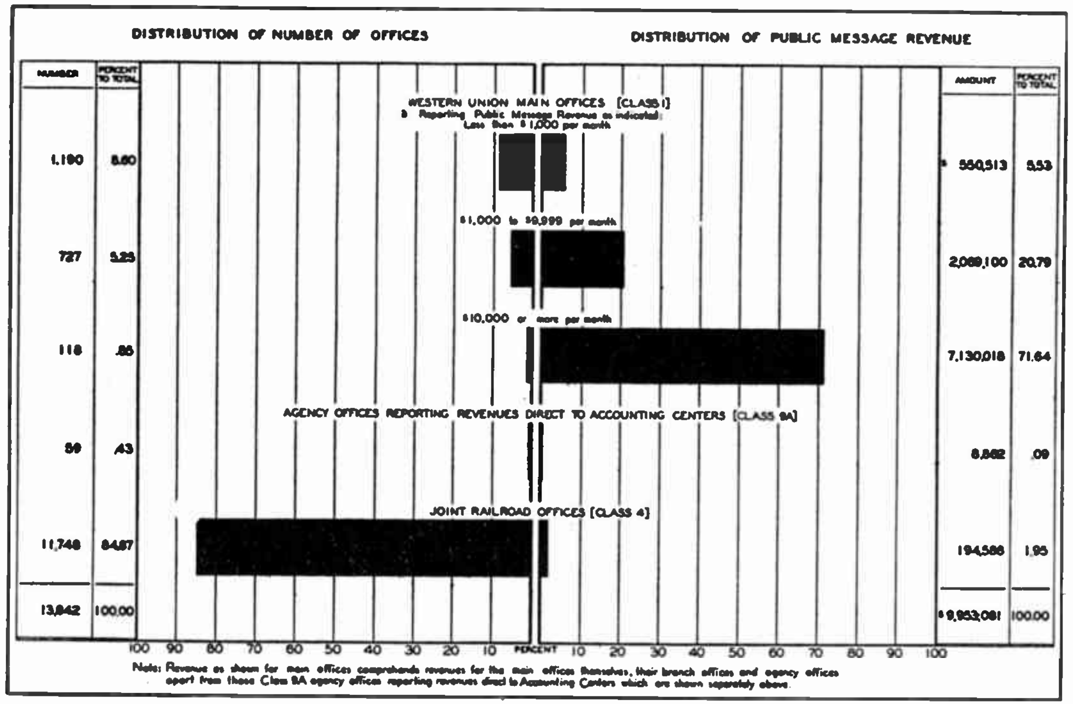
Source: Responses of Bell System Telephone Companies to Telegraph Division Order No. 12 and annual reports of Class A and B Telephone Carriers to the Federal Communications Commission.

Attachment III–L

THE WESTERN UNION TELEGRAPH COMPANY

LAND LINE SYSTEM

DISTRIBUTION OF OFFICES AND PUBLIC MESSAGE REVENUE
ACCORDING TO CLASS OF OFFICE
AND AMOUNT OF PUBLIC MESSAGE REVENUE REPORTED IN JANUARY 1950



Attachment III-M

STATISTICS — 1949

DOMESTIC CONTINENTAL UNITED STATES FEDERAL GOVERNMENT AGENCY OPERATION OF LEASED WIRE TELETYPE LINES — ESTIMATED AVERAGE FIGURES

FEDERAL GOVERNMENT AGENCY	MILES OF LEASED LINES	COST OF LEASED LINES AND EQUIPMENT II	ESTIMATED ORIGINATED WORDS TRANSMITTED (1) III	NUMBER WORDS HANDLED FOR OTHER GOVERNMENT AGENCIES IV	ANNUAL COST T W X SERVICE V	NUMBER WORDS TRANSMITTED VIA WESTERN UNION VI	ANNUAL COST OF WORDS TRANSMITTED VIA WESTERN UNION VII
DEPT. OF AGRICULTURE	17,630	$ 244,036	45,705,272	NONE	$ 2,400	5,412,367	$ 171,031
DEPT. OF THE AIR FORCE (WEATHER)	80,497	2,905,958	(2)	(2)	NONE	NONE	NONE
DEPT. OF THE AIR FORCE (OTHER THAN WEATHER)	33,000	588,000	460,000,000	6,000,000	70,028	(3)	127,943
DEPT. OF THE ARMY	23,423	429,958	330,816,624 (4)	43,500,000	162,326	(3)	524,080
DEPT. OF COMMERCE (CIVIL AERONAUTICS ADMIN)-WEATHER	77,610	1,646,123	10,587,960,000 (5)	(2)	NONE	NONE	NONE
DEPT. OF COMMERCE (CIVIL AERON. ADMIN)-OTHER THAN WEATHER	31,770	695,772	4,317,800,000	25,000	600	47,400	2,400
DEPT. OF COMMERCE (WEATHER BUREAU)	6,279	116,280	100,000,000	NONE	55,280	4,450,866	190,751
GENERAL SERVICES ADMINISTRATION	14,392	246,088	4,882,034	23,762,639 (6)	29,228	7,063,564	163,311
DEPT. OF THE NAVY	12,609	446,157	373,697,016	254,760 (8)	66,840	(3)	116,699
VETERAN'S ADMINISTRATION	8,658	225,000	38,729,040	270,000	125,536	9,215,080	160,912
OTHER FEDERAL GOVERNMENT AGENCIES (9)	20,063	510,505	87,753,000	1,876,304	311,795	7,861,382	256,633
TOTALS	325,931	$ 8,053,877	16,347,342,986	75,688,703	$ 824,033	34,050,659	$ 1,713,760
TOTALS LESS WEATHER FIGURES	167,824	$ 3,501,796	5,759,382,986	75,688,703	$ 824,033	34,050,659	$ 1,713,760
GRAND TOTAL LEASED LINE WORDS (7)			5,835,071,689				

NOTES: (1) FIGURES SHOWN DO NOT INCLUDE RELATED WORDS.

(2) NO ESTIMATE MADE BECAUSE OF THE SPECIALIZED NATURE OF THE SERVICES AND FORMS OF TRANSMISSION.

(3) FIGURES NOT AVAILABLE.

(4) THESE FIGURES REFLECT SOME TRANSMISSION BY RADIO, EXACT PERCENTAGE NOT AVAILABLE.

(5) THIS FIGURE NOT REFLECTED IN TOTALS BECAUSE OF SPECIALIZED NATURE OF SERVICES AND FORMS OF TRANSMISSION.

(6) INDICATES NUMBER OF WORDS TRANSMITTED ON A PRORATE BASIS, UNDER AUTHORITY OF PUBLIC LAW 413 (SEC. 7) 79TH CONGRESS, APPROVED JUNE 14, 1946.

(7) DOES NOT INCLUDE WEATHER TRANSMISSIONS, BUT OTHERWISE INCLUDES WORDS TOTALED IN COLUMNS III AND IV.

(8) SHOWN FOR WASHINGTON AREA ONLY — OTHER FIGURES NOT AVAILABLE.

(9) OTHER FEDERAL GOVERNMENT AGENCIES, WHICH ARE REFLECTED IN THESE FIGURES:

FEDERAL COMMUNICATIONS COMMISSION
DEPARTMENT OF THE INTERIOR
DEPARTMENT OF STATE
DEPARTMENT OF THE TREASURY
MEDIATION AND CONCILIATION SERVICES
EXPORT - IMPORT BANK
FEDERAL POWER COMMISSION
NATIONAL MEDIATION BOARD
HOUSING EXPEDITER
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FEDERAL RESERVE SYSTEM
DEPARTMENT OF JUSTICE
ATOMIC ENERGY COMMISSION
CIVIL AERONAUTICS BOARD

Chapter IV

UNITED STATES TELECOMMUNICATIONS ABROAD

Electrical communications that rival the domestic systems in speed connect the United States with points all over the world. Commercial networks span the globe with messages, conversations, and pictures that give direction to the nation's foreign trade. International radio facilities built up by the Federal Government handle a heavy volume of communications for the conduct of defense and diplomacy. Long-range broadcasting under the supervision of the Department of State is one of the country's essential international activities under current world conditions. Commercial and government interests participate in operation of international telecommunications for protection of life at sea and in the air.

All but the cable systems are directly concerned with the demand for radio frequencies discussed in Chapter II of this Report. Another problem affecting international telecommunications of the United States arises from economic and other difficulties of the companies engaged in cable and radiotelegraph service.

The cable companies have been burdened with a heavy investment in plant. Intense competition with each other and from radio has held down profits. Development of radio in the international field has added circuits faster than traffic has grown. The American companies often have found themselves at a disadvantage in negotiations with the monopolies of government-controlled companies of other countries.

The result has been an intermittent demand for legislation that would permit the merger of some or all of the American companies selling cable and radiotelegraph services.

Many agencies of the Government from time to time have supported the merger idea, but for the most part Congressional policy has been opposed to such action. The Communications Act of 1934 calls for a competitive structure among the international record communication companies. Officials with a primary responsibility for national security are eager that as many international circuits as possible are kept in operation.

To supplement other information available on the economics of the merger question, the President's Communications Policy Board retained the engineering firm of Ford, Bacon & Davis to make a special survey of the record communications industry. These consultants found that, while savings from merger in the international field might make possible reductions in rates, of a group of big customers of the cable and radiotelegraph companies most were opposed to consolidations on the ground that poorer service might result. The engineers concluded, moreover, that the companies now have good chances of operating at a profit.

The staff of the Board, in its over-all study of United States overseas telecommunications, has amassed a great deal of statistical information about the international telecommunications networks, both Government and non-Government. Although this information has been tabulated and a substantial amount of it analyzed, the analysis of the government networks has not been completed.

Much of the information relating to overseas telecommunications of the Federal Government has to do with operations of the armed forces. When the President on December 16, 1950, proclaimed a state of national emergency, the Board decided that security requirements would prevent inclusion of material of this nature in a public report. The material therefore was classified and remains in the files of the Board.

DEVELOPMENT OF COMMERCIAL SYSTEMS

Cables

American companies entered the international communications field in 1881 when a cable was laid between Canso, Nova Scotia, and Penzance, England, and leased to the Western Union Telegraph Company for operation.

British companies already had been operating across the Atlantic for some time and later pioneered also in service to Latin American countries and across the Pacific. In the Atlantic service, a British monopoly prevented companies of other countries from landing their lines at Newfoundland and it became necessary for companies wishing relays there to lease lines from the British interests.

Operation of the transoceanic cables originally involved relaying messages manually at stations located at several points along the cable route. In 1898 cable relays were developed to permit automatic operation. Because of the characteristics of cable transmission, however, direct service was not possible over long routes that involved several relays. In 1921 regenerators were developed to allow operation of cable circuits direct from the United States to Europe, thus speeding up the service and decreasing the cost of operation.

Another improvement came in 1923 when, in order to increase its traffic-carrying capacity, the Commercial Cable Company, an American organization, laid a line with a copper conductor double the size of previous conductors. The following year the Bell System announced development of a high permeability alloy and Western Union laid a cable in which the conductor was wrapped with tape made of the new "permalloy." This cable has a capacity in excess of 300 words a minute, while the Commercial company's 1923 line has a capacity of 200 words a minute and the capacity of the earlier cables is much lower.

Descriptions of the American cable systems in operation today are included in the discussion of the "Economic Outlook for United States Cable and Radiotelegraph Companies" (page 157).

Radiotelegraph

Transoceanic communication by radio was established on a firm basis prior to World War I, after most earlier attempts had met with only sporadic success because of lack of efficient transmitting and receiving equipment. One reason for this situation was that each equipment manufacturer did not have available patented devices controlled by others. As a result, United States radio-communication companies had confined their operations primarily to ship-shore service.

Upon the American declaration of war in 1917, the United States Navy assumed operation of all of the country's high-powered stations built for transoceanic communication. Under its wartime control, the Government combined the patents and scientific resources of all electrical manufacturers. These included use of the Alexanderson alternator and the DeForest tube, which offered a solution to the problem of efficiently generating and receiving continuous electrical waves. By the combining of various other inventions, new devices were developed out of which came practical radio transmitters and receivers satisfactory for wartime purposes. Thus the Navy carried on transoceanic communications during the war, with powerful stations on the Atlantic and Pacific coasts operating on low frequencies (long waves).

After the war, the Government fostered the organization of the Radio Corporation of America (RCA) in 1919 to solve the patent tangle and keep American radio communications free of foreign control. Prior to its incorporation, an attempt to obtain exclusive rights to the Alexanderson generator had been made by the British Marconi Company and negotiations with General Electric had been practically completed when the Navy Department indicated its objection to the ownership of this and other American radio patents by a foreign interest. As soon as RCA was organized, it purchased the assets and patent rights held by the American Marconi Company controlled by British interests. In 1920, RCA entered into exclusive cross-licensing agreements whereby it obtained rights to the use of other important patents, including the DeForest tube.

With these rights, the company quickly established direct radiotelegraph circuits to England, Hawaii, Japan, Norway, France, and Germany. Service was inaugurated to Italy in 1921 and two years later to Poland. After the advent of long-distance high-frequency transmissions in 1927, circuits were established to Java, French Indo-China, the Philippines, and Hong Kong.

As these services grew, RCA established two subsidiaries—Radiomarine Corporation of America and RCA Communications, Inc. (RCAC)—to conduct the business which previously had been operated by company departments. RCAC confines its operations largely to point-to-point service between land stations, and Radiomarine handles service to and from ships almost exclusively. By 1939 RCAC had established 52 international radiotelegraph circuits, and by 1950 it was operating 69 such circuits.

After World War I, other radiotelegraph carriers also became active in the international field. By 1926 the Tropical Radio Telegraph Company had established 12 direct radiotelegraph circuits to the West Indies, Central America, and South America, and by 1950 the number had grown to 24.

The International Telephone and Telegraph Company in 1929 acquired the Postal Telegraph and Cable Corporation and, from its international division, organized the Mackay Radio & Telegraph Company to challenge RCAC's monopoly in the worldwide radiotelegraph service. By 1933 Mackay had established 10 circuits and in 1950 had 35 in operation.

Government policy was to grant transoceanic frequencies only on a public utility basis, and not for private use. As a result, the Robert Dollar Steamship Company organized Globe Wireless, Ltd., and the Firestone Tire & Rubber Company created the United States-Liberia Radio Corporation to meet their special requirements, although the facilities were made available to any customers. Those systems and that of the South Porto Rico Sugar Company offer public service only to a limited number of points.

When the Federal Communications Commission was organized in 1934, its initial practice was to deny applications for circuits to countries already served by other American radiotelegraph carriers. With the outbreak of World War II in 1939, however, the Commission generally granted applications for new circuits, regardless of whether other carriers already were operating to the points concerned.

In January 1942, the Defense Communications Board (later succeeded by the Board of War Comunications) adopted as a wartime measure a policy encouraging establishment of parallel circuits from the United States to overseas points, to be operated by two American companies. Where possible, different locations were to be used in the country with which parallel circuits were set up. In April of that year, the policy was amended so that, if parallel circuits could not be established because of lack of suitable equipment, every effort would be made to establish duplicate circuits to allow two or more American companies to communicate with the same point abroad.

Under these policies, the Mackay company established circuits to Russia, Italy, Eire, and Greenland between 1939 and 1942, and after that time set up communications with 12 more countries.

Press Radio. The value of international radio communication for the expeditious handling of news was recognized early by American press associations and newspapers.

Soon after Marconi's original experiments, the New York *Herald* set up a radio station in New York Harbor to gather news from ships at sea and to send out daily news summaries to them. This station continued in operation until World War I. After the war, the New York *Times* established its own station to communicate with European stations, and soon thereafter similar facilities were installed by the Associated Press, the International News Service, and the Chicago *Tribune*.

As the demand for frequencies grew, the Federal Radio Commission in 1929 entered an order calling for the formation of a single public utility to serve all the American press. This action led to the organization of Press Wireless, Inc. Although it was established to serve the press exclusively, the company's charter does not limit holding of stock to press interests, and its corporate powers extend to and include the operation of fixed public service as a communications common carrier. By 1936 Press Wireless had established six international radiotelegraph circuits, and in 1950 was operating 17 such circuits. In addition to its special services for individual newspapers and press associations, the company handles multiple-addressed press material and program and radiophoto services.

Radiotelephone

Experiments in the field of radiotelephony were begun in 1915 by the United States Government, in conjunction with the American Telephone and Telegraph Company. Messages were sent from the naval station at Arlington, Va., and from Washington to such distant points as San Francisco, Honolulu, and Paris. Interrupted by World War I, tests were continued after the war.

Speech was transmitted to England in 1923, and by the end of 1926 successful test operations were being conducted between New York and London. The first international radiotelephone circuit for general use was established between those cities by A. T. & T. in January 1927. Soon afterward service was extended beyond the terminals of the radio circuit, by means of wire lines, to all of Great Britain and the United States. Cuba and a part of Canada were added for service by the end of 1927 and the following year service was extended to many countries of Western Europe, utilizing the extensive wire telephone network connecting London with the Continent.

By the end of 1933 transatlantic service was in operation for most of North America and the principal countries of Western Europe. Ten direct radiotelephone circuits had been established. In certain cases, a direct circuit was provided to a distant terminal; in many others, the establishment of direct service with several countries was provided on a so-called "forked" circuit basis; in still others, either of these two types of radio channels was used in connection with line wire extensions to countries beyond the distant radio circuit terminals.

Overseas circuits radiating from the United States were centered at three main focal points: New York, Miami, and San Francisco. By 1936 the A. T. & T. had established 27 direct radiotelephone circuits. Fifty-seven such circuits were in operation in 1950.

The Radio Corporation of Porto Rico also engages in limited international radiotelephone service, operating the San Juan terminal of the A. T. & T. circuit between the United States and Puerto Rico. The Honolulu end of the United States-Hawaii radiotelephone circuit is operated by the Mutual Telephone Company of Hawaii. Its radiotelephone transmitters and receivers in turn are operated by RCAC under a lease agreement with the Mutual company.

Regulation of Commercial Systems

Under the Communications Act of 1934, as amended, the Federal Communications Commission is charged with regulating, among other things, international communications by telephone and telegraph, whether wire, ocean cable, or radiobroadcast and other forms of radio services. These functions do not, however, include control of facilities operated by the Federal Government.

Among the provisions of the Act are those affecting common carriers and reflecting Congressional policy that the public interest in adequate public communications service and reasonable rates is to be protected and promoted by Federal regulation.

The Commission's responsibilities in the international common carrier field require it to be active in the area of foreign relations as they pertain to that field.

The United States is a member of the International Telecommunications Union. As such it participates in the negotiations stemming from the Union that relate to international telephone and telegraph questions. Additionally, there are other bilateral and multilateral agreements on the subject in which the United States is concerned. Because the Commission has large responsibilities in the field as indicated above, it must be alert to the effects of such international negotiations upon the public interest, convenience, and necessity as related to non-Federal Government international communications.

Among the regulatory interests of the Federal Communications Commission in this field are merger, circuit arrangements, frequency management, equipment and operating techniques, processing of applications, conference preparation and negotiation, rate schedules, acceptance and delivery practices, distribution of traffic, records, and finance.

One significant matter (Docket No. 8777) has been pending for some time. This case grew out of applications involving the question of whether and to what extent the Commission will authorize a second direct radiotelegraph circuit to countries already served directly by one carrier. This question contains many facets relating to merger, frequency utilization, national defense, and competition between American carriers.

Adequate regulation, however, has been somewhat hampered in recent years because of budgetary limitations.

DEVELOPMENT OF UNITED STATES GOVERNMENT SYSTEMS

Apart from the facilities established during World War I and some minor systems operated between the wars to maintain communication with overseas military bases, ships at sea, and aircraft over the sea, the United States Government had not developed any extensive international communication facilities of its own until the beginning of World War II.

Responding to the requirements of global operations, the Army (including the Air Force) and the Navy then created new worldwide networks for communications. Certain non-military agencies of the Government also established more limited systems. In the early years of the war, these agencies leased some commercial radio and cable facilities until they could install their own equipment and operate it. Certain of these leased facilities, however, were continued throughout the war period and some of them are still in leased use today.

Many of the overseas facilities installed by the Government for war use also have been continued in operation. Some of course were abandoned, but the postwar international situation has required retention of many facilities which otherwise might have been curtailed or eliminated, as well as the installation of additional ones.

Department of Defense

Following unification of the armed forces in 1947, a Joint Communications-Electronics Committee was established as an agency of the Joint Chiefs of Staff in the Department of Defense to coordinate telecommunications activities of the several services and to provide liaison with Government departments and with other public and private agencies having interests in the field. As a result of the committee's work, the Department of Defense has established principles for the integration of telecommunications functions among commands and services.

As the General Services Administration has managerial responsibilities for Government telecommunications services specified under Public Law 152, the GSA and the Department of Defense have agreed on areas of understanding on the procurement of telecommunications facilities in order "to obtain the maximum economy consistent with the requirements of service."

U. S. Army. Before the turn of the century, the Army was devoting attention to wireless telegraphy with a view to adapting it for military purposes. These tests led to the installation of four radio stations in 1900 and within the next eight years the Army was operating 17 stations in the United States, Alaska, Cuba, and the Philippines, plus radio stations on five Army transports.

By the time of the United States entry into World War I, the Army radio network had expanded to 51 stations in the United States and 10 overseas, and 53 Army vessels also had been equipped with radio.

The Army radio net was officially organized in January 1922. In June of that year, 218,000 words were handled over this system. Because of budgetary difficulties, the Army's use of telecommunication facilities grew little until the limited national emergency was declared by the President in 1939. At that time, the Army radio net connected Washington with the Corps Area Headquarters in the United States and its overseas Department Headquarters such as the Philippines, Hawaii, Puerto Rico, and Panama. This net then handled about 5,000 messages a day.

During the early months of World War II, the Army leaned heavily upon the commercial facilities of Western Union, Mackay, A. T. & T., and RCAC. But commercial facilities did not completely fill the bill. Direct circuits and greater security were required. In the circumstances, the Army and the Air Corps drew plans to build worldwide communications to serve the armed forces.

The plan comprehended a "pipe-line" around the world. The first leg put in on the "pipe-line" was from Washington to Asmara, Eritrea, on a multi-channel teleprinter basis. By early 1943 an around-the-world belt line had been completed, extending from Asmara to New Delhi, from New Delhi to Brisbane, from Brisbane to San Francisco, and thence on to Washington. The network's message volume reached 50,000 a day in March 1943.

Before VE-day, the Army Communications Service had been extended into an unprecedented global system, employing the most modern equipment and operating techniques known to United States telecommunications experts, and providing instant communications to all overseas forces and missions and allied countries. By January 1, 1949, this network had been contracted and rearranged, but 14 overseas trunk circuits were still in operation. The Army, in addition, utilizes the services of the international carriers to locations where it has not been necessary to establish Army facilities. The Army also handles radio traffic for some of the other Government agencies when spare circuit capacity is available.

U. S. Navy. Radio communications on an operating basis were established by the United States Navy as early as 1903 for the purpose of communicating rapidly between ship and shore and between ships. Later, radio communication facilities also were provided between shore establishments both at home and abroad. As the Navy grew and the communications art developed, the Navy's communication system became larger and more complex.

Before 1940 the Navy operated several point-to-point multistation radiotelegraph circuits and one Morse wire circuit within the continental United States. In 1941, however, the Morse circuit was converted to private teletypewriter operation. This conversion marked the commencement of the transition from radio to landline for intracontinental circuits.

Today, with the far-flung interests and missions of the Navy, its communication system meets the requirements for essential, continuous, and immediate communication between Navy air, surface, and sub-surface operating forces wherever they may be and between those forces and Navy shore establishments.

The stated mission of the Naval Communication Service "is to provide and maintain an adequate and secure communication system for the Navy, based on war requirements; and to ensure operation thereof to best meet the requirements of the operating forces and the shore establishment, wherever located, primarily to serve command and to facilitate administration."

To implement this mission the Navy provides facilities at strategic locations. These are classified as primary, major, and minor communication centers, and tributary offices. The six primary communication centers are strategically located to furnish, as far as practicable, complete radio communication coverage for the major portions of the ocean areas of the world. Major centers provide more limited area coverage. Minor centers provide fleet communication support as may be required. Tributary offices are served from the primary, major, and minor communication centers.

Certain channels of the radio trunk circuits, particularly overseas circuits, combine with nearly all of the landline circuits of the Navy to form the Naval Teletypewriter System (NTX), which employs the tape-relay method of distributing traffic.

Navy point-to-point radio trunk circuits are integrated with continental point-to-point wire circuits. Many of these circuits were designed and established about 1910 for manual telegraph operation. As the demand for greater speed and capacity increased, these and newer circuits were converted to automatic operation in a progressive transition from Wheatstone and single channel radio-teletypewriter to duplex, multiplex, and finally single-sideband teletypewriter multichannel operation.

U. S. Air Force. The need for an airways communication system capable of supporting military operations under all weather conditions was brought home to the Air Corps in 1934 when a flight of new bombing planes was sent on maneuvers across the United States. All that was available at the time was a series of radio ranges and rotating light beacons operated by the Department of Commerce. Communication between the ground and aircraft was restricted for the most part to short-range voice contacts with the range stations. Messages from point of departure to point of intended arrival were sent by Western Union.

It took four years to get funds and assemble equipment to make the beginnings of what is now the Airways and Air Communications Service (AACS). At its inception, AACS established 33 stations consisting of a combination of control towers, ground-air, point-to-point, and radio range facilities. A personnel total of 3 officers and 300 enlisted men was authorized.

From 1938 to 1941, the East and South were fairly well covered, while most of the Middle West and North West had little coverage. Existing installations serviced practically all the permanent Air Corps stations of that day.

Operations outside the United States were begun in April 1941, when an AACS party was sent to Newfoundland to start work at Gander Lake. From this beginning grew the extensive wartime ferry routes to England, over the North Atlantic and later to Africa through the Azores.

During all of 1942 the AACS was fully occupied in building up ferry routes to all overseas theaters and in developing its plans for further expansion. The leased bases in the Antilles were manned for anti-submarine operations and also as way stations on a South Atlantic route to India through Central Africa. In the Pacific, the pre-war air route to Manila through Midway and Wake was closed off by the enemy and was replaced in early 1942 by a South Pacific route through Fiji and New Caledonia to Australia. In Alaska and Western Canada a ferry route to Siberia and an airway along the Aleutians were developed.

The years 1943 and 1944 were spent improving the routes started in 1942 and in building new stations as offensive plans proceeded. Operations in support of the Air Transport Command's flights over the "Hump" in Southeast Asia were perhaps the most spectacular, but concurrently a number of stations were established in China for the 14th Air Force and later for the early raids of the B29's from China bases.

In the spring of 1945, communications had to be provided for the air power assembled at Okinawa for the projected assault on Japan. In France, the Lowlands, and Germany, the Allied offensives secured new airdromes which had to be tied into the airways system.

Meanwhile, the great increase in the air establishment at home called for more installations, but naturally the overseas areas had first priority. Therefore, not until after the war could AACS inaugurate its planned Military Flight Service Communications System. This is a network of strategically located stations which primarily furnishes point-to-point and ground-air facilities, but also provides aids to navigation such as control towers, radio ranges, direction finders, ground controlled approach units and instrument landing systems. This plan was drawn up to complement the communications of CAA.

Since the end of hostilities AACS has devoted itself to improving its service. Facsimile is rapidly taking the load off the point-to-point radioteletype circuits which transmit weather data. Multi-channel equipment is being installed as rapidly as possible. A global system of communications is in process of development.

AACS has participated in all the major Air Force operations since World War II. It supplied all the airways communications and navigational aids for the Berlin Airlift. It took part in large-scale joint service maneuvers. It supplied communications to the Lucky Lady II on its round the world non-stop flight. It also was responsible for airways communications in Korea.

Department of the Treasury

The only international communications facilities of the Department of the Treasury are those of the United States Coast Guard, which is a part of the department in peacetime. The Coast Guard operates as a service in the Navy Department in time of war, or when the President directs.

The peacetime functions of the Coast Guard include law enforcement or assistance in enforcing all applicable Federal laws upon the high seas and waters subject to the jurisdiction of the United States and promotion of safety of life and property in those areas. These functions require the use of radio for point-to-point, radiolocation, and mobile services.

The Coast Guard operates and maintains ocean stations in both the North Atlantic and North Pacific oceans to provide search and rescue services at sea and over the sea, communications, and air navigation facilities, and meteorological services in such ocean areas as are regularly traversed by aircraft of the United States. It operates land telephone lines along the coastline, connecting lifeboat stations, lighthouses and other units. The facilities include eighteen radio broadcast stations. Medium-frequency direction finder stations, previously operated along the coasts, have been discontinued as a navigational aid to the public, owing to the use, generally, of shipboard direction finders in conjunction with marine radio-beacons and the utilization of radar and loran systems. The direction finder stations have been continued, however, at strategic points for search and rescue purposes.

During 1949 the Coast Guard maintained 37,309 aids to navigation, many of which require radio transmissions. It also operated 34 fixed loran stations along with 14 "racon" stations along the Atlantic and Pacific coasts and in Hawaii, Puerto Rico, and Alaska.

Department of Commerce

The principal users of radio frequencies in the Department of Commerce are the Civil Aeronautics Administration, the Weather Bureau, and the Bureau of Standards. The remainder of the bureaus and offices of the Department, in their international operations use both commercial communications and the facilities of other Government agencies. Most of their messages are exchanged with the Foreign Service of the United States. Departmental procedures have been established for handling such international communications. Under these procedures, messages to and from the embassies, legations, and consulates of the United States are routed through a liaison office in the Department of Commerce and are handled by the Department of State.

Civil Aeronautics Administration. The communications and air traffic control systems of the Civil Aeronautics Administration were established to provide for the safety of life and property in aircraft operated on the civil airways and air routes in the United States, its territories and possessions, and between the United States and foreign countries.

Increased use of aircraft following World War I stirred up concern about hazardous flying over unfamiliar territory and during periods of poor visibility. It also gave rise to two other problems: (1) prevention of collision, and (2) expediting the movement of aircraft. Traffic adjacent to large airports and along major routes had become heavy within a short time.

The Post Office Department, whose air-mail service then was the only operator of aircraft during all types of weather, established aeronautical radio stations in 1920. This was the beginning of the present complex aeronautical communications and radio navigation system, which is the end-product of a number of organizational changes through the years.

The Aeronautical Communications Stations operated by CAA perform the following 14 functions:

Service "A"—Collection and distribution of hourly and special reports on surface weather, airfield conditions, and inoperative air navigation aids, etc.;

Service "B"—Requests for and approval to conduct an aircraft flight; flight plans, in-flight progress reports, and aircraft arrival reports;

Service "C"—Collection and distribution of 3 and 6 hourly weather data; pilot balloon reports, radiosonde, weather forecasts, etc.;

Service "D"—Radio broadcast of meteorological information, advisory messages, and advice to airmen;

Service "E"—Two-way radio communications with aircraft in flight;

Service "F"—Dissemination of messages to assist flow and prevent collisions of aircraft flying under instrument flight rule;

Service "G"—Monitoring radio aids to air navigation and communications systems;

Service "H"—Operation of non-directional type radiobeacons by ground stations;

Service "K"—Flight assistance services;

Service "L"—Operation of lighting facilities (various lighting equipment of airports, etc.);

Service "O"—Collection and distribution of overseas and foreign meteorological data;

Service "R"—Operation of radio ranges by ground stations;

Service "W"—Airway weather observational service;

Service "X"—Determining of information relative to the fixed location, bearing, or heading of aircraft.

Four radiotelegraph stations were in operation in 1920 along the transcontinental airway, and the first radio range station was installed at Bellefonte, Pennsylvania, in 1927. Two years later a teletype circuit was placed in operation, connecting 13 stations by means of 700 miles of leased wire. The general use of teletype machines meant that weather information could be transmitted by employees able to type. This change helped to eliminate interference in the crowded radio frequency spectrum. By the end of 1936 there were 203 weather-reporting teletype stations.

Service "B" was inaugurated in 1938. During the same year the need for communications services in the Territory of Alaska, and for the proposed transoceanic aircraft services was recognized, and action was started on both projects.

The first overseas-foreign aeronautical communications station was completed in 1940 at New York. The station was needed to provide two-way radio communication with aircraft operating on the Atlantic air routes. Communications were also inaugurated between New York and various points in Europe, the Azores, Bermuda, and Newfoundland to collect meteorological data and to transmit information concerning aircraft movements. In Alaska, 6 communications stations were completed and placed in operation. Most communications with Alaska were by means of radiotelegraph because of the lack of landline facilities.

With the advent of World War II, the civil aviation systems were closely coordinated with the military services. Four communications stations to handle overseas traffic were completed in 1942—at San Francisco; Everett, Washington; Anchorage; and Honolulu. Overseas airway communications facilities were further expanded in 1942 to include stations at New Orleans, Miami, and Balboa, Canal Zone. The additional stations provided services to flights operating to South and Central America and the Caribbean. An estimated total of 64 million words of weather and flight traffic was handled during the year.

Today the subordinate services of CAA use radio to maintain communications with commercial and military aircraft, and also for administrative purposes, weather information and safety requirements.

For international aircraft operations, the Administrator of Civil Aeronautics provides directly, or through an agency sponsored by the

Government for the purpose, the basic fixed and mobile telecommunications system for the exchange of the following categories of messages:

(1) Distress messages,
(2) Messages for the safety of life and property,
(3) Flight safety messages,
(4) Meteorological messages,
(5) Notices to airmen,
(6) Flight regularity messages,
(7) Aeronautical administrative messages,
(8) Reservation messages, and
(9) General airline operating agency messages.

It is the practice to handle without charge the messages in categories 1 through 7. Reservation and general airline operating agency message categories are not accepted when private or commercial facilities are capable of meeting aeronautical communications requirements.

Weather Bureau. In addition to its many offices and part-time stations within the United States, the Weather Bureau, under agreements with foreign governments, is active along many of the overseas air routes. It maintains, in cooperation with the Coast Guard, ocean weather stations in both the Atlantic and the Pacific, as well as in the Arctic regions. Over 2.2 million weather report words were received collect from foreign points and from commercial ships at sea during 1949.

The Weather Bureau cooperates extensively with the Civil Aeronautics Administration and the Coast Guard in disseminating weather information for aircraft and ships.

Although the Weather Bureau does not own and operate any international communications facilities, it does lease international landline facilities to Cuba and Canada for the exchange of weather information.

National Bureau of Standards. The National Bureau of Standards uses radio for its international frequency-measurement service, for research, and for special tests. It has no facilities for the handling of rapid communications.

The Bureau's station WWV has a worldwide reputation in its field. The station transmits continuously a highly accurate complex signal on specified frequencies. It transmits accurate time signals, Central Radio Propagation Laboratory forecasts of propagation conditions, accurate audio tones, and accurate carrier frequencies. In addition, the listener can obtain propagational data over the path traversed by the signal to the listener's receiver.

Department of State

The Department of State has a two-fold interest in telecommunications. It is responsible for international negotiations on telecommunications matters. It is also a large user of telecommunications for the conduct of its general operations, for the dissemination of informational and educational matter abroad, and for the Voice of America.

Operational Communications. The Department of State uses practically all forms of communication to meet its requirement for rapid interchange of instructions and information between Washington and missions abroad. Speed, security, and distance dictate heavy use of telegraph service.

The Department maintains its own internal "message centers." In Washington and at several of the large posts abroad, telegraph centers are established for the centralization of the exchange of traffic with commercial carriers and with communications centers of the armed forces.

With the exception of certain isolated emergency operations, the Department of State neither controls nor operates long-distance communications channels, nor does it maintain or operate radio transmitting or receiving stations for the handling of telegraph communications.

The Department of State has a direct leased Western Union cable "varioplex" telegraph channel connection between Washington and the United States Embassy in London and another between Washington and the United States Embassy in Paris. These two direct channels accommodate regular message traffic charged for at the prevailing message rates.

In addition, the Department of State shares the use of another Washington to Paris telegraph facility over a New York-Horta-Cherbourg cable, which is a split Western Union-Army circuit (Western Union from New York to Horta and Army from Horta to Cherbourg over the former German Emden cable). While this facility terminates at the Army message center in Washington, the Department of State message center in Washington can be combined with it when the circuit is not in use by the Army.

Voice of America. The need of the United States for international high-frequency broadcasting has been greatly increased by the upsurge of interest in programs of international information and educational exchange. Between the two world wars, there was a tremendous growth, especially in Europe, of international broadcasting. Only toward the latter years of that period did American commercial broadcasting interests engage in relatively modest programs of international broadcasting, chiefly directed to the Western Hemisphere. During World War II, however, the United States Government created worldwide radio and press services, operated by the Office of War Information and the Office of Inter-American Affairs. These activities were transferred to the Department of State by Executive Order on August 31, 1945, for reduction and incorporation in the small program of information and cultural exchange already started in that Department.

During the period immediately following the termination of hostilities, the program was carried on under authority of annual appropriations acts. Then it came under severe Congressional attack, and was almost eliminated by the summer of 1947.

With the developing world crisis, however, Congress responded to the need for special machinery to tell abroad the story of the United States and of the free world. The presumption of an early return to a peaceful world, which lay beneath the earlier decision to cut the Government program to the bone and let private information agencies carry on, was proved false. In January of 1948 Congress passed the United States Information and Educational Exchange Act "to promote the better understanding of the United States among the peoples of the world and to strengthen cooperative relations."

High-frequency radio bulked large among the media available to carry out this worldwide commitment. With more and tighter restrictions and barriers to the dissemination of information, high-frequency radio appeared to be the best way to get the truth about the free world into iron-curtain areas. The geographical position of the United States has heightened the value of high-frequency operations in its international radio broadcasting.

The Voice of America not only provides service for its own broadcasts, but also for the United Nations at New York and the armed forces of the United States abroad.

For transmissions from the United States, the Voice of America generally leases transmitter time from various commercial broadcast or communications companies. For transmissions from overseas points the Voice of America, in general, owns its own facilities. It also transmits to certain stations in other countries for rebroadcast by them.

This rapid expansion in the Voice of America poses a serious problem for world telecommunications, especially in the high-frequency band. In November 1950 the Voice was using 69 frequencies on the average of seven hours per day each. These are a substantial percentage of the total spectrum space available to the world for international broadcasting under the Atlantic City Table.

Government policy calls for a large increase in radio installations used for the Voice. These increases, however necessary and desirable, may put more pressure on the spectrum during the years immediately ahead. The future after that will depend on the level of international crisis.

Information for the Foreign Press. In addition to the broadcasts of the Voice of America, the Department of State sends around the world a daily news service of information about the United States for use in newspapers and other media abroad.

For this service, the Department's Division of International Press and Publications operates a teletype communications center in Washington. Into this center pour thousands of words daily for transmission to New York, where they are sent overseas by commercial radiotelegraph facilities.

These Morse transmissions are received by radio operators at United States missions abroad and are reproduced and distributed to press and other information outlets in those countries. Ships and other stations of any nation also may intercept these radio news reports.

Other Government Agencies. Many independent agencies and commissions of the Federal Government which do not own or lease international circuits transmit and receive international communications through existing Government or commercial company facilities. Between 85 and 90 percent of this wordage is transmitted over Government facilities at practically no cost to the originating office. The Economic Cooperation Administration and the Veterans' Administration, the largest of these users of international communications, route the majority of their traffic through the Department of State and the military services, respectively.

The American Red Cross, although not a Government agency, is privileged to use Government-owned international communications facilities to handle its traffic. During 1949 over 7 million words were transmitted by the armed forces for this organization.

Control of Government Systems

Federal Government agencies now decide, at something less than top level, the amount and type of record telecommunications matter that is to be transmitted to overseas or foreign points by means of facilities controlled by the Federal Government and established primarily for purposes of national defense. Too great a diversion is not conducive to the best health of the Nation's telecommunications networks.

If our national policy recognizes the desirability of strong private American companies operating in the international telecommunications field, there must be some form of control to insure that a substantial amount of Government message business is handled by commercial agencies, so that the Federal Government does not, perhaps unwittingly and by unilateral action of independent agencies, bring about a total or partial collapse of commercial facilities by eliminating their largest customer—the Government.

From an even broader point of view, there would appear to be a need for a mechanism to coordinate and, to a certain degree, regulate the use of communications facilities by Government agencies. Private companies under the necessity of providing an attractive and economical service to the public and under strict regulation by FCC are forced to justify additional frequency space, adopt rigid economies, and serve the public welfare.

It is recognized that Government departments, especially the military agencies, have from the technological point of view built a superb radio communications system. But they are not under the same pressures as private companies to justify expansion into new frequency channels and to enforce rigid economies. Even the actual costs of operating Government communications facilities are almost impossible to determine. Clearly, in managing such a vital national asset, the Government must keep its own house in good order, as well as do what is necessary to maintain the private facilities which are so essential both to the public and the Government itself.

Use of Government Facilities for Commercial Messages

To provide a service of public correspondence to and from points where commercial facilities are not available, Congress has authorized the Secretary of the Navy to furnish such service through naval radio stations. This authorization is given by Section 327 of the Communications Act of 1934, as amended.

Certain other departments of the Government have recently requested similar authorization from Congress, but such authority has not yet been granted.

Relationships to Commercial Systems

Though Government-owned facilities handle a large portion of Government communications, the Federal Government is dependent upon commercial overseas facilities to round out its over-all needs for international service. This is true in two major respects. The Government finds in some cases that it is more economical and efficient to lease or subscribe to a circuit or channel from a common carrier than it is to install and operate a facility of its own. For the transmission of small amounts of traffic to remote points, the Government often finds it more economical or convenient to route such traffic via common carriers than to send it part way over Government facilities.

Government also depends heavily upon the existence of common carrier facilities during the early stages of war. Because it is not possible to anticipate the precise nature and locale of hostilities, the armed forces try to maintain a minimum basic system in peacetime and depend upon appropriate expansion in wartime, utilizing common carrier facilities to tide them over.

THE MERGER QUESTION IN INTERNATIONAL RECORD COMMUNICATIONS

Historical Summary

Proposals for merger of American companies providing cable and radiotelegraph services have provoked vigorous debate ever since radio emerged as a practical means of international communications. The traditional American policy against monopoly has affected this debate throughout. During the years immediately following the first world war, it was a chief concern of the Government—the Navy Department in particular—that the well-established cable companies should not be allowed to hamper the full development of radio as a medium for telecommunications. Hence arose the obstacles to the ownership or control of radio companies by cable companies later embodied in Section 17 of the Radio Act of 1927 and in Section 314 of the Communications Act of 1934.

A related policy introduced in 1943 calls for the separation of companies doing overseas business in record communications from domestic record communication companies.

Within this broad framework, however, proposals have persistently recurred during the last twenty years for mergers of American communications companies. Fundamental to this problem is the possibility offered by radio of providing, with relatively small capital outlay, circuit capacity exceeding the normal requirements of international communications. This raised difficult economic questions of cost of service, and the future profitability of cables in the face of radio competition. There are some who have suggested that cables are now obsolete, but considerations of reliability and security point to the necessity of retaining cable service.

Several of the companies have asked permission to merge in the hope of avoiding deficits. From time to time, some Government departments have favored consolidations for reasons of national defense, conservation of radio frequencies, or for other reasons, while other Government departments have opposed consolidation. Some of these agencies have shifted their positions from time to time on the desirability of one or another form of merger. At no time have all the interested executive agencies been in agreement on this issue. As of May 1950, this was still the case.

The move for merger in the field of international record communications has never been able to win complete Congressional support because of traditional resistance to monopoly. Numerous hearings have been held by committees of the Congress, but no legislation has resulted. Either the case has not been strong enough, or prevailing international situations have delayed consideration of the various proposals. In the meantime, however, Congress has approved mergers of telephone companies and of domestic telegraph companies, and permits the domestic telephone companies to operate in the international field.

During World War I, when the Government operated the telegraph industry, the United States Navy was given control of the transoceanic radio stations in the interest of national security. Immediately after the war, a bill was introduced in Congress providing for the control and operation by the Navy Department of the then existing private United States radio stations used for overseas communications. The measure had Navy support. Under its provisions, the Navy was to operate the private stations as well as its own stations for the handling of both commercial and Government international communications. The bill did not become law. The country would not accept Government ownership or operation of these facilities.

The first expression of Congressional policy on merger of the privately owned cable and radio companies came in the Federal Radio Act of 1927. This law specifically prohibited mergers of radio with cable companies, and vice versa, if such mergers would lessen competition or restrain trade in interstate or foreign commerce. The Radio Act also declared that anti-trust laws are specifically applicable to the manufacture, sale, and trade in radio apparatus, and to interstate or foreign radio communications.

The Communications Act of 1934 included the same provisions.

In 1939 the Senate Committee on Interstate Commerce requested the FCC to study the merger question afresh. The Commission reported in the following year, recommending permissive merger of the cable and radiotelegraph carriers.

After lengthy hearings, Senator White and Senator McFarland introduced a bill in 1941 to permit mergers in both domestic and international telegraph systems. When the measure was before the full committee during the following year, however, the Navy Department, previously a supporter of merger, objected to changing the law to permit changes in the international industry at that time. The Navy thought that the structure of United States overseas telecommunications should not be altered during the war. Provision for this type of merger was deleted from the bill; although the House restored it, the bill was not voted on before the end of the 77th Congress.

The problem of domestic merger was felt to be so urgent, however, that it could not wait for the conclusion of the war. The Postal Telegraph Company was deeply in debt, and there appeared no prospect that its financial affairs could possibly be put in order. The 78th Congress took up the question of domestic merger in 1943, and amended the Communications Act so as to permit Western Union to purchase Postal Telegraph. This permissive legislation required Western Union to divest itself of its international business, Western Union Cables, within a reasonable period of time according to conditions and procedure specified in the Act, and with the approval of the FCC. Up to the present time, Western Union and potential buyers of its cables have been unable to agree on terms of sale. Western Union Cables continues from year to year as the FCC renews permission for it to continue in its present ownership. This situation has

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given rise to suggestions that the provision for splitting domestic from international carriers be stricken from the law.

In 1945 resolutions calling for study of the international merger problem again were introduced in Congress and further hearings were held. No new action resulted from the Congressional hearings, however. Senator McFarland, on discovering that the Department of State no longer supported merger while other executive agencies and the FCC favored it, took the position that Congress could do nothing until the executive agencies arrived at a common policy.

In 1946 the newly organized Telecommunications Coordinating Committee, at the suggestion of the Navy Department, tried to work out a Government policy on merger. The Committee was unable to reach a unanimous recommendation after thorough exploration of the issues by an ad hoc subcommittee. This ad hoc group submitted a report in December 1946, which set forth the arguments of proponents and opponents of merger. These arguments are summarized below.

Arguments for Merger

The arguments by proponents of merger of the international record communication companies included the following points:

Frequency Conservation. By eliminating duplications in circuits and inefficiencies in routing, unification would release a large number of frequencies, which could be used to handle increasing traffic volumes, establish new circuits, improve speed and reliability of existing services, and promote the development of new services. Such an elimination of the wasteful use of frequencies would relieve pressures on the radio spectrum and would strengthen the United States position at international conferences in urging adopting of new techniques designed to make the most efficient use of frequencies.

Economic Savings. Unification might permit the retirement of a large amount of the telegraph plant maintained by competing carriers. Not all of this plant is necessary to meet the nation's communications requirements. Retirement of some of it would result in savings in communications costs, as well as the ultimate reduction in the investment on which a return is earned, and could be reflected by substantial rate reductions and improved service.

Traffic Routing. Traffic between the United States and foreign points may be handled over a variety of competing cable or radio routes, some of which are more advantageous than others to United States interests. Merger would permit each facility to be used to its best advantage, technically and economically.

Standardization. Unification would promote the use of uniform operating practices and equipment throughout the unified system, a procedure which would strengthen the United States position in favor of worldwide standardization. Standardization among American companies could be at the highest technical level, since merger would permit a complete interchange of patents and pooling of research activities and talents.

Relations with Foreign Carriers. Merger would place the American international communications system more closely on a par, so far as influence and bargaining power are concerned, with the foreign monopolies with which it must deal. This would permit the unified carrier to insist on equitable operating arrangements and would enable the United States Government to give more direct guidance and support to the policies of the unified company in its dealings with foreign systems.

Improved Regulation. Merger would help the Federal Communications Commission to achieve its objectives of providing a worldwide communications system, with adequate facilities at reasonable charges. A unified carrier could be required to extend service to foreign points on a worldwide basis, whereas it might be difficult to impose such a requirement on one out of several competing carriers. Because of the great divergence in earning power among the various carriers, reasonable rates for the most prosperous company would tend to drive competing carriers out of business, a circumstance which may deter completely effective regulation. Unification would also facilitate the severance of the telecommunications system from intercorporate manufacturing affiliates and from foreign activities.

Security. Merger would foster security in the sense that it would provide a more efficient, integrated, and standardized communication system, which would be available for military use and planning, but it would have little or no effect upon cryptographic security, loyalty of communications employees, or anti-sabotage measures.

Arguments Against Merger

Of the Government departments represented on the Telecommunications Coordinating Committee, those opposed to merger based their case on these major points:

Monopoly. United States economic policy, both in the domestic and in the foreign field, traditionally has been opposed to the creation of monopolies, especially those which would receive special Government-sponsored privileges. Generally, a favorable political, economic, and technical climate results from competition tempered to the extent necessary by regulation. In view of this traditional policy, the proponents of merger must sustain a very heavy burden of proof that merger is in the national interest.

Frequency Conservation. It is recognized that a merger would have the potentiality for the immediate conservation of a substantial number of frequencies. However, the strength of a monopoly in its dealings with the regulatory agency might make it difficult to realize this saving.

Economic Considerations. Substantial economies could be accomplished under a merger. But, even if potential savings might be immediately realized, it is questionable from a long-run point of view whether the continued existence of competition would not result in greater economic advantages.

Regulation. Experience indicates that regulation of a monopoly is difficult. Standards of performance are not readily available to the regulatory agency. The self-policing of an industry inherent in a competitive situation is not present in a monopoly. These factors outweigh the apparent superficial advantages which a regulatory agency might have in dealing with a merged company.

Other Considerations. Other considerations such as improvement in traffic routing, increased standardization, and the promotion of advantageous relations with foreign carriers also can be achieved through competition supplemented by vigorous regulation. It was not contended that perfect results would be achieved in those fields, but it was argued that, on the whole, results at least comparable with those under a regulated monopoly would be possible.

ECONOMIC OUTLOOK FOR UNITED STATES CABLE AND RADIOTELEGRAPH COMPANIES

Although many factors have been involved in previous arguments over merger of the international record communication companies, the question now appears to rest primarily on whether the companies can survive economically without merging. All of the Board's discussions of the subject with industry and labor leaders and Government officials stressed the economic problem, while other elements of the controversy were given secondary consideration.

For that reason, the Board arranged for an economic analysis of the industry and a forecast as to its future profitability to be made by the engineering firm of Ford, Bacon & Davis. The balance of this Chapter, except for the Conclusions, is adapted from the survey made by that firm.

Description of Facilities

Major Carriers. The Western Union Company operates 14 submarine cables, of which eight connect the United States with England, two with the Azores, and four with the West Indies. Five of the eight lines to England are leased until the year 2010 from a British company. The 14 cables measure 30,000 nautical miles and permit the company to furnish all classes of telegraphic message service directly, or indirectly through connecting carriers, to all parts of the world.

Three affiliates of the International Telephone and Telegraph Company, all of them wholly owned subsidiaries of the American Cable & Radio Corporation, are engaged in the American International record communications business. Six cables between New York and Europe, via the Azores, Nova Scotia, and Newfoundland, are operated by the Commercial Cable Company. Total length of its lines is 22,000 nautical miles. They make possible cablegram service to all parts of Europe, Asia, and Africa. Through affiliated organizations, the company also provides message service to Latin America. All America Cables & Radio, Inc., has five lines, measuring 24,000 nautical miles, between the United States and South America, Central America and the West Indies. In addition, it operates several cables and a number of international radiotelephone and radiotelegraph stations in South America. Mackay Radio & Telegraph Company, Inc., maintains direct radiotelegraph circuits to some 40 overseas points, furnishing all classes of record communications service on a worldwide basis. It operates radio stations in New York, California, Hawaii, the Philippines, and Tangier. The Tangier station is used to relay messages to points in eastern Europe, North Africa, the Near East, and India.

RCA Communications, Inc., provides worldwide message service through operation of direct radiotelegraph circuits to some 60 overseas points and arrangements with connecting carriers to reach other points. The company has four radio stations near New York City and one near San Francisco, as well as stations in Puerto Rico, Hawaii, the Philippines, Haiti, Dominican Republic, Okinawa, and Tangier. Direct circuits reach Mexico, Central America, South America, the West Indies, Europe, the Near East, the Far East, Australia, Oceania, and North and South Africa. The company also operates a radiotelegraph circuit between New York City and San Francisco for domestic haul of international messages and a leased wire circuit between New York and Washington, D. C.

Smaller Carriers. Radiomarine Corporation of America furnishes all classes of radiotelegraph message service from shore-to-ship and ship-to-shore. Transmitting and receiving stations are located on both coasts of the United States and at St. Louis, Mo., Buffalo, N. Y., and Port Arthur, Tex. The company also manufactures, sells and services mobile radio station equipment.

Press Wireless, Inc., provides a specialized radiotelegraph service to newspapers and press associations. It operates radio circuits to some 19 overseas points, and has stations at New York, San Francisco, Manila and in Europe. The company also owns subsidiaries that manufacture and sell communications equipment in Latin America.

Globe Wireless, Ltd., controlled by the Robert Dollar company, furnishes telegraphic message service from the United States to Honolulu, Manila, Shanghai, and Havana. Its radio stations are located in New York City, San Francisco, and Honolulu. Globe also operates a ship-shore radiotelegraph message service.

Tropical Radio Telegraph Company is affiliated with the United Fruit Company. Tropical's message service is carried over direct circuits to Central America and the West Indies and by connecting carriers to the rest of Latin America. In the United States, it operates radiotelegraph stations at Boston, Miami, and New Orleans. In Central American countries, 20 stations provide both radiotelegraph and radiotelephone services. It also operates ship-shore service.

The United States-Liberia Radio Corporation was established by the Firestone Tire & Rubber Company. Its operations are restricted to a radiotelegraph circuit between Akron, Ohio, and Harbel, Liberia.

The South Porto Rico Sugar Company furnishes radiotelegraph service to five Caribbean points and to ships at sea.

Financial Performance

The financial data used in the study were obtained directly from the companies involved. In the course of obtaining the financial information, conferences were held with accounting executives of the principal companies.

The information contained in Tables I, II, and III was secured from the larger companies and included balance sheets, income statements, and various related data for each of the years 1944 to 1949 and for the nine-month period ended September 30, 1950. The principal purpose of this information was to provide a knowledge of financial status and operating results through the recent years and up to the latest date for which actual data were available at the time of undertaking the study.

TABLE I

INTERNATIONAL RECORD COMMUNICATIONS COMPANIES OF THE UNITED STATES—GROSS OPERATING REVENUES FOR 1949

Major Carriers	*Revenue (Thousands)*	*Per Cent of Total*
Western Union Telegraph Company (Cable Division) (WUC)	$8, 208	17.85
American Cable & Radio Corp. Subsidiaries:		
Commercial Cable Company (CCC)	3, 951	8.59
All America Cables & Radio, Inc. (AACR)	9, 713	21.12
Mackay Radio & Telegraph Co. (MRT)	6, 528	14.19
Total A. C. & R. System	20, 192	43.90
RCA Communications, Inc. (RCAC)	12, 226	26.58
Total Major Carriers	40, 626	88.33
Smaller Carriers		
Radiomarine Corp. of America (RM)	1, 277	2.78
Press Wireless, Inc. (PW)	1, 294	2.81
Globe Wireless, Ltd. (GW)	1, 306	2.84
Tropical Radio Telegraph Company (TRT)	1, 406	3.06
United States-Liberia Radio Corporation	78	.17
South Porto Rico Sugar Company	7	.01
Total Smaller Carriers	5, 368	11.67
Total All Companies	45, 994	100.00

TABLE II

AGGREGATE ADJUSTED NET INCOME BEFORE INCOME TAX—MAJOR CARRIERS—INTERNATIONAL INDUSTRY (*Thousands*)

Year	*Basis for Measure**	*Adjusted Net Income Before Income Taxes*	*Income in Percent of Measure*
1946	$61, 478	$1, 622	2.6
1947	60, 830	−2, 395	−3.9
1948	61, 206	−738	−1.2
1949	60, 710	1, 177	1.9
1950 (9 mos.)	63, 605	2, 618	4.1

*The basis for measure of income isi n each instance the sum of net property and actual net working capital.

TABLE III

COMPARISON OF GROSS AND NET OPERATING REVENUES MAJOR CARRIERS—INTERNATIONAL INDUSTRY

(Thousands)

Company	*1946*	*1947*	*1948*	*1949*	*9 Months 1950*
Gross Revenues					
WUC	$7,790	$7,402	$8,224	$8,208	$5,993
CCC	4,445	4,642	4,144	3,951	2,854
AACR	8,639	9,934	9,835	9,713	7,991
MRT	4,767	6,041	5,599	6,528	4,919
RCAC	13,226	11,700	12,386	12,226	9,674
Total	38,867	39,719	40,188	40,626	31,431
Net Revenues					
WUC	1,296	613	1,411	1,505	1,438
CCC	−1,039	−1,896	−1,075	−1,111	−597
AACR	673	554	324	536	1,019
MRT	−1,042	−837	−818	71	224
RCAC	2,481	−29	752	854	959
Total	2,369	−1,595	594	1,855	3,043
Net Revenues in Percent of Gross Revenues					
WUC (%)	16.6	8.3	17.2	18.3	24.0
CCC	−23.4	−40.8	−25.9	−28.1	−20.9
AACR	7.8	5.6	3.3	5.5	12.8
MRT	−21.9	−13.9	−14.6	1.1	4.6
RCAC	18.8	−0.2	6.1	7.0	9.9
Average (%)	6.1	−4.0	1.5	4.6	9.7

As shown in the preceding table, the average ratio of aggregate net revenue to gross revenue has improved since the low point or deficit in 1947. The Commercial Cable Company continues to show a net revenue loss in 1950 although its position has improved. While to some extent the continuing net revenue losses of Commercial Cable may be attributed to the decline in gross revenue, it is evident that

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total operating costs are higher in relation to gross revenues than those of the other major carriers.

Comparative Utility of Services

In making their survey, the engineers prepared a questionnaire to determine the basic objectives sought in using each type of rapid international communications (air mail, telephone, cable, and radiotelegraph) and the experiences of the users with respect to how well these objectives had been achieved. Selected customers were asked whether they were making a conscious effort to change from one type of communication to another. They were also questioned as to amounts presently spent on cables and their estimates as to the amounts likely to be spent in the near future.

Information was sought to determine whether each type of communication did have its definite place in customers' operations. It was believed that if this were true and that each type was serving its purpose, it would be unlikely that the present pattern of services used would change much in the future. If customs and habits have been the main influence in determining the uses of each type, however, material changes in the pattern might occur.

The consensus was that the use of a particular type of communication is dictated by its utility and that each fills its particular need. It does not appear, therefore, that there are any conditions that may materially change the pattern in the near future. Each type has been available for a considerable period of time and the pattern has become fairly stabilized.

The survey disclosed that there is a definite field for cable and radio messages in which they are unlikely to be supplanted by either the telephone or air mail. In addition, there are fringe areas in which the use pattern of telephone, telegraph (cable and radio), and air mail is variable. These fringe areas, however, appear to be relatively small compared to the area in which the use of cables and radiograms is fixed.

Answers to the inquiries indicated that the various types of rapid communications are used under the following conditions:

Cables and Radiograms

1. When speed and certainty of delivery at a definite time are necessary, and

2. When a written record is important, or

3. Where cost is a consideration as compared with long-distance telephone, or

4. When immediate responses or a conference are not necessary.

Overseas telephone

1. When immediate decisions or responses are necessary, or

2. When a conference (back and forth conversation) is desirable.

Air Mail

1. When high speed is not essential, and

2. When certainty of delivery as of a definite time is not essential, or

3. Where the length of the message renders a letter preferable, and

4. Where communication costs are of importance in comparison with the amount of the transaction affected.

It was generally agreed that the international telegraph service is, on the whole, very good and reliable. Besides the features noted above, cables and radiograms have the additional advantage of getting prompt attention whereas letters may be set aside temporarily. A large insurance company stated that this is one of the chief reasons it uses cable and radio messages to the extent it does. Some companies attempt to overcome this by writing important air mail letters on special forms that resemble cables but they have found that this practice is not altogether successful.

The delivery time for "ordinary" telegraph messages is said to range, at present, from about ten minutes (in the case of major direct points like London and Paris) to about an hour. A cable or radio message can be sent from New York to London and a reply received in 20 to 30 minutes. Prior to World War II dealers in arbitrage used to send cables and receive replies in from two to four minutes, but such service is not rendered now.

Many companies reported extensive use of the night letter classification of cable and radio service. This is borne out by the records of the major international companies which show that about 64 percent of the public messages sent during the third quarter of 1950 were night letters. This service assures delivery at the start of the following business day, a period of 12 hours elapsed time from New York to London, whereas an air mail letter from New York to London, under minimum pickup and delivery conditions, requires 18 hours. There is, therefore, no question as to the necessity for a cable or radiogram when delivery at the start of the next business day must be assured.

Telegraph service also is preferred to long-distance telephone in many cases except when immediate decisions or discussions are required because (1) delivery at a certain time is more sure, (2) it is usually less expensive, and (3) it gives a written record.

The principal advantages of long-distance telephone messages lie in the ability to engage in discussion, which may be important in clarifying certain situations. They also get immediate attention whereas a telegram or a letter may be put aside. Great strides have been made in international long-distance telephone service and the average elapsed time to put through a call has been materially reduced. The major time-consuming factor, however, is that of locating the person called. This may take considerable time. In fact, it was said to be common practice to send a cable to make an appointment for a telephone call.

While the cost per word on the telephone may be quite low as compared to a telegram, it was the consensus that the actual cost per message generally was far less by telegram than by telephone. In the latter case, much time is often wasted in amenities and irrelevant conversation whereas in a telegram the heart of the message can usually be compressed into relatively few words.

While the transmission over the telephone was said to be usually satisfactory, it is not entirely reliable and instances were cited where poor transmission seriously impaired the value of telephone service. This is not apt to occur with telegrams, for if the message can not be sent one way it can be rerouted and will get through by another way.

Although air mail is widely used and has taken business from the cable and radio industry in the past, it appears that this competition has reached a stable condition. Two factors have been cited as limiting the use of international air mail—first, the possibility of planes being grounded or diverted on account of weather conditions, and, second, regardless of the flight speed, pickup and delivery services are time-consuming. Delivery service is said to be particularly poor in all foreign countries except in the major cities. The engineers were advised that for most inland points at least 24 hours should be added to the scheduled 16-hour service to London, Paris, etc. One company having extensive operations in the Near East stated that the normal air-mail delivery service from its office in New York to its branches in the field was from five days to one week. This compares with a normal telegram service of a few hours at most for ordinary messages and overnight for night letters.

The main drawback, however, appears to be the uncertainty as to delivery time of air mail. While practically all air-mail messages might go through on schedule the fact that a few might be delayed is a serious deterrent to sending any message by air mail when certainty of delivery time is of material importance. Air mail is widely used to send longer messages than would be economical by cable or radio, to send documents and confirmations, and to send many messages for which certainty of delivery is not important. For other purposes, however, the uncertainty of delivery of air mail is often too great a risk for the savings involved.

It appears, therefore, that except to correct abuses by correspondents in the use of cables and telephone by periodic expense-saving campaigns, there is little likelihood that air mail will seriously encroach further on the cable and radio business.

Distribution of Business Among International Carriers

Except as specific cable and radio companies have direct service to certain areas, or when they serve certain areas exclusively, customers reported dividing their cable and radio business among the various companies in the industry. One bank said that it follows a policy of reciprocity and distributes its business approximately in proportion to the balances maintained in the bank by the various carrier companies. One large insurance company conducting business mainly with London through night letters reported confining its business almost exclusively to one carrier because of the satisfactory service received. However, this is an exception, as most companies said they believed that by dividing their cable and radio business they maintained competition and thus got better service from all carriers.

Potentialities of Merger

Rates, Service and Development. The fundamental purpose of any merger is to save money. This is generally accomplished by greater flexibility and efficiency in the use of facilities, reduction in duplicated facilities, and savings in administrative and labor costs. A portion of the monetary savings is assignable to the stockholders up to a reasonable return on the investment; that is, a return sufficient to assure adequate financing of current plant investment and reasonable development costs.

It is to be expected that at least some of the savings derived from a merger would be reflected in direct public benefits; principally through reduced rates. Also, it may be reasonably assumed that any development expenses ultimately would be reflected in similar direct public benefits.

The fact that the Western Union-Postal Telegraph merger in the domestic field was followed by reportedly poorer service and higher rates is not a criterion unless it can be shown that the service would have been better and the rates lower if the competitive situation had continued. The evidence at the time of that merger indicated that the Postal Telegraph Company was on the verge of going out of business, in which case the service, at least in so far as coverage is concerned, might have been less than now exists under the merged companies. The engineers' survey of communications users, including the State Department, clearly indicated that there was a greater interest in service than in rates. Rate reductions are a measurable public benefit and may, therefore, be overemphasized and given too much weight, to the detriment of service. To this end, it is important that a large share of any merger saving be directed to maintenance of adequate service and to development expenditures having the same ultimate objective.

The allocation of income, after operating expenses and taxes, is generally subject to supervision by the regulatory authority. At the same time, the regulatory authority is expected to police the matter of adequate and proper service and this directly affects operating expenses. Excessive service to the detriment of adequate development or rate decreases may be just as improper as insufficient or relatively poor service. Competition may cause excessive service in competitive areas to the detriment of service in other areas.

The matter of the maintenance of less profitable or unprofitable services is of considerable importance in considering the question of merger versus competition. While competition may serve as an incentive for the preservation of borderline services in competitive areas, obviously the maintenance of dual service, in areas where even one service may not be justified, is uneconomical and has the effect of increasing costs over the whole system which will be reflected ultimately in the over-all rates of both competing operations. The effect of merger is to—

1. Eliminate unnecessary duplication of services, and
2. Remove the incentive to maintain any service in areas where revenues are insufficient to support costs.

While the first is a beneficial result of merger, the second may be a disadvantage overcome either through an enlightened management or rigid supervision by the regulatory authorities. Actually, a monopoly, through the elimination of duplicated out-of-pocket expenses and general reduction in assignable overhead charges, should be better able to sustain certain borderline operations. Finally, certain other points not now served may become economically feasible to serve under a unified operation.

Customers' Attitude. The customers consulted were almost unanimous in their reaction to the possibility of a merger of all cable and radio companies. All but one of the customers opposed the suggestion in principle as being detrimental to the type of service they might expect to receive. Although the engineers' questionnaire did not seek their opinions on this subject, practically all of them volunteered their views when the reasons for the survey were explained to them. In substantiation of their views, many cited their experiences with foreign carriers, most of which are monopolies. These experiences indicated to them that, without competition, carriers were very indifferent to customers' reactions. Inquiries regarding confirmation of messages originating abroad often were unanswered for several days or disregarded entirely. This condition appeared to be so common as to convince them that it was a definite result of a monopolistic position. Also, while a number of the largest users of domestic telegraph services said that they had not noted any reduction in the quality of domestic service after the Western Union Telegraph and Postal Telegraph merger, another and even larger group stated that they had observed a definite deterioration in the quality of service since that merger. A few users expressed the view that there might be no objection to merging all the cable companies into one group and all the radio companies into another as this would still retain a degree of competition which they believe to be essential to maintaining telegraphic service of high quality.

Labor's Position. Consideration should be given to the contention that wage scales in the record communications field have been held down to some extent because of the long-standing record of unprofitability of the industry. It is to be anticipated, therefore, that labor would expect a share of any financial benefits resulting from general improvement in the business, whether it be the result of merger or any other cause. Consideration must also be given to the probability of delay in savings on labor costs under a merger. It is unlikely that permissive legislation would allow an immediate general reduction in force. Rather, it would probably require retention of employees for periods of time in proportion to their length of employment in the industry.

There does not appear to be any unanimity on the part of labor for or against merger, expressed opinions ranging from unqualified approval through conditional acquiescence to outright opposition. It appears that labor is not satisfied with the results of the Western Union-Postal Telegraph merger. Opportunity for expansion of labor's views would normally be provided through public hearings held in connection with any proposed legislation.

Carriers' Position. The major international carriers told the engineers that they are in favor of permissive legislation for merger of international record communications. There is no positive evidence that these organizations actually would merge under such legislation. There may be an effort on their part to agree upon a merger but there is considerable difference of opinion among them as to the terms and conditions.

Western Union has suggested not only that the international operations should be merged but that they should be consolidated with its domestic telegraph business under its management. This company claims, among other reasons, that the terms of its lease of five cables from Anglo-American Telegraph Company, Ltd., might prove an absolute block to the transfer by Western Union of these five cables into a merged company which did not include Western Union's domestic operations.

American Cable & Radio Corporation and RCA Communications, Inc., adhere to a consolidation of international facilities only.

Because of these differences of opinion, it has been stated that any permissive legislation should at least clearly indicate an intent, if not contain a specific directive, as to the desirability of such mergers. This should be sufficiently emphatic so that it could be used to resolve inter-company differences.

Radiomarine Corporation of America would participate in a consolidation of international facilities only to the extent of its ship-shore communications, but not its equipment manufacturing, selling and servicing operations.

Press Wireless, Ltd., and the South Porto Rico Sugar Company told the engineers that they do not oppose permissive merger legislation of international companies, provided they are adequately protected from unfair competition by the merged organization and from any undue pressure upon them to join any such merged operation. These companies would remain outside of any merged operation resulting from permissive legislation.

Tropical Radio Telegraph Company is the only carrier opposed to merger. Should such legislation be written, however, their position is similar to that of Press Wireless. Globe Wireless, Ltd., said that it does not, at this time, desire to express any views on an international merger. United States-Liberia Radio Corporation has not expressed any opinion.

Accordingly, it may be said that the consensus of the industry is for permissive merger of international record communications specifically divorced from domestic operations with provision for adequate protection of the carriers which do not wish to join the consolidation.

Legislation. There appears to be some difference of legal opinion as to limitations in respect of consolidation or mergers under present laws. It is agreed that a clarification of Congressional intent would be desirable and that any merger of international companies now in competition probably would require specific legislative exemption from anti-trust law provisions.

Company officials said they believed that mandatory legislation is unnecessary, is not in the public interest, and probably would be a step in the direction of ultimate Government ownership.

In general, it appears that any legislative action permitting merger of international record communications companies should contain protections for the independence of companies desiring to remain in an independent status, specifications as to protective measures for labor, and protection from alien control. It should also provide for all possible economies. Resulting savings should be reflected in reduced rates after provisions have been made for sufficient earnings to allow for adequate capitalization, reasonable research and improvement in facilities, and good and sufficient service to the public.

Savings under Merger. The major carriers, in 1949, made studies of their facilities and operations to determine those facilities which would be in excess of the industry's requirements in the event of a merger. A review of these studies indicates that where duplicate telegraph cables or radio transmission and receiving equipment were operated, the oldest facilities were to be abandoned. Where the companies operated competing branch offices at particular points, these would be combined into one office.

The facilities which were determined as excess in the event of merger had a gross book cost of $13,279,000 for cable plant and $6,471,000 for radio plant. The gross costs less depreciation were $3,752,000 and $2,753,000, respectively. Combining the facilities of various companies would involve some expense in consolidating offices and combining cable and radio circuits into one location in order to make possible further savings in operating cost.

The engineers discussed the combining of facilities with representatives of the principal companies which would be involved in a merger and were assured that the capacity of the merged facilities would be sufficient to handle any annual volume of business which the industry might reasonably expect in the future up to 800 millions of words. It was further explained that recent developments in the industry would permit an increase in capacity of about 50 per cent in the cable facilities and two or three times the present capacity in the radio facilities. The additional investment required for these increases in capacity would be relatively minor.

The companies also made studies of the personnel and the amount of operating expense necessary to staff and operate the combined facilities properly. Estimates were prepared of expenses for conducting operations and maintenance of the cable and radio facilities and for general and administrative expenses. These estimates involved the projection of the expenses of the individual companies as now constituted and a pro forma estimate of the merged expenses. The difference between them indicated the savings to be realized from a merger of the industry. The annual savings that might be anticipated, as estimated by the companies, if the industry were merged, are as follows:

COMPANY ESTIMATES OF ANNUAL SAVINGS FROM MERGER

	Amount (in thousands)
Conducting Operations Expenses:	
Cable	$1,464
Radio	2,633
Maintenance and Repairs Expenses:	
Cable	678
Radio	540
General and Administrative Expenses	1,565
Total	6,880

The estimated savings resulting from the proposed merger were based on a volume of business ranging from 300 millions to 500 millions of words annually. However, since the facilities provided for a merged operation are stated to be adequate to handle a volume of up to 800 millions of words, there should be no necessity for any additional facilities to handle the increased volume of business indicated by the engineers' study of future prospects.

It follows, therefore, that the savings expected from a merger as estimated by the companies in 1949 took into consideration all expenses of a fixed or basic nature that might be eliminated by a merger. Thereafter, if the volume of business increased, any additional expenses would be of a variable nature and would be substantially the same in either a merged operation or an individual company operation.

The engineers did not make any independent estimate of the savings that might be realized from a merger of the several companies, nor was a detailed study made of savings estimated by the companies. However, a review of their working papers indicated that consideration was given to all of the principal factors involved in the merger. The methods and bases used in making estimates were sound and the results seem reasonable. There are, however, certain observations applicable to the companies' estimates which are discussed below.

Since the companies' estimates were prepared in 1949, there has been an increase in wage rates. This would mean an increase in savings from merger over the original estimates. The extent of the wage increase in relationship to wages paid at the time the merged savings were computed could not be determined without an exhaustive analysis. A review of the operating expenses of the five major companies in the years 1949 and 1950, however, indicated that there had already been a substantial reduction, particularly in salaries and wages. Such savings may be attributed to modernization of facilities, devaluation in foreign currencies, and some economies of the same nature as those attributed to savings resulting from a merger. To the extent that savings in this latter category have already been made, they could not again be realized in the event of merger but would tend to offset any increase in the savings as a result of wage adjustments. It is also recognized that among the parties to the merger, there are certain differentials in wage scales. In order to place all employes on a uniform basis, the tendency would be to increase some wage rates, which would reduce the indicated savings resulting from a merger.

The companies' estimates made no allowance for savings in depreciation expense. It is to be expected that if facilities were to be reduced, there would be a corresponding reduction in depreciation expense. However, it is recognized that in the event of merger, some arrangement would have to be made with the Federal Communications Commission to amortize the amount of abandoned facilities. Since any estimate of such an arrangement would be largely conjecture, no adjustment of depreciation expense has been made.

The companies, in their estimates of savings, did not give any consideration to changes in pension expenses. Discussion with the company representatives led the engineers to conclude that the current pension plans of the individual companies are not comparable. In the event of a consolidation, a uniform pension plan would have to be adopted for the new organization. It is possible that the existing plan which is most favorable to the employees would have to be adopted, and this would tend to increase pension expenses. However, the reduction in the number of employees as a result of merger would tend to decrease the over-all pension expense. It is also recognized that the reduction in the number of employees would reduce the amount of payroll taxes, which also was not considered in the companies' estimate.

From the foregoing discussion, it will be recognized that an independent estimate of the profitability of a merger would require a detailed and lengthy study which was not indicated for the purpose of this survey. It was the opinion of the engineers that the savings resulting from a merger as estimated by the companies were reasonable as applied to conditions existing in 1949. The engineers felt that the net effect of the offsetting factors discussed above and changes in conditions since 1949 would not materially alter the companies' estimates and that such savings therefore could reasonably be applied to projected levels of operation.

Estimates of Future Business

The method used by the engineers in preparing their estimates of future business for international record communications systems included statistical studies and limited customer survey. Statistical studies were made to determine whether any economic indicators could be found that parallel the curve of international telegraph revenues in the past and hence might be used to estimate the revenues in the future. The customer survey was made to find out whether customer policies might materially alter the present pattern of distribution of rapid communications and thus affect the estimates established by the statistical method.

The engineers felt that as the actual users of telegraphic services determine the volume of business, their reactions would establish the pattern for the future. Accordingly, the customer survey sought to find out the conditions under which the various types of rapid communications are used, as well as any indications of intentions to use cables and radio to any greater or lesser extent than in the past.

This survey was conducted by interviews with responsible persons in 35 companies in 12 different industries. The aggregate cable and radio business done by these companies amounts to about $2,400,000 per year, or 7 percent of the total public outgoing cable and radio revenues in the year 1949.

The extent of the survey was limited by the time available but the unusual uniformity of the responses indicated that a pattern of answers had been established and that it was unlikely that more interviews would materially have changed the picture.

Statistical Indicators. The engineers tested several statistical indicators to determine their correlation with the volume of telegraph business. Among these, they investigated the possibility of using the volume of foreign trade (total of United States imports and exports) as the indicator of volume in international record communications. To test the accuracy of this economic indicator, the engineers examined the relationship of the volume of words (total of incoming and outbound) and the volume of foreign trade, not only for the world as a whole but for various areas of the world separately and for certain

REPORT

President's Communications Policy Board

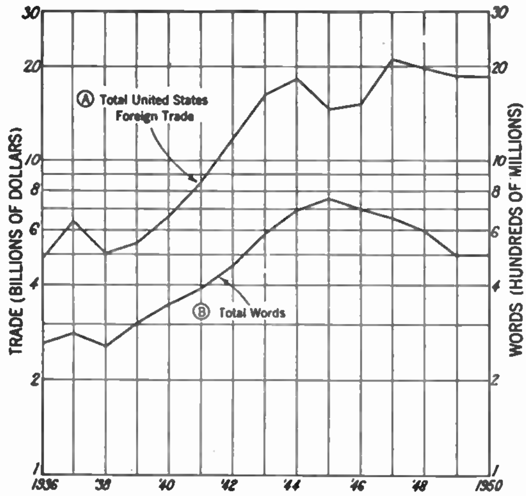
Washington, D. C.

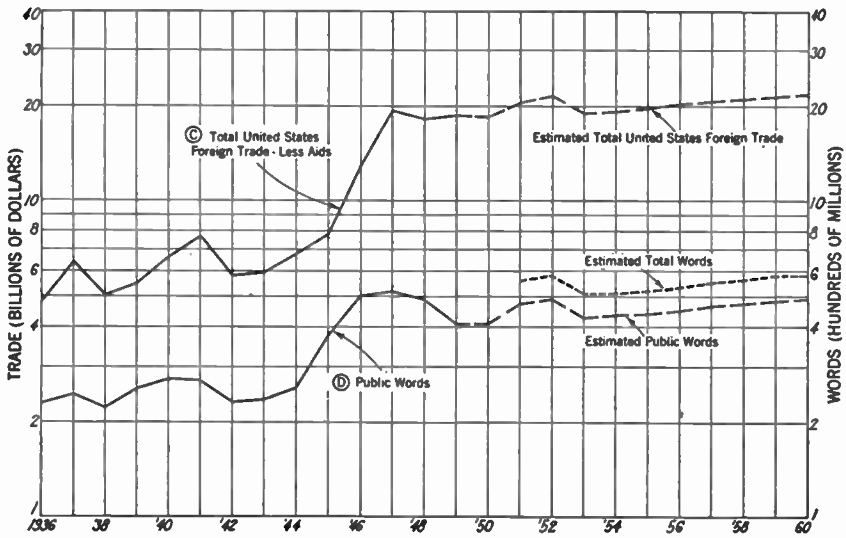
INTERNATIONAL TELEGRAPH VOLUMES AND UNITED STATES FOREIGN TRADE

Ford, Bacon & Davis

Incorporated

Engineers





individual countries. In some instances, foreign trade with particular areas varied considerably from foreign trade with the world as a whole. It was found that, in general, there has been a similarity of trends between the volume of foreign trade and the volume of cable words not only for the world as a whole but for the various areas studied. While other factors than trade do, at times, affect the volume of words, foreign trade evidently has had the predominating influence on it.

The relationship of United States foreign trade with international telegraphic business is shown in the accompanying chart by the lines A and B. It will be noted that although there is a general similarity of trends, the correlation is not very close during the period 1941 to 1947. During the war period 1941 to 1945 the normal relationship between the volumes of words of public messages and other messages, including Government and press communications, was distorted. Normally, public words account for about 85 percent of the total words, but in 1944 the public words dropped to a low of 37 percent. Government words increased from the normal of about 4 percent prewar to better than 30 percent in 1944, and press words increased from a normal of about 10 percent prewar to about 20 percent in 1944. The remaining 13 percent of the word volume in 1944 included "miscellaneous" messages, a low-rate classification used during the war for personal messages by members of the armed forces. In the first half of 1950 the percentages resumed the prewar pattern, i. e., public messages were 84 percent, Government messages 6 percent, and press dispatches 10 percent of the total words.

Assumptions. The projection of volume and revenue into the future involves making assumptions as to conditions that may prevail. The future trend of the indicators of volume and revenue can then be estimated. For this purpose, the Department of Commerce supplied estimates of U. S. imports and exports over the next ten years on the basis of assumptions made by the engineers. Among these were the probability of continued tension in the international situation through 1951 with no outbreak of large-scale hostilities, of a gradual decline in military expenditures beginning in 1953, of normal growth in gross national product after 1952, of no general economic recession during the decade, and of an immediate spurt in stockpiling of imported critical and strategic materials, with the purchases falling off rapidly after 1952. Assumptions which, in view of current conditions, the engineers felt were equally conservative were made with respect to exports from the United States.

Future Volume and Revenues. In the field of international record communications, the preponderance of revenues is directly related to the number of words. The engineers therefore used words as representing the measure of volume of business.

Starting with 1950 conditions, the line for public words (Line D in the chart) was extended parallel with Line C to arrive at estimates of the volume of words for the short-range period 1951 to 1955 and the long-range period 1956 to 1960. The level of public words was then raised from 84 to 100 percent to determine the volume of total words. On this basis, it was estimated that the average volume of words during the short-range future would be of the order of 540 millions of words per year and for the long-range would be of the order of 565 millions of words per year.

Multiplying the estimated volume of words by the average rate of 8 cents per word, the engineers concluded that the transmission revenues of the international cable and radio companies for the short-range period will be of the order of $43 million per year and for the long-range period will be $45 million per year, as compared with 1949 revenues of about $36 million.

Estimates of Future Profitability. The estimates of future profitability of the international industry, based on the operation of the carriers as separate corporate entities, were made by the engineers for the groups of major and smaller carriers.

The estimated international message revenue was allocated to the two groups on the basis of the average of the actual distribution of this revenue in the year 1949 and the first nine months of 1950. This resulted in an allocation of 90 percent to the major carriers and 10 percent to the smaller carriers. To the message revenues thus allocated were added the estimates of other revenues as they applied to the two groups.

The estimates of gross revenues for the major and smaller carriers for the short-range and long-range periods were as follows:

ESTIMATED GROSS REVENUES INTERNATIONAL INDUSTRY

(Thousands)

	Short-range Average Year	*Long-range Average Year*
Major Carriers		
International Message Revenue	$38,880	$40,680
Other Revenues	7,210	7,210
Total	46,090	47,890
Smaller Carriers		
International Message Revenue	4,320	4,520
Other Revenues	1,797	1,797
Total	6,117	6,317

The estimates of future profitability are based on the above estimated gross revenues to which have been applied estimated revenue deductions and other income account items. Actual totals for the year 1949 are included in the following estimates of future profitability of the two groups of carriers, for purposes of comparison:

ESTIMATED FUTURE PROFITABILITY INTERNATIONAL INDUSTRY

(Thousands)

		Estimated	
	Year 1949	*Short-range Average Year*	*Long-range Average Year*
Major Carriers			
Gross Revenues	$40,626	$46,090	$47,890
Net Income before Income Taxes:			
Amount	$828	$5,966	$7,308
Per Cent of Gross Revenues	2.0	12.9	15.3
Smaller Carriers			
Gross Revenues	$5,283	$6,117	$6,317
Net Income before Income Taxes:			
Amount	$309	$1,164	$1,307
Per Cent of Gross Revenues	5.8	19.0	20.7

The engineers also computed bases for measure of income, to which the estimates of profitability of the international industry were related. This relationship of net income to the bases of measure of income for the major and smaller carriers for both the short and long-range periods was as follows:

MEASURE OF ACTUAL AND ESTIMATED INCOME INTERNATIONAL INDUSTRY

(Thousands)

		Estimated	
Major Carriers	*Year 1949*	*Short-range Average Year*	*Long-range Average Year*
Basis for Measure	$56,596	$58,369	$58,618
Net Income before Income Taxes:			
Amount	$828	$5,966	$7,308
Per Cent of Basis for Measure	1.5	10.2	12.5
Smaller Carriers			
Basis for Measure	$8,240	$8,988	$9,164
Net Income before Income Taxes:			
Amount	$309	$1,164	$1,307
Per Cent of Basis for Measure	3.8	13.0	14.3

General Observations

It is clear from what has been set forth above that the privately owned United States international telecommunications network is an invaluable asset to this country in peace and an indispensable military facility in time of war. During the early part of World War II, this network was almost the sole means of linking the United States headquarters with its forces overseas. During the war, of course, vast additional networks had to be created by the military services.

At the end of the war, those private facilities which had been taken over by the Government were returned to their owners and a portion of the Government network was dismantled. What was left of the Government-built net, however, is still a substantial communications facility, and this facility is now to a considerable extent competitive with the private systems. That is, Government-owned facilities built for military purposes are now used by both military and non-military Government departments for administrative and other non-security traffic which might be handled by the common carrier companies. Faced already with serious economic problems, these carriers are now faced also with a Government-owned competition which handles much of the business of the carriers' biggest customer—the Government itself. At the same time, it is to the Government's own best interest to see that the private carriers remain strong, for their facilities may be needed again in time of crisis. Indeed, they are needed now.

The President's Communications Policy Board can hardly enunciate a formula which will at once solve for all time this critical problem. For the problem changes from year to year, almost from day to day. It must be under continual surveillance and Government policies and practices must be flexibly adapted to meet changing conditions.

What has concerned us is that there is no adequate mechanism for dealing with the problem, for examining its nature, or for evolving solutions. For example, Federal agencies now decide for themselves at something less than top level which portion, if any, of their overseas traffic shall be handled by private or by Government facilities. And these decisions are based entirely on considerations of convenience, availability of circuits, or apparent cost and certainly not on consideration of how their actions may affect the health or even existence of the private carriers.

We believe the Government must have a mechanism for keeping under continual review the way in which privately owned international telecommunication companies are affected by Government policies and procedures. The Government should adopt the general policy that it will seek in every feasible way to follow such procedures as will maintain the health and strength of the common carriers. The Government should avoid, within limits set by national security, such procedures as weaken these carriers.

Urgent recommendations have been made to Congress that legislation be enacted to permit companies in the international cable and radio field to merge. One of these recommendations calls for one company to handle all American domestic and international record communications, thus providing an integrated system.

The Board finds no urgent or imperative reasons calling for an immediate merger of these companies; we conclude, on the contrary, that recent improvements in the profitability of these companies encourage a continuation of their present independent status. Moreover, in our judgment, a period of partial mobilization is not a good time to undertake a reorganization of these important components of our communications system.

Our conclusions in regard to merger are based on conditions as we now find them and can project them. We believe, however, that the situation can change and that the welfare of our national communications system demands constant attention to the condition and stability of these companies. We recommend that the Telecommunications Advisory Board, proposed in Chapter V, take this as one of its assignments, working jointly with the Federal Communications Commission. We are mindful of the strong conviction held by informed members of Congress and others that merger is desirable. While we believe it in the national interest that such a merger be deferred, we, too, recognize that changing conditions may provide compelling reasons for a merger later on. If so, these should be adequately anticipated by the Telecommunications Advisory Board and by the Congress. The kind of merger which might thus be indicated, as well as the timing of it, may be dictated not only by economic forces but by the wisdom of the Government's own policies vis-a-vis these companies and by technological developments. Such technological developments, in fact, may prove to be the conclusive factor in determining the future of these companies.

Conclusions

1. The Government should adopt the policy of maintaining the strength of the private competitive international communications system.

2. There should be a Government agency charged with the responsibility for implementing this policy.

3. Urgent recommendations have been made to Congress that legislation be enacted to permit companies in the international cable and radio field to merge. One of these calls for a single company to

handle all United States domestic and international record communications, thus providing an integrated system. We find no imperative reasons calling for an immediate merger of these companies; we conclude, on the contrary, that recent improvements encourage a continuation of their present independent status. Moreover, in our judgment, a period of partial mobilization is not a good time to undertake a reorganization of these important components of our communications system. Our conclusions in regard to merger are based on conditions as we now find them and can project them. We recognize, however, that the situation can change and that the welfare of our communications system demands constant attention to the condition and stability of these companies. We are mindful of the strong conviction held by informed members of Congress and others that merger is desirable. We have ascertained that interested Government departments are divided in their views on the subject. While we believe that the national interest does not at this time require the repeal of existing prohibitions against merger, we recognize that changing conditions may provide compelling reasons for a merger later on. If so, the anticipation of them by adequate study and legislation will be essential. The kind of merger which might thus be indicated, as well as the timing of it, may be dictated not only by normal economic forces, but by the wisdom of the Government's own policies vis-a-vis the companies and by technological developments. Technological developments may in fact prove to be the conclusive factor in determining the future of these companies.

Chapter V

GOVERNMENT ORGANIZATION

Our study of each of the main telecommunications problems to which we have addressed ourselves has led us to a single common conclusion: The United States Government must strengthen its organization to deal on a continuing basis with telecommunications policies and problems.

In our study of the problem of scarcity of space in the radio spectrum relative to increasing demand, we found an enormously complex problem of frequency management. The Government is trying to cope with this problem by dividing responsibility for frequency assignment between the Federal Communications Commission and the President, and thus establishing a dual system of control over a single physical entity.

In our study of the problem of the relationships of Government communications activities to non-Government activities, we again found divided responsibility and a lack of comprehensive assignment of authority to deal with the problem as a whole. Nowhere did we find any agency or system of collaboration among existing Government agencies dealing comprehensively and continuously with policies or integrated execution of Government programs affecting non-Government telecommunications activities.

In our review of the question of merging the overseas operations of our commercial telecommunications companies, and in our examination of factors affecting the economic health of these and other commercial telecommunications carriers, we were struck first by the lack of economic and technical information on which we could base a sound conclusion. Although we decided, on the basis of the facts and testimony we were able to collect, that no Government action need be taken now to assure the financial soundness of these activities for the immediate future, we arrived at the strong conviction that the

Government needs to strengthen its existing organization to keep abreast of economic, technical, and other data affecting the health of commercial telecommunications carriers, so that helpful measures can be taken promptly whenever conditions require them.

In our efforts to discover the current state of Government telecommunications policy as preliminary to recommending needed steps toward a total national communications policy, we once more encountered dispersion, confusion, gaps, and deficiencies in the product and performance of those agencies charged with telecommunications policy responsibilities.

Since our appointment, the nation has passed into a state of national emergency, and our country faces deepened crisis and heightened threat of war. Thus we examined the problem of the need for appointment now of a Board or Administrator of Defense Communications to exercise the President's powers over the nation's telecommunications system, public and private, in the interest of the national security. Again we concluded that neither existing organizations, nor the creation of an ad hoc organization like the Board of War Communications, would suffice. We suggest that the permanent agency we describe below, headed by a board, or by a single individual, can discharge these responsibilities.

During the past year we have become aware of the possibility of radical technical developments which may affect fundamentally the economics and the engineering of our present telecommunications system, particularly in the international field. It is impossible for us to foresee the specific impact which these developments may have. But we are more than ever convinced that the Government requires a strengthened telecommunications organization to keep such developments under constant review.

Both the present and the potential threat of unfriendly interference to international communications underline the urgency of the need for this strengthened organization.

Dimensions of the Problem

The telecommunications field is one affected with the public interest.

Telecommunications by wire have long been regarded as such a business, and therefore appropriately subject to regulation by public authority.

Telecommunications by radio fall even more clearly into this class, since the basic medium they use for the transmission of information lies in the public domain.

Nature has presented the inhabitants of this world with what used to be called the "ether," the medium through which radio waves of all frequencies are propagated. Like the air we breathe, the radio spectrum is there for all to use. Unlike the air, there is not enough of it to accommodate all claimants. Everyone who uses a portion of the radio frequency spectrum automatically excludes others from using this same portion at the same time, unless the other potential user is far enough away geographically to cause or suffer only tolerable interference. Since impulses of certain frequencies can be sent by low power half way around the earth, the conflicting interests of peoples in all nations of the earth, as well as of all those within a single nation, must somehow be brought into harmony. Otherwise there will be chaos.

Clearly it is a responsibility of every government to manage this world resource, this element of the public domain, in such a way as to maintain an ordered use of the radio spectrum by its own citizens. Each government must also reach agreements with other governments for equitable sharing and mutually compatible use of this world resource.

The Government of the United States has recognized these responsibilities for many years, and has from time to time established a succession of agencies to deal with various aspects of this problem. But as the use of the radio spectrum has grown, as the Government has itself become a major user, and as other nations of the world have sought a larger share of the spectrum, the problem has outgrown the authority and capacity of existing Government agencies to deal with it.

What are the major issues arising out of the problems and responsibilities the nation now faces in utilizing its telecommunications resources—including both wire and radio—which existing agencies are admittedly not equipped to handle? We have found five.

1. How shall the United States formulate policies and plans for guidance in reconciling the conflicting interests and needs of Government and private users of the spectrum space—that is, for guidance in making the best use of its share of the total spectrum?

2. How shall the United States meet the recurrent problem of managing its total telecommunications resources to meet the changing demands of national security?

3. How shall the United States develop a national policy and position for dealing with other nations in seeking international telecommunications agreements?

4. How shall the United States develop policies and plans to foster the soundness and vigor of its telecommunications industry in the face of new technical developments, changing needs, and economic developments?

5. How shall the United States Government strengthen its organization to cope with the four issues stated above?

The first four of the questions require brief explanation.

1. *Reconciling Uses of the Spectrum.* This task—which is known as frequency management—is one of enormous technical complexity. Different portions of the spectrum have radically different propagation characteristics; that is, their range and dependability vary. Some are usable for long-distance and others only for short-haul purposes. Their efficiency also changes from night to day, and from day to day, and is affected by atmospheric conditions and by sun spots. Technical advances in the art alter the degree of possible use of a particular band. The difficulties inherent in these facts are aggravated by the increasing congestion of certain spectrum bands.

By better management of the spectrum, much more could be done with frequencies now available. There is opportunity for more effective sharing of frequencies, for more intensive use of individual frequencies, and increased economy in kilocycles assigned to each circuit. Sharing includes division both of time and of geographical area. Frequency-conserving practices call for use of the most efficient and stable receiving equipment available, compatible with economic soundness.

These in turn permit smaller allocations of spectrum space to accomplish given tasks.

The assignment of space in the spectrum among private users (including state and local but not Federal Government agencies) is a responsibility of the Federal Communications Commission (FCC). The total amount of such space available for assignment, however, is not determined by the FCC. In effect, it is determined by the President, who is responsible for the assignment and management of those frequencies used by Federal Government agencies. The Interdepartment Radio Advisory Committee (IRAC) is the instrumentality through which frequencies are assigned to Federal users. Thus far, no national policy has existed to clarify this dual control of a single resource and thus to aid in governing the apportionment of space between private users and Government users as groups. No criteria have been established for use in choosing between the conflicting needs of a Government and a private agency.

2. *National Security.* In the present period of recurrent crisis, it is likely that we shall be faced with a continuing problem of adjusting the use of telecommunications—especially radio frequencies—to what may be violent fluctuations in the requirements for national security. Indeed, we may face a situation in which the President's emergency powers to control, take over, or close down communications facilities will have to be invoked, and arrangements for the delegation and exercise of those powers will be essential. We may also be faced with the necessity of creating wholly new telecommunication facilities.

Telecommunications of course play a major role in the economic and cultural life of the nation. They are the vital nerve system of our modern military establishment. Since spectrum space is demonstrably insufficient to meet both the full needs of national security and the full needs of other affairs, the latter must give way to the former in time of emergency. When the emergency has passed, frequencies and facilities must be restored to civilian use. To create an ad hoc agency to meet each crisis as it comes would be a clumsy expedient at best, and indeed, the problems of transfer and retransfer of spectrum space and of facilities for using it are too complex for ad hoc control to be adequate. A continuing mechanism is needed for the foreseeable future.

3. *International Agreements.* Just as the United States has no clear policy for dividing its share of spectrum space, so it has lacked satisfactory means of determining policy as a basis for negotiations with other nations for the world division of the spectrum. The United States, in preparing positions for international negotiations, has in effect asked Federal and other claimants to state their needs, and then presented the total as the United States requirement. In those portions of the spectrum where these totals have been small enough to fit within the world complement, our delegations to conferences have had a negotiable position. In some cases, however, the total stated requirements have exceeded not merely those which could reasonably be put forward as the proper United States share, but have actually exceeded the total physical content of the bands. Furthermore, there is no permanent mechanism by which the stated requirements of the United States users could be adjusted with equity and safety. The imperative need for means of making such adjustments hardly requires elaboration.

4. *Maintaining a Sound Industry.* The private telecommunications industry of the United States is one of the nation's most valuable assets in peace or in war. The normal life of the country is supported and facilitated by it in numberless ways. In abnormal times, the industry can place at the disposal of the nation its large reserve capacity, built up because of its competitive structure. This capacity helps to take up the immediate surge of military requirements. The industry can release radio frequencies, cable capacity, and other communications facilities, when required for Government purposes, without seriously affecting its ability to carry the civilian load.

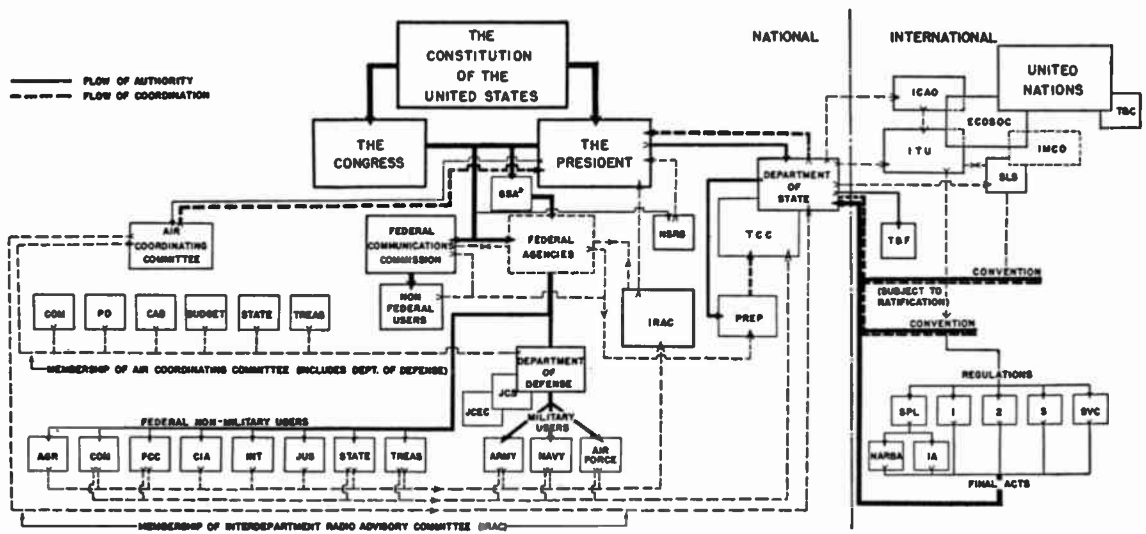
It is essential that the industry be in sound economic condition. Some of its components, however, have faced serious difficulties. These have arisen in part from changing economic conditions and from new technical developments, and in part from the varying international situation. The industry also has objected to practices and policies of the Government, such as taxation policies, subsidies to competing facilities, and the Government's increasing extension and use of its own communications system. To meet these difficulties, the companies have from time to time taken individual action, and from time to time Government has been of assistance to them in rate adjustments and other ways.

But there has been no long-range study of the question, no long-range planning. There should be. No agency of Government is in a position to take a comprehensive view of the problem. Regulatory authority over all communications common carriers in interstate commerce, wire or radio, is centered in the FCC. However, the FCC does not have power, for example, to require Government agencies to make greater use of private facilities, or even to investigate whether such transfer of traffic would be feasible or desirable from the Government's point of view. There is no agency qualified to advise the President in fields where the interests of private and Government telecommunications users are in conflict. Meanwhile, in the absence of guiding policy, the action of Government agencies could seriously handicap the industry.

In addition to these special problems which are directly concerned with telecommunications policies and programs, it is necessary to keep in mind the fact that these policies and programs do not exist in a vacuum; they are part and parcel of the policies and operations both of the Federal Government and of the political, economic, military, and social life of the country as a whole. Therefore we must take into account, in estimating the dimensions of the problem before us, the point that telecommunications policies and programs must not be considered as entities in themselves. They should be constantly related to the larger whole of which they are part.

One further fact is important in understanding this problem. All Federal Government agencies have interests as users of telecommunications. The degree of user interest varies; the most prominent users are the Department of Defense, the Department of State, and the Civil Aeronautics Administration. The Civil Defense Administration is vitally concerned with the adequacy and dependability of domestic communications. The General Services Administration has a threefold interest: as a user, as a provider of long-distance communications systems to other Federal agencies, and as the controller

FLOW CHART OF NATIONAL AND INTERNATIONAL TELECOMMUNICATION AUTHORITY AND COORDINATION



—LEGEND—

AGR – DEPARTMENT OF AGRICULTURE
BUDGET – BUREAU OF THE BUDGET
CAB – CIVIL AERONAUTICS BOARD
CIA – CENTRAL INTELLIGENCE AGENCY
COM – DEPARTMENT OF COMMERCE
ECOSOC – ECONOMIC AND SOCIAL COUNCIL (UN ORGAN)
FCC – FEDERAL COMMUNICATIONS COMMISSION
GSA – GENERAL SERVICES ADMINISTRATION
IA – INTER-AMERICAN CONVENTION AND AGREEMENT
ICAO – INTERNATIONAL CIVIL AVIATION ORGANIZATION
IMCO – INTER-GOVERNMENTAL MARITIME CONSULTATIVE ORGANIZATION
INT – DEPARTMENT OF THE INTERIOR
IRAC – INTERDEPARTMENT RADIO ADVISORY COMMITTEE
ITU – INTERNATIONAL TELECOMMUNICATIONS UNION
JCEC – JOINT COMMUNICATIONS — ELECTRONICS COMMITTEE
JCS – JOINT CHIEFS OF STAFF
JUS – DEPARTMENT OF JUSTICE
NARBA – NORTH AMERICAN REGIONAL BROADCASTING AGREEMENT
PO – POST OFFICE DEPARTMENT
PREP – CONFERENCE AND POSITION PREPARATORY COMMITTEES
SLS – INTERNATIONAL CONVENTION FOR THE SAFETY OF LIFE AT SEA
SPL – SPECIAL ARRANGEMENTS BETWEEN ITU MEMBER COUNTRIES
STATE – DEPARTMENT OF STATE
SVC – RADIO SERVICE CONFERENCES
T&C – TRANSPORT AND COMMUNICATIONS COMMISSION (UN ORGAN)
T&F – TERRITORIAL AND FOREIGN RELATIONS
TCC – TELECOMMUNICATIONS COORDINATING COMMITTEE
TREAS – DEPARTMENT OF THE TREASURY (INCLUDES COAST GUARD)
1 – REGION 1 OF ITU, EMBRACING EUROPE AND AFRICA
2 – REGION 2 OF ITU, EMBRACING NORTH AND SOUTH AMERICA AND HAWAII
3 – REGION 3 OF ITU, EMBRACING AUSTRALASIA

* AUTHORITY UNDER PUBLIC LAW 152 OVER PUBLIC UTILITY COMMUNICATION SERVICES OF EXECUTIVE AGENCIES EXCEPT FOR CERTAIN OF THEIR ACTIVITIES.

PREPARED BY P. C. P. B., DECEMBER 21, 1950.
(PRESIDENT'S COMMUNICATIONS POLICY BOARD)

and manager of telecommunications (subject to certain restrictions) for all Federal agencies. The Federal Communications Commission, although not itself a prominent user, speaks in Federal Government councils for the interest of the non-Government user.

While all Federal agencies have greater or lesser interests as users of telecommunications, the use of telecommunications as such is not a major interest or function of any of them, but is a tool to accomplish their missions.

* * * * * *

The problem now facing the Federal Government is how to organize itself to meet its responsibilities for policy formation and program execution in the telecommunications field, which will meet the four special problems just outlined.

Current Organization

We turn now to a study of the existing Government telecommunications agencies to determine the extent to which they can cope with the problem just stated. In order, they are the Federal Communications Commission, the Interdepartment Radio Advisory Committee, and the Telecomunications Coordinating Committee. Their position in the intricate pattern of national and international telecommunications is indicated in the accompanying chart. In our study of each of these agencies, we have examined the record and discussed with qualified observers the basic nature of these organizations, their past record and their probable adaptability to meet more adequately the exigencies of the present and future. We have been mindful of the advantages of building on existing men and organizations; we have no wish to add to the number of existing Government organizations unless the need is inescapable; we have looked for ways and means of adapting these agencies so they can more effectively carry out the tasks we think need to be done, or done better.

From this special point of view we have appraised each of these agencies, as a means of arriving at our conclusion as to what should be done to strengthen Government telecommunications policy machinery.

The Federal Communications Commission

The Federal Communications Commission was created by the Communications Act of 1934 as an independent agency to regulate interstate and foreign commerce in communications by wire and radio. The Commission's jurisdiction extends not only to private radio broadcasters and to common telecommunications carriers engaged in interstate and foreign commerce, but to the communications activities of state and local governments as well.

The ultimate public policy embodied in the Act is

> "to make available, so far as possible, to all the people of the United States a rapid, efficient, Nation-wide, and world-wide wire and radio communications service with adequate facilities at reasonable charges, for the purpose of promoting safety of life and property through the use of wire and radio communication. . . ."

An immediate objective was to secure "a more effective execution of this policy by centralizing authority heretofore granted by law to several agencies and by granting additional authority with respect to interstate and foreign commerce in wire and radio communication. . . ."[1]

The Commission has broad powers to regulate common carriers engaged in interstate or foreign communications activities, and radio broadcasters. The Commission enforces those provisions of the Act which require ships to carry specified radio equipment and comply with procedures for safety at sea. The Commission carries out the necessary inspections and investigations, and can compel actions by those it regulates to conform to the broad purposes of the Act. The Act provides sanctions and empowers the courts to enforce Commission decisions. The Act also specifies elaborate procedural provisions, designed to afford appeals to the courts to any party who is aggrieved by a Commission decision, or whose interests are affected thereby. These provisions for due process of law, these protections against arbitrary or capricious Government action are necessary elements of the Commission's concept and conduct.

[1] Communications Act of 1934, as amended, Sec. 1.

The Communications Act was passed with the intention of centralizing in one agency the task of viewing non-Federal Government communications as a whole, of developing communications policies for wire and radio on an integrated basis, and of providing for regulation of specific forms of communication with due regard to the effects of particular actions on other forms of communications. It was recognized this was a technical field in which Congress could not hope itself to carry out the quasi-legislative process of rule-making, or the administrative process of applying the standard of "public convenience, interest, and necessity" to numerous specific cases. Those provisions of the Communications Act which require the Commission to study special problems and recommend legislation to cure them explicitly reflect the intent of Congress to give the Commission special policy-forming responsibilities for telecommunications matters.

As such, we considered carefully whether the Communications Commission is not an appropriate place to put the functions we have in mind.

The Communications Act itself, however, suggests otherwise.

Division of Powers between the President and the FCC. The Communications Act vests defense powers in the President alone, and divides Government power to assign spectrum space. While the preamble to that Act recognizes the value of communications to national defense, and implies that the Commission has a direct interest in the management of telecommunications for defense purposes, Section 606 of the Act clearly vests in the President the power to take over civilian telecommunications facilities, both wire and radio, for emergency and war purposes. The President need not turn to the Commission for any sort of prior consultation or advice before exercising his powers under the Act. Furthermore, Section 305 of the Act specifically gives the President the power to assign radio frequencies to Government stations, and specifically exempts Government stations from the licensing and other regulatory powers of the Commission when they are operating as such. The Act on the one hand provides no standards to guide the President in assigning frequencies to Government stations; his determination is final. On the other hand, the Act places the Commission under no duty to respect the President's assignments;

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either the Commission or the President could start a radio war by assigning a frequency already in use to an interfering user.

Similarly in the field of foreign relations, the preamble to the Act suggests the Commission should concern itself with foreign relations by including, as part of the Commission's broad public policy objective, regulation of foreign commerce in part with an eye to fostering a rapid and efficient worldwide wire and radio communication service. Yet it is patent that Congress could not and did not wish to give the FCC powers in the field of foreign relations which are constitutionally within the prerogative of the President.

This division of responsibility offered ample room for the Government to get its telecommunications policies and administration into serious snarls. Two factors have worked against this. One is the relatively small need for close coordination between the Commission and the Chief Executive during the early years of the Commission's life; the other is the spirit of sensible cooperation which has marked the relations between the Commission, in particular its chairmen, and the President.

The Communications Act was passed at a time when there was far less conflict than there is now between the requirements of the Government and the requirements of other claimants for radio frequencies. Technological and economic developments kept pace with valid demands for frequency assignments, in the main. Expectations for defense needs were geared to the thinking of the times. The nation's concept of the size and importance of its responsibilities and commitments in the field of foreign relations was also far more modest than now.

Accommodation between the President and the Commission was, however, a *de facto* political result, not a necessary legal result from the powers and structure of the Commission and legislative specification of its relationship to Congress and to the Executive. The Commission, as an independent regulatory agency, does not report to the President, nor need it consult the President in arriving at its decisions in actions before it. Members of the Commission are appointed by the President, with the advice and consent of the Senate. The Commission must come to the Bureau of the Budget in presenting its appropriations requests to Congress. The Commission is subject to presidential power in reorganization and management matters. The President on the one hand has issued Executive Orders affecting the Commission and its participation in Government activities, and the Commission has complied with them. On the other hand, the President has been chary indeed about using his budget and reorganization powers with respect to the Commission. Chairmen of the Commission have voluntarily taken up many policy matters with the White House, and the record shows a high degree of cooperation on matters of joint concern.

Congressional Interest. Relationships between the Commission and the President are always conditioned by the views of Congress—and in particular of those Senators and Representatives who take a special interest in broadcasting or other communications matters—as to the proper role of the Commission and the degree of independence from the President it should enjoy.

Many Congressmen take special interest in matters before the Commission which may affect availability of nationwide outlets for political debate, or which may affect communications activities in their home areas. These interests are largely concentrated in the fields of broadcasting and television. We take account of this fact here because of its effect on the Commission's freedom to emphasize the various parts of its total responsibility under the Communications Act according to its own sense of their importance or priority.

Some Congressmen regard the FCC as an "arm of Congress," and are anxious that the Commission maintain a healthy independence from presidential influence and control.

Hoover Commission Views. The Commission on Organization of the Executive Branch of the Government (the Hoover Commission) pointed in 1949 to the dilemma under which the FCC has long suffered: the FCC has been unable to deal effectively with the workload before it because it has not formulated the broad policies to guide its decisions and thereby expedite its handling of cases; it has been unable to formulate those policies because of the pressure of current business. The Hoover experts also reported that the FCC has characteristically faced its tasks by dealing with problems as they arise, rather than by conscious policy-making, planning, and programing for the broad future of communications regulation and development.

Other Views. Many have pointed to the tremendous burdens placed on the Commission by requirements for hearings and other time-consuming processes needed to furnish protection to the rights of claimants. The FCC has been hampered in the discharge of its full regulatory responsibilities by difficulties in getting funds to make requisite inspections, special studies, and analyses of pressing regulatory problems. All these counsels have been urged as reasons why we should not recommend for the Commission new responsibilities for critical policy-making tasks, dealing with frequency utilization both by Government and by non-Government agencies, and treating of other comprehensive telecommunications issues.

We are also impressed by the fact that no Government agency or official with whom we have discussed this matter, including the Chairman and members of the FCC, has recommended that we expand the powers and staff of the FCC to deal with the policy-forming problems we think must be met.

Appraisal. The arguments involving excessive work-load, method of organization, and time-consuming administrative practices are persuasive but not conclusive. The Commission has already taken steps to reorganize itself in line with the Hoover group's recommendations, and expects to complete this process by the end of 1951.

The argument of excessive concentration on the problems of domestic broadcasting and television is even more persuasive. We do not think that the Commission will ever be free from the persistent pressures which force it to devote the majority of Commissioners' time and attention to these portions of the field. The solution of dividing the Commission into panels, already authorized by the Communications Act, is not a complete answer, as suggested by the Hoover Commission report. Similar conclusions were stated in 1949 by a subcommittee of the Senate Committee on Interstate and Foreign Commerce.[1] Panel consideration and decision is not Commission con-

[1] S. Rept 49, 81st Cong., 1st Sess., Feb. 10, 1949, pp. 2–3. Despite the provisions of Sec. 5 of the Communications Act, the subcommittee thought "that adoption of the panel system without enactment of legislation specifically dealing with the subject is not contemplated by

sideration and decision. To organize a regulatory commission into panels according to specialized types of work is to divide what should be comprehensive attention to the interrelations of communications problems.

The two most important considerations against placing new functions in FCC, and in our opinion the conclusive ones, are these: First, the FCC in its capacity as representative of the interests of non-Federal communications agencies, is in effect a user. As such, it would never be accepted as an impartial arbiter by other Federal users. Second, it would be unwise and improper to give to the FCC the power to make decisions which affect the administration of executive agencies, or which relate closely both to foreign relations and to national defense. These must be made by the President.

The Interdepartment Radio Advisory Committee

The Interdepartment Radio Advisory Committee was created in 1922 by letter to interested Federal agencies from the Secretary of Commerce for the purpose of coordinating the uses of the frequency spectrum by the several Government agencies. Thus it antedates both the Federal Communications Commission and its predecessor, the Federal Radio Commission. These agencies were brought in on their creation, however, and IRAC has always been the nearest approach to an inclusive body in which the needs of both Government and non-Government agencies for frequency spectrum space could be considered.

IRAC membership has always included those Federal agencies most interested in the use of radio communications. Eleven are now represented: the Department of Agriculture, the Department of the

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the existing law which contemplates that all decisions must be made by the whole Commission." With respect to the merits of panels, the subcommittee concluded that litigants had a right to expect that decisions on matters affecting them vitally should be made by the entire Commission authorized to decide such issues. However, "the Commission must find a method of speeding up its work and reducing the current backlog of cases, which we are informed represents as much as 15 months' work." The subcommittee made concrete proposals to that end, and recommended reorganization of the FCC into the three functional divisions (broadcast, common carrier, safety and special services) recommended by the Hoover experts and in process of adoption by FCC.

Air Force, the Department of the Army, the Department of Commerce, the Federal Communications Commission, the Department of the Interior, the Department of Justice, the Central Intelligence Agency, the Department of the Navy, the Department of State, and the Treasury Department. The Federal Communications Commission acts as spokesman for non-Government users (that is, all users not within the Federal Government; state and local governments must come to the FCC for frequency assignments). Other Federal agencies are present or represented when matters affecting them are before the Committee.

Thus, IRAC is a group of users.

As such, it has been severely limited in its capacities as a policy-forming body. The practices and priorities it has generated have always been restricted to those by which a group of users with equal rights could get along.

IRAC's most important task through the years has been to serve as a technical forum in which users could agree on assignment of spectrum space to Federal claimants, and in which Government users could inform the Federal Communications Commission of their comments on proposed Commission allocations and assignments of frequencies to non-Government users. The Commission, as spokesman for the non-Government users, could also comment on the effect of requested assignments to Government users on present or future interests of other users.

IRAC's decisions are incorporated in a Station List which is not available to the public. This list gives all particulars required for coordination necessary to minimize radio interference. These particulars are binding delimitations on the use of the assignment.

IRAC recommends to the President lists of broad assignments of frequencies to Federal users, which are then promulgated in Executive Orders. These orders have recognized IRAC by reference, in giving it power to make interim assignments pending preparation of a new Executive Order. These orders were expected to be issued once every two or three years; nothing is fixed about this period. However, the latest order appeared in 1944, and there is little prospect for a new one in the near future. IRAC, or in effect its sponsoring agencies, has given higher priority to other tasks.

Problems of IRAC. Theoretically, since the IRAC "advises" the President on the use of his power to assign frequencies to Government users under the Communications Act of 1934, an appeal can always be made to the President. Practically, such a case would come up only if an agency felt that it was denied something so important that the agency thought it appropriate to bring its request to the President's attention. As a group of users representing coequal agencies, IRAC has a *de facto* rule of unanimity in frequency assignment matters. In practice, there have been only three or four cases in which an aggrieved department did appeal to the President. The first of these, in 1928, demonstrated the difficulty of trying to use an interdepartmental committee of coequal users for generating policy, and resulted in a working rule of first-come first-served, with assignments to be made on a non-interference basis. Under formal IRAC procedures, those to whom assignments have been made may enjoy them until they wish to give them up. Practice again, however, is something different. Back of the rule of unanimity and absence of compulsion has lain a complex process of bargaining and accommodation. New users or old agencies looking for new assignments during the more recent years of frequency scarcity have had to engage in a highly skilled, technical process of searching for combinations of frequency, power, time of use, direction and area of propagation, and stability of receiving and sending equipment in order to fit new uses into the existing pattern of operations.

Although there has been no compulsion by directive, all the users have been under strong suasion to find mutually agreeable solutions in order to avoid having to seek decisions at a higher but technically unqualified level. Furthermore, to the telecommunications specialist it is fundamental that the alternative to agreement is chaos.

Hence arises the technical reconnaissance and negotiating process which takes place between seeking agencies and possessor agencies whenever new assignments are sought. Requests usually come in to IRAC only after the agencies affected have come to some sort of private understanding.

We have been told that IRAC never concerns itself with "policy" and that Government users are not required to justify their requests for frequency assignments or their retention. IRAC has made some real contributions to policy—as for example its recommended priorities for allocating the spectrum to services which should underlie the United States Government position at the Atlantic City telecommunications conference of 1947. These priorities and policies were not generated, however, for IRAC to follow in dealing with its own business. They were valuable contributions of technical specialists intimately associated with governmental operations to the formulation of an international agreement.

The extent to which Government claimants must justify their requests is important to an evaluation of IRAC's role. The key to the matter is the nature of the group—a group of users, rather than an independent judging body. IRAC points to various criteria which have been decided as relevant to the justification of frequencies in its deliberations.[1] Whatever the relevance of the criteria, no body of users acting as judge of its own requirements can take an impartial view of the requests of its members. Security problems have complicated these issues, especially in time of war, when the fact of value to national defense would often be alleged, but no supporting data brought forth on which the claim could be evaluated.

In sum, we find that IRAC has done a good technical job of frequency assignment through the years, within the inherent limitations imposed on it by its constitution. It has taken advantage of the incentives to technical achievement and agreement inherent in its peculiar situation. It should remain as a technical body in which the day-to-day tasks of Government frequency assignment can be carried out. It is obvious, however, that a different kind of agency is needed for the future to solve the problems that will arise from congestion of the radio spectrum.

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[1] Eligible reasons include: specific legislative directives; international commitments, such as treaty obligations; national defense requirements; internal security; protection of national resources; essential mobile communications; communications affecting safety of life or property; research and experimental services; and absence, inadequacy, or impracticability of establishment or use of other means of communication. See IRAC By-Laws, 1 January 1950, Article X, "Principles Governing the Assignment and Use of Radio Frequencies."

The Telecommunications Coordinating Committee

The Telecommunications Coordinating Committee is an informal, voluntary group created in 1946 by exchange of letters between the Secretary of State and the heads of four other departments and the Federal Communications Commission. The purpose of this move was to create a body to consider telecommunications policy questions, and thus to fill for the postwar period the gap left by the demise of the Board of War Communications. The Committee is composed of one representative each of the Departments of State, Treasury, Commerce, and of the Federal Communications Commission, and three from the Department of Defense (one each from the Departments of the Army, Navy, and Air Force). The Bureau of the Budget is represented by an observer. Representatives are designated by the heads of each agency; they are supposed to be of the Under Secretary or Assistant Secretary level for the non-military agencies and the chief communications officers of the armed services. Several efforts have been made by member departments to set up the organization more firmly by Executive Order. This has never been done. Subsequent to its formation, other departments have from time to time sought membership but have been excluded by the Committee on the ground that membership is restricted to those agencies having a "high policy" interest in telecommunications. The Committee, as a matter of practice, includes in its meetings, and in the composition of any ad hoc working committees, representatives of any agencies having a special interest in the work in hand.

At the outset it was thought this committee could formulate policies and develop plans and programs which would promote the most effective use of wire and radio facilities. The FCC, however, pointed to its statutory responsibilities for policy formulation and advice to Congress on such matters, and stated that its participation in any group such as TCC could not relieve it of these obligations or bind it in any way. The State Department reiterated its initial view that the TCC could work only by unanimity, and that there must be no intrusion on the statutory or other authorized responsibilities of any of the component agencies. TCC accordingly adopted a more modest charter in which it was agreed by the members that its mission was

> "The coordination of policies of the various departments and agencies of the United States Government relating to domestic and international communications matters . . .; and advise on problems of an international nature including preparation for international telecommunications conferences. The Committee shall act in an advisory capacity only, but may take final action when specifically authorized by unanimous concurrence of all Government agencies represented by the membership. . . . In accordance with the foregoing, the primary objective of this Committee is the formulation of a national communications policy." [1]

The TCC is served by a small part-time secretariat furnished by the Department of State. Although it has no formally elaborated organization, it does set up ad hoc working groups.

Problems of TCC. From the evidence before us, and from discussions with participants, it appears to us that the TCC, in its present form, is inadequate by itself to play the major role in the formulation of a national telecommunications policy.

TCC is bound by the rule of unanimity. TCC can act when the Government departments are in agreement, or can be brought into agreement by intragovernmental persuasion and diplomacy. TCC can lay out the areas of agreement or disagreement on any issue before it, but since its members represent agencies with user interests, the Committee cannot easily weigh and evaluate points of disagreement, resolve them, and advise the heads of their agencies, and through them the President, of a national telecommunications policy.

TCC is hampered by the difficulties, found in other technical fields as well, of translating technical differences of opinion into policy alternatives, so they can be dealt with by the President or by Cabinet officers. TCC membership has suffered the decline inevitably to be expected when staff officers are unable to master this thorny task of translation. Under Secretaries and Assistant Secretaries have been replaced at meetings by Directors of Offices; Directors of Offices have been replaced by technical specialists, so TCC meetings are often con-

[1] TCC Document No. 11, Organization/6, April 8, 1946.

ventions of IRAC representatives acting under different instructions. This situation might have valuable advantages from the standpoint of continuity of problem consideration and economy of personnel, if it were not true that technical user-oriented personnel do not occupy positions which permit them to act as plenipotentiaries to make policy commitments on behalf of their agencies.

When the Government, after the passage of the National Security Act of 1947, could have replaced the War and Navy Department representatives either by a single Department of Defense representative or by representatives of the three service departments, the choice was for the latter. This meant in practice that TCC is weighted with representatives of military interests and functions, who besides are chiefs of the communications services of the three departments—that is, users and operators of specialized services rather than officials charged with agency-wide responsibilities.

In most instances, this would have been salutary, since close relationships between major operational responsibility and policy responsibility are wanted. The difficulty here arose from the fact that much of telecommunications policy formation has to do with dividing scarce resources among military claimants, other Federal Government claimants, and non-Government claimants. Officials heading extensive service agencies, with larger potential demands on their services than they can expect to meet, can hardly be expected to take an impartial view of such questions as the national requirement for a share of the world's frequencies, or division of the national share among all claimants.

TCC has done good work of a preparatory character toward policy formation. But TCC as presently constituted has found it difficult if not impossible to complete policy formation tasks. In those cases where unanimity does not prevail, TCC could never do so. However, TCC, better organized and staffed, could do a far better job of preparatory work so sub-Cabinet level members might go farther than now toward resolution of policy differences, and in any event make possible intelligent resolution of remaining differences at the level of the Cabinet or the Presidency. We believe that reorganization and strengthening of TCC will make possible such a contribution.

The existing organization for frequency assignment to Government and to private users was set up at a time when—outside of the standard broadcast band—there was enough for all, and the proportion of spectrum space needed for Government purposes was small in relation to the whole. In such circumstances, it was feasible to leave Government frequency administration to the Executive Branch, as a proper extension of executive control over the substantive functions of Government which its communications serve; to leave assignment to non-Government users to the Federal Communications Commission as a proper extension of its regulatory functions; and to leave interrelations between the two to good sense and a will to get along.

Government now occupies something under half of the presently usable radio spectrum and was doing so before the Korean crisis. Although the Federal agencies have acquired this large portion of the spectrum under established procedures and with consideration to private interests as represented by the FCC as spokesman, these allocations were made by officials who could not weigh all demands for spectrum space, Government and private, and judge them impartially on the basis of full explanation according to a single set of standards and a well-considered national policy.

We have found conflicting evidence as to the seriousness of the scarcity of frequencies in relation to demands. Some think there is no problem, and that the expected rate of technical advance, continued good will among those competing for space, and the elimination of wasteful uses will meet the nation's requirements for the indefinite future. Others think the problem is critical. Without passing judgment here as to the precise degree of scarcity, we are convinced that pressure of present and future demands is so heavy as to force the Government ultimately to consider telecommunications resources as a whole, and to apportion them as a whole to meet the most pressing requirements of the whole nation.

As for telecommunications policy formation, recent experience has demonstrated that the available machinery works only in the case of unanimity, and that the event of unanimity has become increasingly rare. Although there was unanimous acceptance of the Atlantic City Convention, unanimity disappeared when attempts were made to translate accepted policy into practice. The United States thus was unable to devise a reasonable position for implementing an agreement it had initiated and urged on other nations. Neither the TCC nor any specially devised machinery has so far been able to provide that detailed position.

Conclusions

1. Fundamental changes in telecommunications require the overhaul of Government machinery for formulating telecommunications policy and for administering certain telecommunications activities in the national interest.

2. The Communications Act of 1934 established a system of dual control of the radio frequency spectrum. This dual control arises largely from the fact that the regulation of private telecommunications is a function of Congress exercised through the FCC, while the operation of Government telecommunications is primarily a function of the Executive. For example, the assignment of frequencies to military services is an exercise of the President's powers as Commander-in-Chief of the armed forces.

3. The Federal Communications Commission, though needing further strengthening, should continue as the agency for regulation and control of private users.

4. The President has exercised his power to assign frequencies through the Interdepartment Radio Advisory Committee, made up of representatives of the using Government agencies. While this Committee should continue as a forum to arrange the use of the spectrum in such a way as to avoid interference, it is not an adequate means for keeping in order the large portion of the spectrum occupied by Government agencies.

5. The Telecommunications Coordinating Committee has served a useful function and should continue as a mechanism for interdepartmental discussion of telecommunications matters.

6. The whole Government telecommunications structure is an uncoordinated one and will be even less adequate in the future than

it has been in the past to meet the ever-growing complexities of telecommunications. A new agency is needed to give coherence to the structure.

7. There is need for a better determination of the division in the national interest of frequency space between Government and non-Government users. To achieve that end, close cooperation between the Federal Communications Commission and the proposed new agency will be necessary.

The Solution Recommended

The urgency of the need for remedial steps in telecommunications organization calls for prompt action.

We recommend the immediate establishment in the Executive Office of the President of a three-man Telecommunications Advisory Board served by a small, highly qualified staff to advise and assist the President in the discharge of his responsibilities in the telecommunications field. Its task would include formulating and recommending broad national policies in this field, and giving advice and assistance in the formulation of policies and positions for international telecommunications negotiations.

The Telecommunications Advisory Board should exercise on behalf of the President his powers in the telecommunications field—in the main, those powers arising from Sections 305 and 606 of the Communications Act of 1934. Thus the Board would be responsible for assignment of frequencies to Federal Government users, and for the exercise of the President's emergency and war powers over the radio and wire communications of the country. This agency would also be available to discharge any other tasks the President might lay upon it.

While we believe that a three-man board, as suggested above, is preferable, we recognize the possibility of appointing one man, a Telecommunications Adviser, to exercise the functions of the proposed board.

We believe that an immediate task of the new agency would be to assure that the Federal Government's use of radio frequencies is in as good and economical order as possible and to further the most rational use of the entire spectrum.

Another closely related and important function of the new Board will be to establish and maintain effective working relationships with the Federal Communications Commission for the informal solution of those joint questions of frequency allocation which will inevitably come up under our system of dual control over the spectrum. The vast growth in public demand for television has made acute the problems of deciding how to allocate space in the higher frequency bands as between Government and non-Government users. The claims of a multi-billion-dollar industry with a tremendous potential impact on the daily life of every citizen must be put over against vital needs of Government agencies for services necessary to the security and welfare of the entire nation. If this cannot be done promptly and wisely by joint action of the FCC and the new Board, it may be necessary to seek a change in the Communications Act so as to set up a single authority where such decisions can be made.

We recommend that the Telecommunications Coordinating Committee should be left much as it now is, so far as its legal basis and scope of activities are concerned. We see no particular merit in formalizing it by Executive Order; to do so might unduly institutionalize what should be a flexible, informal interdepartmental committee composed of representatives of those Federal departments and agencies possessing statutory or other formalized responsibilities relating to telecommunications. The chairmanship of the TCC should be held by someone primarily interested in telecommunications. We suggest he should be a member of the proposed Board.

We recommend that the Interdepartment Radio Advisory Committee should also continue much as it is now—a specialized agency to perform the detailed work of assigning frequencies to Federal Government users, but under policies promulgated by the Telecommunications Advisory Board. IRAC recommendations for frequency assignments should be made to the Telecommunications Advisory Board for authentication.

We recommend that no changes be made at this time in the powers and duties of the Federal Communications Commission. The FCC should continue to regulate telecommunications common carriers and to control the use of the radio spectrum by non-Government agencies according to the standards of public convenience, interest, and necessity specified in the Communications Act. The Commission should continue to afford to interested or aggrieved persons full opportunity for public hearings and other safeguards of due process of law. The Commission's present efforts to reorganize itself as recommended by the Hoover Commission should be pressed, in order that it may quickly increase its capacity to help in Government-wide formulation of telecommunications policy.

We do, however, think that the FCC should have more funds and a stronger staff to keep up with engineering and economic developments affecting the commercial telecommunications carriers of the country. We foresee the possibility of quicker and more radical change in these fields; we think the Commission should be in a position to take necessary action without delays caused by the need to get special appropriations, recruit special staff, and conduct special studies before sound decisions can be made.

We recommend the creation of this Telecommunications Advisory Board after an exhaustive review of alternative solutions. We believe that a board acting to advise the President has the best opportunity within the philosophy of our Government operation to set our communications house in order.

We call attention to the one alternative most frequently suggested—that is, the creation by Congress of a board having complete power to assign frequencies both to Government and to civilian users. The creation of such a board would mean a fundamental change in the present Communications Act. It would involve, we believe, serious conflicts with the proper exercise of the executive function of the Government. We mention it only as a possible last resort in the management of our communications resources. We hope that the solution proposed here can obviate the necessity of such fundamental change in our communications policy.

The Telecommunications Advisory Board—Qualifications and Emoluments. High caliber of membership is the most important single factor which will determine the success or failure of the proposed Board. The Board should combine sound engineering knowledge with experience and skill in governmental affairs. The business of the Board will not be confined to technical questions of electronics and engineering; its problems of Government policy and operation branch out into many fields of public policy. It is therefore important that the members of the Board should be men of broad vision, able to resolve complex telecommunications issues with due attention to probable impact on related fields.

Salaries of Board members should be sufficient to attract men of high qualifications.

The Telecommunications Advisory Board—Detailed Functions and Powers. The Telecommunications Advisory Board should be established preferably by Executive Order. This agency should:

A. Act for the President in carrying out his responsibilities arising from:

(1) Section 305 of the Communications Act of 1934, as amended. (Assignment of frequencies by the President to Government stations or classes of stations.)

(2) Section 606 of the Communications Act of 1934, as amended. (Emergency and war powers over telecommunications common carriers, and protection for telecommunications activities.)

The Telecommunications Advisory Board should carry on such planning functions as are necessary to the discharge of its duties under this Order.

B. Stimulate and correlate the formulation and publication of plans and policies by appropriate existing agencies to insure:

(1) Maximum contribution of telecommunications to the national interest.

(2) Maximum effectiveness of U. S. participation in international negotiations.

C. Recommend to the President and advise him on proposed legislation in the telecommunications field.

D. As preliminary and preparatory steps in the discharge of the duties specified above:

(1) Approve and promulgate engineering standards for allocations and assignments to Government users.

(2) Provide for adequate initial justification and periodic rejustification and reassignment of frequencies assigned to Government users.

(3) Maintain such records of United States frequency assignments as it deems necessary.

(4) Make arrangements with the FCC or with other agencies for monitoring and check to determine compliance with conditions attached to frequency assignments, and for other purposes.

(5) Keep abreast of research programs in those aspects of the telecommunications field which bear on radio propagation and frequency utilization, and stimulate and support research where most needed in these areas by governmental and private agencies.

(6) Stimulate and sponsor such studies pertinent to the broad objectives of the Board as are necessary to keep the President informed of the health of the telecommunications industry and the effects upon it of Federal telecommunications policies and procedures.

F. Cooperate with the Federal Communications Commission for the purpose of arriving at an equitable distribution of frequency space between Government and non-Government users.

G. Establish and maintain liaison as required with departments and agencies of the Federal Government.

H. Create advisory bodies, or utilize the assistance of existing advisory groups, as required in the discharge of its duties and responsibilities.

I. Carry on such other duties and responsibilities as may be directed by the President from time to time.

Access to Information. All departments and agencies of the Government, including the military services and the Central Intelligence Agency, should be authorized and directed to furnish to the agency whatever information it requires to make a full determination of the questions before it.

The Board must always be in a position to receive and consider the most highly classified matter submitted by military or other Government agencies in justification of their proposals. Only thus can it hope to make reasonable judgments based on complete facts. Obviously, the Board must be in a position to protect such confidences.

Discussion of Functions and Relations to Other Agencies. If the new Board acts for the President in carrying out his responsibilities arising from Sections 305 and 606 of the Communications Act, it will have real power. In our view, both of these functions are continuing functions involving the exercise of substantial governmental power. They are the heart of the mission of the new agency.

Section 305 gives the President power to assign radio frequencies to Federal Government users. This is a power vital to national defense and security. Under the growing use of international telecommunications for international information, the power to assign space in a most important medium for disseminating such information is increasingly vital to peace, security, welfare, and prosperity. Radio frequencies are vital to the development of aviation. Radio frequencies are playing a larger part than ever before in domestic security and law enforcement measures. Because of these developments, problems of priorities of claims on the spectrum are keener than ever before within the Federal Government itself. A continuing agency, with real power to assign and review assignments of frequencies to Government users, is needed to set Government policies and to supervise the work of IRAC in carrying them out.

In World War II, Government powers for taking private communications resources for public purposes in time of emergency and war were exercised by an ad hoc agency. This solution is a wise one for periods in which world wars and international crises are far apart. It is hardly prudent in a period of constantly recurring crises with the ever-present possibility of world conflagration. We are now in a period of national emergency, which may become even more serious. Plans should be made promptly to see that the nation's communications resources are put to their best use to meet any emergency in an orderly way. These plans must consider the net benefit to the nation of leaving communications wholly or partly in private hands. During emergency or war, there should be constant attention to the best combination of governmental and non-governmental operation of the nation's telecommunications.

Needless to say, the exercise of the President's power under Section 606 calls for advance planning. Obviously no board or single person, assisted by a small staff, can do this job alone. Several existing agencies are charged with related responsibilities and it will be necessary for the new agency to enlist their cooperation. The Department of Defense and its components, the Department of State, and the FCC must be called on; there must also be close working with such agencies as the National Security Resources Board and the Office of Defense Mobilization. The new agency may have to avail itself promptly of its recommended power to set up advisory or other working groups to cope with its responsibilities under Section 606.

The role of the new Board in stimulating and correlating the formulation and publication of plans and policies by existing agencies is of great importance. Our own work has been hampered by the lack of comprehensive, correlated, and readily available statements of telecommunications policy. We have encountered examples of the failure of existing policy machinery to meet the requirements of international negotiations or of other Government action.

Yet the answer to this lack is not to create an agency specialized to deal with telecommunications policy formulation. Telecommunications policy must be integrated with policies and programs for the full range of Government and national activities. If it is elaborated in isolation, it is almost sure to be incomprehensive or faulty, and will require reconsideration by other agencies in order to be correlated with other policies and programs.

Our solution leaves the main responsibility for the elaboration of telecommunications policy with existing Government agencies which already must relate telecommunications to other functions for which they are responsible. The new agency will provide a point for stimulus and correlation which we do not think has been satisfactorily provided in the past by the Telecommunications Coordinating Committee. Since the new Board is also given responsibility for weighty functions in the telecommunications field, we prevent a divorce of policy formulation from operating responsibility.

Our solution implies the following corollary: Existing Government departments and agencies which participate in this policy-formulating process must markedly strengthen their units for carrying out policy formulation in the telecommunications field, and in adjusting telecommunications policy to related policy.

The Telecommunications Advisory Board has been designed to facilitate formulation of policy helpful in international negotiation. If it is to function effectively for this purpose, it is imperative that the Department of State shall have a strong telecommunications staff, and our plan is predicated on the assumption that such a staff will be maintained and available.

In approving and promulgating engineering standards for allocations and assignments to Government users, the agency should direct major attention to setting up standards which will make it possible for the Government to meet its telecommunications needs with a minimum use of spectrum space. The new agency should have several highly qualified engineers on its staff who will work with engineers already employed by other Government agencies, toward the end that operating equipment and practices be as efficient and economical as possible.

It is highly important to concentrate upon adequate standards relating to efficiency and stability of equipment, minimum separation of frequency assignments, and sound circuit engineering which relates the load to the band width and number of frequencies necessary to do the work, if maximum use of the spectrum is to be achieved under standards of minimum harmful interference.

Our suggestion that the agency should provide for adequate initial justification and review of frequency assignments to Government agencies is designed to correct a basic fault in the present situation: protection to first-comers irrespective of the relative needs of conflicting claimants later on, which results in premature requests for frequencies. While many factors in the present situation temper the potential evils of our present system of assignment to Government users, we are not convinced that the present system can yield as good results as the country should have. All Federal requests for frequencies should go to IRAC in the first instance, where they should be screened for conformity to current policies and for potential interference. Where IRAC cannot act, conflicts should be carried to the new agency. One of the most difficult problems under this system will be to prevent IRAC from failing to settle anything and referring every problem to higher authority. Every encouragement should be given to IRAC to settle problems itself. This calls for firm leadership.

We have suggested the new Board maintain such records of U. S. frequency assignments as it deems necessary. IRAC now keeps reasonably complete records of Federal assignments; the FCC, of non-Federal ones. However, there is no one central place where a complete list now exists. While the new agency should not maintain more in the way of records than it needs for its own purposes, it should take strong steps to see to it that somewhere in the Government a comprehensive and current record of U. S. assignments is maintained. The FCC is the most logical place for this. If lack of funds or staff block achievement of this purpose, Congress should provide the remedy.

We wish strongly to stress the need for more intensive and comprehensive research on problems of radio propagation and frequency utilization. In the recent past, critical decisions about use of the spectrum, including geographical and frequency separation of stations, have had to be made in the absence of sufficient scientific data.

The Board should not itself engage in research; indeed there is no necessity for it to contemplate such a role. The newly established National Science Foundation, whose principal concern will be the fostering of basic research, provides one avenue for the Board's support of projects in this field. The Research and Development Board in the Department of Defense, moreover, is in a position to deal with problems closely related to telecommunications.

At the beginning, the agency should try to improve the coverage of research on pressing problems by suggesting research projects to agencies already equipped to conduct them. Such projects should include research on propagation in particular sets of conditions, and for particular bands of the radio spectrum. The Board should be represented in the Executive Council of the Central Radio Propagation Laboratory. If stimulation in the form of funds is needed, the agency should encourage an existing Government department to seek such funds and to allocate them or expand them as executive agent for the particular research envisaged.

If the Board is properly to advise the President, it should also conduct and stimulate other studies pertinent to the various phases of its mission.

There is also a continuing task of considering basic Government policies for the handling of the Government's business with privately owned communications companies. This is not a regulatory matter appropriate for the FCC, although it has important implications for regulatory decisions. Government traffic is proportionately so large a part—and promises to become an even larger part—of private communications business that its terms and conditions can affect the health, the scope, and the serviceability of private communications companies. This task involves questions of Government economy, of efficiency and promptness of telecommunications service, of the impact of future telecommunications capabilities for defense and for economic progress; it is thus a continuing question appropriate for the new Board.

The General Services Administration deals on a day-to-day basis with these questions of telecommunications management. It is our opinion that GSA should turn to the Telecommunications Advisory Board in the first instance for the determination of those issues of high policy relevant to the discharge of GSA's telecommunications management responsibilities.

Inherent in our concept of the Board and its duties is the conviction that the Government has a responsibility to preserve the present free enterprise status of the telecommunications industry.

The Board should be authorized to create, if necessary, and to utilize such exiting panels, advisory groups, working committees, and ad hoc working parties as are required to carry out its responsibilities. It should use, where feasible, the personnel and services of existing departments and agencies of the Federal Government, and of state and local governments on a reimbursable or other mutually agreeable basis.

Only thus can the Board take full advantage of existing resources in knowledge, skills, and people, and itself remain a small organization.

While the agency should be small, we recognize that it may have to take on certain operating functions necessary to the full completion of its major missions. We recommend it be flexibly constructed so it can do so if necessary.

* * * * * *

It should be clear from the foregoing that it is our intention that the new Board should not supplant or encroach upon the responsibilities of existing Government agencies. We do not wish to lessen the normal responsibilities of the Department of State in the field of foreign affairs; we wish to facilitate the formulation of national telecommunications policies on which policies and positions for telecommunications negotiations can be based, and thus to fill a gap which the Department has had increasing difficulty in closing.

* * * * * *

Federal Communications Commission. Our desire is to make the tasks of the Federal Communications Commission more manageable and to take full advantage of its resources. As an independent regulatory agency, the Commission bears major responsibility for assuring to private persons full consideration of their rights, interests, and claims in telecommunications matters. The courts see to it that this is done. Nothing we propose will infringe on the Commission's powers to assure such procedural protection. The Commission should remain in this role. Because of the burden thus placed on the Commission, especially the Commissioners themselves, we have thought it prudent to supplement the Government's machinery for arriving at comprehensive telecommunications policy.

It is neither appropriate nor desirable to try to put the FCC in a position to tell executive agencies what are the most important uses of the radio spectrum. Nor would it be proper for executive agencies to decide for the Commission how to carry out its regulatory and policy responsibilities under the law. We know of no neat solution to this governmental dilemma. We see no reason to reorganize the regulation of privately owned communications carriers, placing it under the President. The good sense and accommodation which have marked legislative-executive relations in this field in the past can be expected to continue.

* * * * * *

If the new Board is to work harmoniously with the Telecommunications Coordinating Committee and the Interdepartment Radio Advisory Committee, these latter organizations need to be strengthened.

The particular changes required are discussed in the paragraphs that follow.

The Telecommunications Coordinating Committee. The Telecommunications Coordinating Committee should work out for itself clarified terms of reference; it should also be authorized to establish necessary subcommittees and special working groups, and be equipped with an adequate secretariat.

This Committee should remain an advisory and coordinating body. It should be a forum in which Government agencies possessing substantial responsibilities or interests in the telecommunications field can meet in an attempt to work out a coordinated policy in telecommunications matters arising out of those responsibilities. In case of agreement, each agency affected can take administrative action within its own established powers to put agreed decisions into effect. In case of disagreement, the matter involved can be promptly referred to the new Board for consideration of the reasons for disagreement and for evaluation of the probable consequences for the nation of following alternative courses of action. Thus, in effect, the Committee would be a means for taking the first important steps toward the formulation of a comprehensive telecommunications policy; it would uncover areas of agreement and disagreement, permit action in case of the former, and point up policy choices in case of the latter. The rule of unaniminity would no longer block action, since participating agencies could always act by reporting their differences.

It is recommended that the level of membership be determined through the appointments by the heads of those agencies to be represented on TCC. The present membership is supposed to be of the Under or Assistant Secretary level, but it is well known that these officials rarely attend. One reason for this is the fact that rarely if ever have problems been well enough prepared so persons of this level can deal with them expeditiously. Technical issues have not been well enough translated into policy choices. TCC has failed as a top policy organization because of its lack of substructure.

Level of membership should be left flexible, and agency representatives should be as high as necessary to deal with the particular policy issues under consideration. The Committee needs a competent

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and energetic full-time Executive Secretary as well as the power to create whatever working committees it requires to deal with special fields or non-recurring problems. With such resources, the Committee should be able to solve many interagency problems at the working level, and to reserve for higher officials the consideration of policy choices which could not or should not be resolved by specialists.

The TCC should consider carefully the merits of associating industry representatives with its subcommittees as observers. The Air Coordinating Committee has done so with marked benefits. The Telecommunications Policy Staff in the Department of State should continue to call on industry advisers to help in preparation of positions for international conferences. The Federal Communications Commission should continue to carry the main load of industry relationships. Other Government departments should continue or increase their efforts, where appropriate, to base their particular planning and operating responsibilities on sound industry relationships.

As suggested above, the top responsibility for systematizing and recommending Federal Government frequency-assignment policies should rest with the new Board; the Telecommunications Coordinating Committee should serve as the forum in which spokesmen for Government agencies meet to lay out the existing pattern of views. If TCC is to do this job completely, it must include within its membership or afford rights of representation to all Federal agencies with substantial interests in telecommunications.

The Interdepartment Radio Advisory Committee. The Interdepartment Radio Advisory Committee should be continued as a specialized working body to assign frequencies to Government users under policies promulgated by the new agency. Frequency-assignment priorities have been generated in IRAC by the stream of day-to-day decisions. We think that this process should be replaced by conscious policy consideration at the appropriate policy level.

IRAC recommendations for assignments of frequencies by Executive Order should be transmitted to the new telecommunications Board, and IRAC should keep the Board informed as to interim assignments. IRAC should take on the new task of periodic review of assignments to Government agencies, and should hear in the first instance justifications of agency requests to retain assignments already made. These tasks are considerably larger than those IRAC now carries; representatives of agencies composing IRAC may have to devote most or all of their time to IRAC business. The new agency should spotcheck IRAC assignments to determine compliance with presidential policy. IRAC should be kept flexible to participate as technical adviser to the various Government agencies in the formulation of Government telecommunications policies and positions.

IRAC's membership should include as a matter of course every Federal agency which is a substantial user and operator of radio communications.

Chapter VI

TOWARD A NATIONAL POLICY

In our study of existing telecommunications policy, we find little to go on. Extant policy is meager, and varies from self-evident generalities about very broad issues to filigreed treatment of highly specialized detail. The policy statements in this Chapter have been assembled by the Board in the course of its work. They include:

(1) statements of published policy drawn from treaties, laws, and expressions by committees or other groups dealing with telecommunications, which are enclosed in quotation marks;

(2) statements of commonly accepted policy, not hitherto formally expressed, which are indicated by *italics;* and

(3) statements of newly formulated suggested policy, which are presented in Roman type without special indication.

We have arranged this material in a logical order to produce an integrated statement of general policy and specific policy actions. As far as possible, the Chapter has been circulated informally to interested organizations in the United States for comments and suggestions, many of which have led to improvements.

The time available to the Board did not allow us to obtain judgments and observations on all phases of the subject; nor could we pursue the ramifications of telecommunications policy into related policy for other fields. Hence this compilation is not considered as conclusive or binding, nor in itself sufficient for guidance in telecommunication activities. Rather, it is regarded as a starting point from which national telecommunications policy can be further developed.

The concept is not new; it has proved its value to the establishment of efficient national procedures in comparable fields. For example, "A Statement of Certain Policies of the Executive Branch of the Government in the General Field of Aviation," prepared for the

President by the Air Coordinating Committee in 1947, is a valuable document setting forth policies essential to the advancement of United States aviation.

In the preparation of this effort at a kindred statement regarding United States telecommunications, their relationship to the national defense and security and to the national welfare and prosperity has been taken into account. Telecommunications are here considered to relate to national defense as part of the resources which the nation uses in combating hostile armed forces; to national security as part of the organized effort to maintain the national strength and to safeguard the nation against harmful influences, internal or external; to national welfare as they are used for the growth of national enlightenment and health; and to national prosperity as they aid in the growth of trade, in the production effort of the nation, and in the resultant enhancement of the nation's influence in world affairs. These relationships, taken as a whole, constitute the national interest.

I. GENERAL TELECOMMUNICATIONS POLICY

A. Public Communications—Purpose

There shall be "available, so far as possible, to all the people of the United States a rapid, efficient, nation-wide and world-wide wire and radio communication service with adequate facilities at reasonable charges. . . ."

B. Public Communications—Policy

1. The radio frequency spectrum is a world resource in the public domain. Our Government must adopt policies and measures to insure that this resource is used in the best interests of the nation, with due regard to the needs and rights of other nations.

2. The United States, almost alone among the nations of the world, relies on privately owned telecommunications companies to play the principal part in the country's telecommunications system. It should continue to be the policy of the United States Government to encourage and promote the health of the privately owned companies as a vital national asset.

3. The United States telecommunications system is essential to the national security, to international relations, and to the business, social, educational, and political life of the country. Hence Government must remain alert to the problems of this system, and be prepared to support measures necessary to insure the continued strength of the telecommunications system as a whole.

C. National Defense

In time of war or national emergency, as proclaimed by the President, the Government of the United States shall have available to it the total telecommunications resources of the nation for utilization with due regard to the extent of the war or emergency and to the continuing operation of services considered to be essential or desirable for the welfare and interests of the United States during such a time.

D. Safety at Sea

"The national security, the nation's sea commerce, and the assurance of adequate safety of life and property at sea require an efficient, integrated, standardized system of radio and electronic aids for marine navigation. . . .

"In consequence, it is vital to the national interest that the United States play a leading role in the development, investigation, selection and standardization of a world-wide system for marine navigation. . . . at the earliest practicable moment consistent with open-mindedness and sound technical judgment directed toward the attainment of optimum results, with due consideration for the cost to ship operators being kept as low as possible. . . .

"To simplify standardization, to effect the greatest economy in operation and to further the most economical use of the radio spectrum, the joint use of radio aids by both air and sea craft is. . . . advocated where mutually advantageous." (See Appendix II.)

E. Safety in the Air

The nation's air travel and the assurance of safety of life and property in flight require an efficient, integrated, standardized system *of radio and electronic aids to long-distance air navigation; therefore* "The United States will support and promote a single system of electronic long-distance aids to (air) navigation for United States and world-wide standardization. . . .

"The United States will take the necessary steps to obtain and maintain at all times the qualitative and quantitative data by which the choice of electronic long-distance aids to navigation can be determined and furthered internationally." (See Appendix III.)

F. International Communications

1. The United States considers the International Telecommunications Union to be the competent and appropriate international forum for the purpose of negotiating worldwide agreements on telecommunication matters.

2. The United States should be appropriately represented at any international telecommunications conference when such a conference is considered to be related, directly or indirectly, to the national defense, security, welfare, or prosperity.

3. The United States should foster and encourage the participation, for the purpose of providing advice and information, of experts from its commercial communications enterprises in the work preparatory to and at telecommunications conferences which involve the commercial communications interests of the United States.

4. The fact that both cable and radio facilities are required by the United States for its overseas telecommunications system shall guide consideration of any material matters which affect the availability, in the form of continued operation, of either medium.

II. SPECIFIC POLICY ACTIONS

A. Radio Frequencies

1. *The United States considers that a basic guide to follow in the normal assignment of radio frequencies for transmission purposes is the avoidance of harmful interference.*

2. *Long-range radio frequencies for other than overseas circuits normally shall be used only when other forms of communication, notably wire communication, are not adequate.*

3. *Priorities in the normal peacetime assignment of radio frequencies shall be as follows in the order named:*

(*a*) *Frequencies used predominantly, primarily, and directly for national security and defense, which means that such frequencies are used for purposes which are vital to the safety of the nation.*

(*b*) *Frequencies used primarily, predominantly, and directly to safeguard life and property in conditions of distress.*

(*c*) *Frequencies used in services that have no other adequate means of rapid communication, when such communication is considered to be necessary or desirable in the national interest.*

(*d*) *Frequencies used for all other purposes, the assignment of which must be judged upon the merits of individual need.*

B. Radio Spectrum Utilization

1. *In view of the limitations of the usable radio spectrum, and to insure the best possible return from the use thereof, it is in the best interests of the United States in time of peace to require all of its users to:*

(*a*) *Justify, in a satisfactory and equitable manner, any except an emergency request for radio frequencies prior to the assignment of such frequencies, and*

(*b*) *Confirm periodically, in terms of pre-determined standards, that the use of a frequency since its latest assignment, justified the assignment, and*

(*c*) *Submit evidence to indicate whether the continued assignment of a frequency is necessary.*

It will further be in the best interests of the United States, in consideration of (*a*), (*b*) *and* (*c*) *heretofore* (*among other considerations*) *to decide by high-level impartial determination, the disposition of any frequency or frequencies not assigned or re-assigned to a claimant user.*

2. Common standards of performance and efficiency of radio spectrum utilization shall be developed and applied to each type of radio operation. All users of the radio spectrum shall be required to adhere to these standards.

C. Miscellaneous

Fixed Service

1. Frequency-conserving techniques shall be applied whenever practicable in radio operations and particularly in the operation of point-to-point radio circuits. These techniques include such developments as single sideband operation and frequency-shift keying.

Aeronautical

1. Public correspondence shall not be transmitted on frequencies exclusively allocated to the aeronautical mobile service.

2. The United States supports a system of radio communication between aircraft and the stations of Maritime Mobile Service, which provides a means for the exchange of public correspondence between aircraft in flight and the general public on a worldwide basis, and enhances safety.

Maritime

1. Use of the distress frequency of 500 kilocycles, as prescribed by the current International Radio Regulations, shall continue to be the means primarily employed to summon assistance or to safeguard life and property on the high seas.

Amateur

1. The Amateur Service shall be fostered and encouraged because the immediate availability to all world areas of the Amateur Services' frequencies and the amateurs who utilize them is vital during times of emergency, whether such emergency be of a localized nature or national in scope.

2. The United States considers its own Amateur Service to be vitally necessary to the national defense and security because it provides a pool of personnel trained in the techniques of telecommunications, including skilled operators.

Telegraph

1. The Government of the United States should operate domestic communication circuits as it considers necessary for the conduct of Federal Government business; further, such domestic communication circuits shall be available for any Federal Government use if such use *is considered to be practicable and to afford economy; provided, that such domestic circuits operated by the Federal Government be leased or rented, whenever possible or practicable, from the commercial communications companies. The Government should not, in general, install its own domestic circuits wherever adequate and efficient facilities may be economically leased or rented from commercial sources.*

2. *The United States subscribes to the standardization of the 5-unit code of International Telegraph Alphabet Number Two.*

3. *The United States advocates the elimination of special rates for Government telegrams in the International Service.*

Appendix I

STATEMENT BY THE DEPARTMENT OF DEFENSE OF MILITARY DEPENDENCE ON THE DOMESTIC (COMMERCIAL) COMMUNICATIONS FACILITIES OF THE UNITED STATES

1. *General.* The nerve system of National Defense is the sum total of all communications systems that are available, operationally and potentially, for the prosecution of any emergency or war effort. The operational existence of nation-wide systems of rapid voice and record communications in peacetime is indispensable from the standpoint of meeting the wartime requirements of both the Military Services and the civil economy. As the intensity and complexity of warfare continues to increase, correspondingly greater demands will be placed on the communications systems of the nation from the standpoint of both circuit capacity and flexibility of operation. It is, therefore, considered in the vital interest of National Defense that there be maintained within the United States to meet that need, as many nation-wide commercial communications systems as are economically feasible.

2. *Military Policy Regarding Use of Commercial Facilities.* It is impracticable to employ similar concepts and standards in assessing military and commercial communications requirements. In the development of commercial facilities, expected revenue must of natural consequence be a prime consideration. Military communications, on the other hand, as an essential element of command must first satisfy military needs with economy of force or funds an important but secondary consideration. As a result of this fundamental difference, it is impossible for the Military to enunciate a policy which will under all conditions prescribe the specific degree to which it will utilize or depend on commercial communications facilities. It is incumbent on all military commanders, in compliance with the basic principle of economy of force, to make maximum possible use of all existing facilities available to them including commercial service. Before reaching a decision to employ other than strictly military facilities, each commander based on the conditions prevailing in his area must weigh any advantages from the standpoint of economy against the resulting effect on military security and control, dependability of service and the rapid flow of military messages. As general policy, therefore, it may be stated that the Military Services will, whenever practicable, utilize commercial

facilities and service in the interest of economy of force or funds provided that acceptable military standards of security, control, and service can be maintained.

3. *Military Use of Commercial Facilities in the Zone of the Interior.* During the early period in the development of national communications systems, it was necessary for the Military Services to construct and operate their own communications facilities in the Zone of the Interior. Today, however, extensive, dependable commercial communications networks cover the length and breadth of the United States. From the standpoint of security, the risk normally involved in partial military control of its communications has been considered as being relatively low within the continental United States. This condition is a result of the close working relationship that exists between the Military Services and the commercial communication organizations and the existence of adequate legislation to permit prompt government operation and control if deemed advisable in the national interest.

Under these conditions, the construction and maintenance of completely separate communications systems within the United States for exclusive military use would entail an unjustifiable outlay of funds, manpower, and equipment. Military policy concerning use of commercial communications facilities in the Zone of the Interior may, therefore, be summarized as follows:

> "Within the continental limits of the United States, the Military Services, in establishing communications networks for the purpose of interconnecting their various headquarters, installations and activities, will, by lease or other contractual arrangement, utilize commercial facilities and services when available and feasible except where unusual security or operational conditions are required. The terminal facilities including communications centers and relay stations of these networks will be operated and controlled by the Military Services."

4. *The Commercial Communications Networks as a Source of Trained Personnel for Military Service.* The Military Services can maintain in peacetime only the nucleus of a wartime communications system. It is also well established that the impact of a state of war or national emergency on military communications systems is instantaneous and can only be met through immediate expansion of both trunk and terminal facilities.

Modern communications facilities while extremely efficient require a comparatively long lead time in the training of operator and maintenance personnel. Hence in the critical period between the outbreak of hostilities and the time when military training programs can meet over-all demands, the commercial systems of the United States represent an important source of additional trained communications personnel for military service.

In this connection, it is the policy of the Military Services to maintain a close working relationship with the commercial communications companies of the nation in order that anticipated wartime military requirements may be reflected in peacetime expansion and training programs and to the end that emergency military needs for trained communications personnel may be met and with minimum effect on the continued operation of vital domestic communications facilities. Further, to facilitate the transition of commercial communications personnel from civilian to military operation, it is the policy of the Military Services to utilize fixed communicatons equipment of standard commercial design to the maximum possible extent and to prescribe similar operational and maintenance techniques.

5. *Trends in Military Use of U. S. Domestic Communications Facilities.* The Military Services do not foresee the necessity for any material change in current policy concerning their use of commercial facilities within the Zone of the Interior. In both peace and war, these facilities have proven to be operationally reliable and fully responsive to military requirements. This, in effect, means that for continuous, effective coordination of military operations within the United States, the Military Services will remain largely dependent on the commercial communications systems of the nation. Hence, while not being in a position to pass judgment on measures designed to improve the economic well-being of the commercial companies, the Military Services will have a vital interest in any changes which might adversely affect the capacity and operational efficiency of the commercial systems.

The advent of long-range, highly destructive warfare, including intensive infiltration by subversive elements, will require greatly increased defensive measures on the part of both military and civilian agencies. The impact of this increase on the domestic communications facilities of the nation has not been fully determined, but may reasonably be expected to be of considerable proportion.

Instrumentalities now exist which provide that in time of war or national emergency, the total telecommunications resources of the nation can be placed at the disposal of the government. The Military Services are mindful, however, that any successful prosecution of a war effort will require that all agencies contributing to this effort be afforded use of these facilities on a just and equitable basis, and in addition, must insure reasonable safety, comfort, and security for the civilian populace. To this end, the Military Services believe that the domestic communications systems of the United States should be as efficient and dependable as sound engineering, reasonable economy and good operating practices will allow, and that their capacity should reflect not only the ability to handle greatly increased wartime volumes, but maximum flexibility in terms of as many alternate routings and types of facilities as can be had consistent with the ability of the commercial companies to realize a reasonable profit from their investments.

Appendix II

UNITED STATES POLICY FOR RADIO AND ELECTRONIC AIDS FOR MARINE NAVIGATION*

The national security, the nation's sea commerce, and the assurance of adequate safety of life and property at sea require an efficient, integrated, standardized system of radio and electronic aids for marine navigation.

A multiplicity of new radio and electronic devices and systems possessing potential applicability for marine navigation have been developed during recent years, both at home and abroad. In fact, the devices and systems which have been developed and made potentially available as aids to navigation are so numerous that standardization is mandatory if the encouragement and development of United States sea commerce is to take place economically and realistically.

In consequence, it is vital to the national interest that the United States play a leading role in the development, investigation, selection and standardization of a worldwide system for marine navigation. This role should be played at the earliest practicable moment consistent with open-mindedness and sound technical judgment directed toward the attainment of optimum results, with due consideration for the cost to ship operators being kept as low as practicable.

An open-minded attitude shall be maintained toward novel systems and devices which eventually may develop to be superior to existing systems. This attitude, however, shall not be permitted to retard the adoption of a world system based on systems already proved and in wide use over a large part of the world's waterways.

To simplify standardization, to effect the greatest economy in operation and to further the most economical use of the radio spectrum, the joint use of radio aids by both air and sea craft is hereby advocated where mutually advantageous.

The policy contained herein is applicable for domestic guidance as well as for use as a basis for international discussions on standardization of devices, systems and performance.

For the present and at least the immediate future the following devices and systems are advocated as being practicable.

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*Approved by TCC (Document No. 112) September 4, 1946.

I. Navigation

A. *Anti-Collision*

The use of radar shall be encouraged in order to enhance safe and economical operation primarily to reduce the risk of collision.

B. *Position Fixing*

1. *Distances over 50 miles.*

(Aid to ocean navigation requiring accuracy of 1% and allowing 15 minutes to obtain position fix.)

(*a*) Loran—This system shall be continued, improved and expanded.

(*b*) Shipboard MF/DF with radiobeacons (useful up to 200 miles). This system shall be continued; improved and expanded.

2. *Distances between 50 and 3 miles.*

(Aid to approaching land, coastal navigation and port approach requiring one-half mile to 200 yards accuracy and allowing 5 minutes to one-half minute respectively to obtain position fix.)

(*a*) Shipboard MF/DF with radiobeacons. This system shall be continued, improved and expanded.

(*b*) Shipboard radars. Their use shall be encouraged and the devices shall be improved.

(*c*) Radar aids, both active and passive. They are necessary for the special marking of navigational aids, dangers and shore features, to facilitate identification by radar. Their further development for purposes of operational evaluation should be continued.

3. *Distances less than 3 miles.*

(Aid to harbor entrance requiring 50 yards accuracy and instantaneous position and track fixing.)

(*a*) Shipboard radars (high resolution). Their use should be encouraged and the devices shall be improved.

(*b*) Radar aids, both active and passive. They are necessary for the special marking of navigational aids, dangers and shore features, to facilitate identification by radar. Their further development for purposes of operational evaluation should be continued.

(c) Shipboard MF/DF with radiobeacons. This system shall be continued, improved and expanded.

II. Harbor Control and Harbor Communication

A. *Harbor Control Radar.*

This service shall be provided as required.

B. *Harbor Control Communications.*

VHF radiotelephone channels for harbor control purposes shall be provided. The channels and modulation should be standardized internationally.

III. Frequencies

The United States shall advocate the international standardization of frequency allocations for use or operational evaluation with respect to the above devices and systems.

It is believed that the frequency allocations recommended to the Department of State by the Interdepartment Radio Advisory Committee and the Federal Communications Commission will meet the operational and technical requirements of the radio navigational devices and systems herein designated. These are as follows:

A. Shipboard Radar:	3000 to 3246 Mc
	5460 to 5650 Mc
	9320 to 9500 Mc
B. Radar Beacons:	3256 Mcs ±10 Mc
	5450 Mcs ±10 Mc
	9310 Mcs ±10 Mc
C. Loran:	1800 to 2000 kc
D. LF/MF Radiobeacons	280 to 320 kc
E. Harbor Control Communications in the Band:	152 to 162 Mc

Appendix III

UNITED STATES NATIONAL POLICY ON ELECTRONIC LONG-DISTANCE AIDS TO NAVIGATION*

POLICY

1. The policy of the United States in respect to electronic long-distance aids to navigation is as follows:

a. The United States will support and promote a single system of electronic long-distance aids to navigation for United States and worldwide standardization.

b. At the present time the aids which the United States has adopted and now supports and promotes are Loran and high-power LF/MF Non-Directional Beacons in that order of preference.

(1) "Loran" is considered as one type of aid regardless of the frequency employed.

(2) Loran will be continued, improved, and expanded to provide needed coverage. The choice of a frequency for Loran installations in any particular area will be governed by the requirements to be met and the frequencies available in that area.

(3) Wherever it is technically, economically or operationally desirable, the United States supports LF/MF Non-Directional Beacons of sufficient power to meet requirements in a specific area.

(4) Recognizing the special recommendations set forth in Attachment A of the draft document, "Annex 10 to the Convention of International Civil Aviation," during the interim period the continued use or extension of other systems will not be acceptable if such system or systems require airborne or shipborne equipment in excess of, or different from, that required for the use of Loran or LF/MF Non-Directional Beacons.

c. The United States will take the necessary steps to obtain and maintain at all times the qualitative and quantitative data by which the choice of elecronic long-distance aids to navigation can be determined and furthered internationally.

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*Approved by TCC (Document No. 557), January 31, 1950.
Approved by ACC (Document No. 58/5D), April 19, 1950.

Appendix IV

REFERENCE SHEET

I. General Telecommunications Policy

A. Public Communications—Purpose	Communications Act of 1934
B. Public Communications—Policy	New
C. National Defense	Executive Order #8546, dated September 24, 1940, defining functions and duties of Defense Communications Board
D. Safety at Sea	United States Policy for Radio and Electronic Aids for Marine Navigation, 1947
E. Safety in the Air	Air Coordinating Committee Document 58/5D, April 19, 1950
F. International Communications	Present practice

II. Specific Policy Actions

A. Radio Frequencies	1. Atlantic City Convention 2. IRAC Report to Subcommittee of the House Committee on Interstate and Foreign Commerce, 81st Congress, 2nd Session
B. Radio Spectrum Utilization	Proposed
C. Miscellaneous	
Fixed	Atlantic City Convention, Art. 42 Atlantic City Radio Regulations, Sections 396 and 398
Aeronautical	Atlantic City Radio Regulations, Article 27
Maritime	Atlantic City Radio Regulations, Articles 5 and 33
Amateur	Present Practice
Telegraph	U. S. proposals to International Telegraph and Telephone Conference, Paris, May–August, 1949, (Report of Chairman of U. S. Delegation, dated Oct. 31, 1949).

Appendix I. Military Statement re Domestic U. S. Communications, (Department of Defense)

Appendix II. "United States Policy for Radio and Electronic Aids for Marine Navigation." Prepared by an ad hoc committee headed by Admiral Merlin O'Neill, U. S. C. G., and representing all major U. S. maritime interests. Approved by the Telecommunications Coordinating Committee on September 4, 1946, TCC Document 112.

Appendix III. ACC-TCC Document on Electronic Long-Distance Aids to Navigation.

HISTORY AND ORGANIZATION

President's Communications Policy Board

Shortly after the appointment of the President's Communications Policy Board on February 17, 1950, the Chairman came to Washington to discuss plans and programs with officials in the Executive Office of the President.

On March 10, the Board held its first meeting in the offices of the Federal Communications Commission. Federal agencies concerned with telecommunications problems were represented. The meeting was devoted to a review of specific issues related to the Board's mission. At this meeting, the Signal Corps invited the Board to set up its offices in the Pentagon, and undertook to provide necessary administrative services. During the next month, the Board commenced organization of its staff.

The Board held 59 sessions. Procedure was informal and off the record. Much of the time in these sessions was spent in discussion and analysis of major telecommunications problems and policies with specially qualified people in Government, in industry, and in private life. This procedure enabled the Board to secure a maximum of pertinent data in minimum time.

The Board also requested and received formal statements on the issues before it from a large number of Government and private officials and experts. Members of the Board and its staff drew heavily on these and other sources on an informal basis as well.

A small and highly competent professional staff was set up to make detailed studies and analyses of telecommunications policies and problems.

The Board wishes to express its indebtedness to Charles A. H. Thomson, Staff Director and chief executive officer, for his effective management of the staff work of the Board. It also wishes to thank Fred C. Alexander, who ably organized and directed the technical studies, particularly on frequency utilization, which have contributed so much to the report.

Other senior members were William E. Plummer, William F. Minners, Ralph O. Smith, Ernest C. Shaffer, and John J. Keel. These senior members were assisted by Julia M. Gilbert and Charlotte Hazard. Margaret J. Myers and Doris Gates served as Secretary to the Board. Carol Ashworth, Robert J. Eames, and Betty T. Walters gave secretarial and clerical assistance.

F. G. Fassett, Jr., and Charles Schwarz gave special help in writing and editing the report.

All members of the Staff contributed time and energy beyond any normal call to duty, and in a very real sense shared in the work of the Board.

The Board contracted with Ford, Bacon and Davis, engineers, for a study of the economics of the record communications industry, and with Dr. Bonnar B. Brown of the Stanford Research Institute for special economic consulting service.

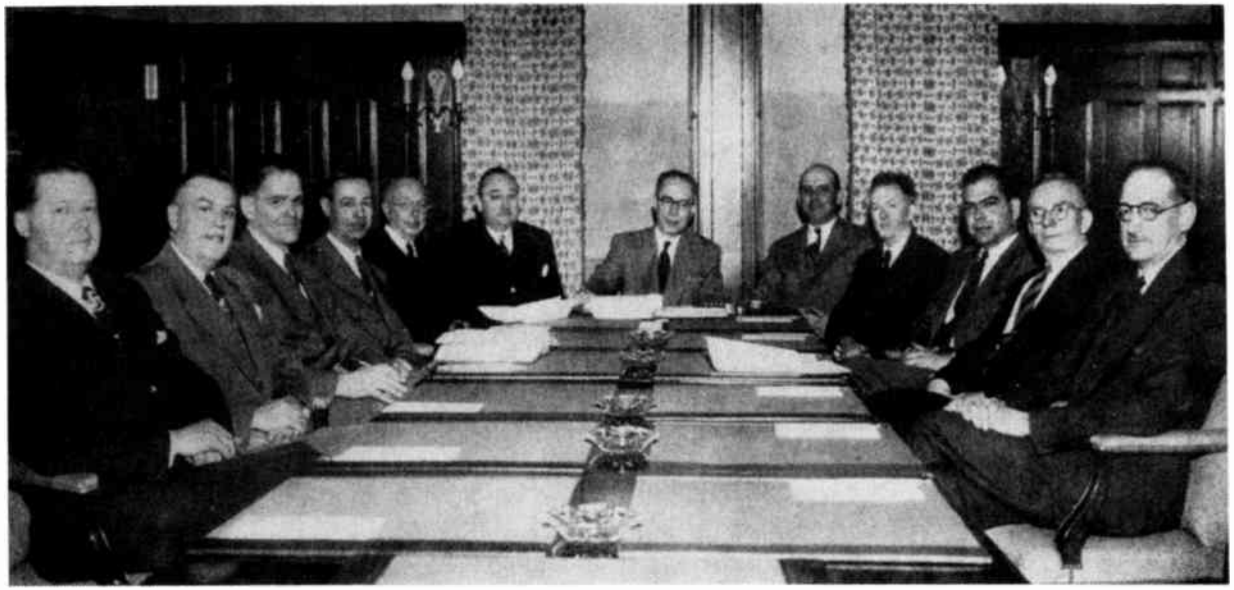
Many Government departments and agencies—in particular, the Federal Communications Commission, the Department of Defense, the Department of State, and the Department of Commerce—made available a large mass of detailed information about telecommunications operations and policies. The commercial communications companies also gave material assistance. These public and private organizations prepared special reports for the use of the Board which permitted a more comprehensive view of the telecommunications system of the country than had previously been possible.

Without this opportunity to tap special resources, the Board could not have, in the time available, covered the ground necessary to completion of its report.

ABBREVIATIONS

AACR	All America Cables & Radio, Inc.
AACS	Airways and Air Communications Service
A.C.&R.	American Cable and Radio Corporation
A.T.&T.	American Telephone and Telegraph Company
CAA	Civil Aeronautics Administration
CCB	Combined Communications Board
CCC	Commercial Cable Company
DF	Direction finder
EHF	Extremely high frequency
FAC	Frequency Allocation Committee
FCC	Federal Communications Commission
FM	Frequency modulation
GSA	General Services Administration
GW	Globe Wireless, Inc.
HF	High frequency
IFRB	International Frequency Registration Board
IRAC	Interdepartment Radio Advisory Committee
ITU	International Telecommunications Union
JCB	Joint Communications Board
JCEC	Joint Communications-Electronics Committee
kc	Kilocycle
LF	Low frequency
Mc	Megacycle
MF	Medium frequency
MRT	Mackay Radio and Telegraph Company
NTX	Naval Teletypewriter System
PFB	Provisional Frequency Bureau
PW	Press Wireless, Inc.
RCA	Radio Corporation of America
RCAC	RCA Communications, Inc.
RM	Radiomarine Corporation of America
SHF	Super high frequency
TCC	Telecommunications Coordinating Committee
TRT	Tropical Radio Telegraph Company
TWX	Teletypewriter Exchange Service
UHF	Ultra high frequency
VHF	Very high frequency
VLF	Very low frequency
WU	Western Union Telegraph Company
WUC	Western Union Cables

RADIO SPECTRUM CONSERVATION



The Joint Technical Advisory Committee (as of April 1952, reading from left to right): Laurence G. Cumming (non-member secretary); Ewell K. Jett (past member); Thomas T. Goldsmith, Jr.; Haraden Pratt (past member); John V. L. Hogan; Philip F. Siling; Ira J. Kaar (chairman); Donald G. Fink; Arthur V. Loughren; David B. Smith; Melville Eastham (past member); Ralph Bown (vice-chairman).

Radio Spectrum Conservation

A PROGRAM OF CONSERVATION
BASED ON PRESENT USES
AND FUTURE NEEDS

A Report of the

JOINT TECHNICAL ADVISORY COMMITTEE
IRE—RTMA

1952
NEW YORK TORONTO LONDON
McGraw-Hill Book Company, Inc.

RADIO SPECTRUM CONSERVATION

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PREFACE

The subject of this volume is one of far-reaching importance to society at large. Since its inception radio communication has been plagued by a shortage of space for ever-increasing numbers of stations and new services, from ship-to-shore "wireless" in 1902 to television in 1952. As new regions of the radio spectrum have been explored and opened to practical operations, commerce and industry have found more than enough new uses to crowd them.

As a result it has become increasingly clear that the spectrum is a public domain which must be conserved as carefully as if it were farm land, forest preserves, water power, or mineral wealth. The job of conservation has been complicated by the fact that wise administration by government, while essential, is not sufficient. Radio obeys the laws of nature, and its administration must proceed within the confines of scientific knowledge and procedures, some of which, such as the equations governing the propagation of radio waves over and above the earth, are as complicated as any that science has to offer.

Add to this the fact that radio transmissions, in one form or another, affect the life of nearly every inhabitant of the globe. Radio is essential to the safety of sea and air travel, carries a substantial portion of all information across international borders, makes the difference between winning a war or losing it, gives entertainment and, it is to be hoped, education to half the population of the world. Add these facts, and it is clear that this intangible public resource, the radio spectrum, requires wise and courageous conservation no less than its tangible brothers, oil, coal, copper, forests, and water power.

The purpose of this book is to review the properties of radio transmission, in language as simple as the subject allows, and to discern the course to be pursued in order to bring its benefits in maximum measure to the largest possible number of the world's people. It has been prepared under the auspices of the Joint Technical Advisory Committee (JTAC), a group of distinguished radio engineers who have, since 1948, performed numerous acts of public service, particularly as advisers to the Federal Communications Commission (FCC).

JTAC was formed in June, 1948, by joint action of the Boards of Directors of the Institute of Radio Engineers (IRE) and the Radio-Television Manufacturers Association (RTMA). Its purpose is to consult with government agencies and other professional and industrial groups, to determine what technical information is required to ensure the wise use and regulation of radio facilities, and to collect and disseminate such information. The present volume is the eighth in a series of reports prepared by the Committee which would, in the normal procedure, have been published in mimeographed form and distributed to several hundred interested individuals and agencies. However, the sponsoring organizations, IRE and RTMA, believing its content to be such as to warrant the widest possible distribution, have decided to underwrite its publication in book form.

According to the JTAC charter, its members are "chosen on the basis of professional standing, integrity and competence to deal with the problems to be considered." They are chosen from among qualified engineers, irrespective of the organizations with which they are associated, and they operate in a spirit of complete objectivity, without instruction from any person or organization. The roster of men who now serve, or have served, on the Committee is Ralph Bown, Melville Eastham, Donald G. Fink, Thomas T. Goldsmith, Jr., John V. L. Hogan, Ewell K. Jett, Ira J. Kaar, Arthur V. Loughren, Haraden Pratt, Philip L. Siling, and David B. Smith. Publication of this book was approved unanimously by these men, except Eastham, Jett, and Pratt, who were not members at the time the report was completed.

The actual preparation of the report was entrusted to a subcommittee of 3 JTAC members, 5 consultants, and 17 other contributors, whose names are listed in the Introduction of the report. The undersigned, in behalf of the organizations they represent, wish to express their deep appreciation of the effort expended by the members of the Committee and their colleagues.

W. R. G. Baker
DIRECTOR, ENGINEERING DEPARTMENT,
RADIO-TELEVISION MANUFACTURERS ASSOCIATION

Donald B. Sinclair
PRESIDENT, THE INSTITUTE OF RADIO ENGINEERS

New York, N. Y.
May, 1952

CONTENTS

INTRODUCTION

This report has been prepared in fulfillment of one of the primary objectives underlying the formation of the Joint Technical Advisory Committee: to analyze and evaluate the current uses of the radio spectrum and to formulate constructive suggestions for the future. All those concerned with radio engineering are aware of the congestion of the spectrum; those concerned with particular branches of the art know well the consistent shortage of channels that has plagued every form of radio, old as well as new, during the past quarter century.

The prospect of relief from this situation seems dim, in view of the ever-increasing use of established radio services and the regular development of new services whose values are such as to require admission to the spectrum. If radio science is to fulfill its destiny, if it is to meet the demands which the people of the world levy upon it, advantage must be taken of our great store of technical knowledge. In the public interest, the mistakes of the past must be recognized and corrected as rapidly as the administrative procedures now available will permit, and a sound doctrine for dealing with current and future problems must be devised and administered with courage and wisdom.

Commissioner George Sterling of the United States Federal Communications Commission has stated the need clearly in these terms: [1,*] "If we could devise a mechanism for tak-

* Numbered references appear under appropriate headings in the Bibliography.

ing a long-range view of the radio spectrum . . . in an atmosphere which gave full weight to the fact that the intensive use of radio as it exists today in 1951 is based upon only a half century of piecemeal development, I feel frankly confident that we could render a real service to those who will follow us in the next hundred years. The need for consideration to be given to this matter is apparent. It seems to me that all that remains is for us to find a way to give the matter the serious attention it deserves and to breathe life into it."

At its meeting on January 9, 1951, the members of the JTAC voted unanimously to undertake the preparation of this report and appointed a subcommittee to compile it. The subcommittee called upon a number of recognized authorities for information and assistance.

This report was prepared for the JTAC by a JTAC subcommittee consisting of Donald G. Fink, Chairman, Haraden Pratt, and Philip F. Siling, assisted by Dr. J. Howard Dellinger, Arthur F. Van Dyck, Trevor H. Clark, G. C. Southworth, and J. P. Veatch acting as consultants to the JTAC. Chapter 2, on propagation phenomena, was compiled by: Dr. J. Howard Dellinger, Sec. 2.1; Mrs. M. L. Phillips, Sec. 2.2; W. S. Duttera, Sec. 2.3; T. N. Gautier, Sec. 2.4; Dr. C. R. Burrows, Sec. 2.5; and Dr. G. C. Southworth, Sec 2.6. Contributions to the other parts of the report were supplied by Austin Bailey, T. L. Bartlett, I. F. Byrnes, A. J. Costigan, Harry Edwards, A. N. Goldsmith, R. F. Guy, John Huntoon, C. B. Jolliffe, J. H. Muller, D. E. Noble, F. M. Ryan, and Julius Weinberger.

The report is divided into five chapters and a Bibliography. The first is a historical survey which reviews the development of the radio spectrum from the first regular use of wireless telegraphy in 1898 to the present and outlines the activities of the international conferences which devised the present allocations. Chapter 2 consists of six sections which summarize the present state of knowledge of radio-wave propagation, in the regions 10 to 200 kc, 200 to 2,000 kc, 2 to 30 mc, 30 to 3,000 mc, and 3,000 to 300,000 mc.

Chapter 3 presents an ideal allocation table, based on a rational appraisal of the needs of the various services and the propagation characteristics described in Chap. 2. To arrive at this ideal proposal, assumptions are made which, if not justified in the light of current events, are nevertheless essential in considering an adequate long-range view. It is assumed that the world is at peace and that all the knowledge and experience we now possess are available to begin a new technically valid allocation without consideration of presently existing economic or political involvements.

Chapter 4 considers the actual allocation table of the present day, following the frequency divisions laid down in Chap. 2. This part of the report serves as a critique of present allocations in view of present knowledge, current trends, and present and prospective needs.

Chapter 5, entitled Dynamic Conservation of Spectrum Resources, contains specific suggestions for bringing the actual allocation more nearly in line with the ideal, including a doctrine of conservation sufficiently flexible to deal with future developments. Perforce, this part of the report deals with economic and political factors, as well as purely technical matters.

Following Chap. 5 is a comprehensive bibliography, including general references as well as specific items referred to elsewhere in the report.

SPECTRUM NOMENCLATURE

Frequency Range	*Designation*
Below 30 kc	Very low frequency (VLF)
30–300 kc	Low frequency (LF)
300–3,000 kc	Medium frequency (MF)
3–30 mc	High frequency (HF)
30–300 mc	Very high frequency (VHF)
300–3,000 mc	Ultra high frequency (UHF)
3,000–30,000 mc	Super high frequency (SHF)
30,000–300,000 mc	Extremely high frequency (EHF)

Chapter 1

HISTORY OF THE ALLOCATION OF THE RADIO SPECTRUM

1.1 THE PERIOD 1896–1906. FIRST AND SECOND INTERNATIONAL RADIOTELEGRAPH CONFERENCES

The first practical use of radio communication (wireless) was between ships and shore, following Marconi's first patent on wireless telegraphy in 1896 and the demonstration of his development to officials of the British Post Office in that year. The initial application for regular communication service came in 1898, when lifeboats were sent to aid in a marine disaster off the coast of England which had been reported by wireless telegraphy.

This new method of communication had become sufficiently important to the maritime service by 1902 to stimulate the seeking of an international understanding in order to facilitate the establishment of orderly operating procedure. In that year Prince Henry of Prussia attempted to send President Theodore Roosevelt a courtesy message while crossing the Atlantic after a visit to the United States (the ship at the time was out of range of United States stations but within range of an English station). He was refused service because the Marconi Company which operated the station would not deal with a ship station of its German competitor. The German Emperor, when informed of this, enlisted the aid of President Roosevelt in bringing about an international conference.

The conference was held in Berlin in 1903 to establish an arrangement which would prohibit shore radio stations from refusing messages from ships at sea. The final protocol, signed on August 13 by Great Britain, Austria-Hungary, France, Germany, Italy, Spain, Russia, and the United States, required that communication service with ships be provided regardless of the system used, and it specified certain operating rules and tariffs. Reservations were taken by Great Britain and Italy, which were the countries where Marconi was exploiting his system. The inability to agree upon a convention was attributed to opposition by his interests.

Another conference embracing a large number of countries met in Berlin in 1906. This meeting resulted in a convention and annexed regulations which went into force in 1908 except as to the United States, which did not ratify until 1912. This convention dealt only with the ship-to-shore service; it included provisions which had been prepared by the 1903 conference and, in addition, adopted rules relating to the radio frequencies to be used to permit two stations to establish communication with each other quickly. Three hundred meters (1,000 kc) and 600 meters (500 kc) were designated as common calling wavelengths. Designation of the latter frequency has survived to the present day, and it is still the most important calling frequency in this service.

The earliest equipment employed an antenna which was shock-excited into oscillation by a spark apparatus, thereby generating a radio-frequency current whose value was determined by the resonant frequency of this antenna system. Subsequent developments produced equipments which used a shock-excited local-resonating circuit coupled to the antenna. However, the state of the art for many years did not permit much divergence between the resonant frequency of the antenna and the frequency of operation. For these reasons the frequencies designated by the Berlin convention were primarily determined by the dimensions and configuration of the supporting antenna masts available on ships. In those days knowledge of propagation characteristics and signal-to-noise ratio data were rudimentary, bands of emission were wide, and the selectivity of the receivers was poor.

1.2 THE PERIOD 1907–1917. THIRD INTERNATIONAL RADIOTELEGRAPH CONFERENCE

Point-to-point communications developed next. At first, the same methods and frequency band were used as had become established for the ship-to-shore service. Long-distance point-to-point service first started about 1907. Antennas of larger dimensions were built to develop greater radiation effectiveness, and it was discovered that the resulting longer waves (lower frequencies) propagated over longer distances. The advent of continuous (undamped) waves subsequent to 1910 greatly stimulated the development of radio-communication systems and the accumulation of knowledge by making possible narrow-band emissions. This was followed by improved selectivity of reception, using the heterodyne principle with vacuum-tube receivers.

By 1917, sufficient reasonably precise propagation knowledge, within the then-developed band between about 20 to 1,500 kc, was on hand to enable the point-to-point services to organize their usage of frequencies in the interest of efficient propagation. Because the growth of such services did not then create troublesome interference and the ability of stations to contact each other universally was not then required, no need arose for general international understandings.

The ability of known transmitting systems to generate power was found to drop sharply at the higher frequencies. This fact, combined with the effects of absorption in the transmission medium, became very apparent near the 1,500-kc region and fixed the upper boundary of the developed part of the spectrum in the neighborhood of 1,500 kc. In fact, because frequencies above 1,500 kc were considered of little usefulness, amateur experimenters in the United States were required by law in 1912 to confine their operations to that region so that they would not occupy space in the already somewhat crowded usable spectrum.

The ship-to-shore service became so important in guarding safety of life at sea (as evidenced by the "Republic" and "Titanic" marine disasters) that the International Radiotelegraph Conference was called in London in 1912 to draft pertinent international regulations. These included provisions dealing with frequency utilization and led to a convention and regulations adhered to by the United States and many other nations but limited to the maritime mobile service. These regulations continued the basic concepts adopted at Berlin in 1906, not only because of the widespread established service using the frequencies agreed on at Berlin but also because the usable frequency band was still determined by the physical dimensions of ships. However, the frequency of 300 meters (1,000 kc) was given much less emphasis than that of 600 meters (500 kc). The former frequency had, from a practical standpoint, fallen into disuse.

The end of the decade saw the start of a ship-to-shore service for very long distances in the band 120 to 160 kc. This grew out of experience with point-to-point service using continuous waves and the efficiency of ship-to-shore service gained through freedom from interferences due to the improved selectivity of receivers using such waves.

1.3 THE PERIOD 1918–1927. THE FIRST UNITED STATES CONFERENCES AND THE FOURTH INTERNATIONAL RADIOTELEGRAPH CONFERENCE

The development of the vacuum tube and improved circuit arrangements not only led to transmitters and receivers capable of functioning at frequencies above those used previously but also made possible communication of voice and music through the process of modulation. These developments and the resulting radio-communication facilities were greatly advanced during the period of World War I and led to the Inter-Allied Radio Conference in August, 1919. This was the first occasion to consider the needs of services other than maritime mobile. While its protocol and annexes never came into force, they did provide assistance in the preparatory work for the next international conference.

Up to this time the use of frequency bands had developed on the basis of the exclusivity principle. The ship-to-shore service came first, and as the fixed services grew subsequently, they found other frequency bands. The 1919 conference recommended that the allocation of frequencies to radio services be discarded as a principle and that frequencies be allocated to countries. It is of interest that this proposal was dismissed and has never been made again. This conference defined a single wavelength as a band 1 per cent wide and established a "right of way in the ether" consisting of one or more single wavelengths. On its assigned wavelengths a country would have a firm right of use, including freedom from interference by other stations anywhere in the world.

The era of radio broadcasting began in 1922, followed by the rapid development of long-distance world-wide communications exploiting the band 2 to 25 mc. It had been discovered that sky-wave propagation existed in this region, enabling signals on these frequencies to travel long distances without encountering high levels of atmospheric noise.

The new broadcast service was not free to select frequencies that then seemed best suited for it, because these (300 to 550 kc) had already been preempted by the 24-year-old ship-to-shore service. Without the benefit of any carefully considered long-range planning, the new industry became established in what seemed the next best area, the band roughly 550 to 1500 kc. This selection was dictated partly by expediency, as technical difficulties and costs were less in this region than at frequencies below the ship-to-shore service.

The first serious conflict between services resulted from the pressure to secure frequency accommodations for broadcasting stations bordering on the upper edge of the ship band, where better transmission ranges were possible, whereas ships, due to the capital investment in the great number of installations, could not readily be moved to lower frequencies. In any event, such a move at that time would have involved loss of transmission efficiency because of the inflexibility of antenna dimensions.

The rapidly growing new services soon created chaotic radio-interference conditions. The United States found it necessary, after holding four governmentally sponsored domestic conferences (1922–1925), to provide first for licensing and later for regulation of radio-frequency usage by law, creating the Federal Radio Commission in 1927. The problems arising from the growth of the ship-to-shore service, particularly in the new and growing LF band, led to an informal regional understanding between agencies operating maritime mobile services called the North Atlantic Agreement (about 1927). Contemporaneous international growth generated frequency-allocation problems that precipitated the holding of the International Radiotelegraph Conference of Washington in October, 1927.

This conference was limited in basic planning not only by the ship-to-shore and broadcasting services already established but by the new ship services in the HF range that had already accommodated themselves in harmonically related bands near 4, 8, 12, and 16 mc and at about 22 mc and by the existence of many fixed service stations. This situation prevented the adoption of idealized allocations, and the sought-for principle of exclusive bands for each of the various services could not be fully applied. The future needs for frequency space to accommodate aviation and international communication were not adequately foreseen. The status of equipment development made it virtually impossible to exploit the region above 25 to 30 mc, and such data on propagation characteristics as were then available led to the conclusion that the useful upper spectrum limit for long-distance use was about 23 to 25 mc.

1.4 THE PERIOD 1928–1938. FIFTH AND SIXTH INTERNATIONAL CONFERENCES

A period of rapid growth of all existing services, both in extent and in technical perfection, the development of new services, and the opening up of new frequency bands in the region above 30 mc then followed. Navigational aids, aeronautical communications, land mobile, television, and FM broadcasting services came into being or were under development. Spark- and arc-transmission methods became obsolete.

Four meetings of the International Radio Consultative Committee (CCIR) to advance world-wide technical coordination were held during the period. New international agreements were made, resulting from telecommunication conferences held in Madrid in 1932 and in Cairo in 1938. These did not depart materially, except for upward extension, from the allocation provisions adopted at Washington in 1927.

The development of the region above 30 mc proceeded with an inadequate knowledge of propagation characteristics. Because equipment development at any given time imposed a practical upper useful frequency limit, services were forced to employ frequencies for which usable equipment could be made. During this early growth in these upper bands, the relative importances of various types of service could not be wholly foreseen and priority factors for them could not be established on a long-term basis.

The Cairo Conference for the first time recognized the communication needs for aviation along international routes and made allocations in the band 4 to 25 mc. Some general allocations above 30 mc were also blocked out.

In the United States the Federal Radio Commission was superseded by the Federal Communications Commission (FCC), which was given enlarged regulation powers by the Communications Act of 1934.

1.5 THE PERIOD 1939–1947. SEVENTH INTERNATIONAL CONFERENCE

Great technical advancements occurred during the ensuing years, spurred by the needs of World War II and by the commercial and industrial applications engendered by the tremendous developmental effort of the war. The emphasis was on navigational aids, the newly developed fields of radio location or radar, and the proximity fuse and other uses of frequencies up to 10,000 mc.

Large demands for radio frequencies in the HF band (4 to 27 mc) for aviation and broadcasting appeared during this period. High-frequency broadcasting was not limited to long-distance services but was also used for low-power local broadcasting in tropical regions, theoretically to overcome the high-level noise conditions prevalent in those areas on the lower-frequency bands. The resulting overcrowding of the HF broadcasting bands forced many countries to operate broadcasting stations outside the allocated bands. This use of high frequencies created interference problems at great distances, because of sky-wave propagation.

To use the high frequencies effectively, it became imperative to have day-to-day knowledge of radio propagation conditions. For this purpose the Inter-Services Ionosphere Bureau was established in England in 1938 and the Interservice Radio Propagation Laboratory in the United States in 1939. Extensive research was undertaken on propagation at frequencies in these and higher bands.

Recognizing the increased demands for frequency use for all purposes which would follow the conclusion of the war, the chairman of the FCC of the United States in 1943 suggested that American industry form an organization to study requirements, formulate standards, and make recommendations. The resulting Radio Technical Planning Board, consisting of 13 panels representing all service aspects, made comprehensive studies which were helpful in determining new frequency allocations promulgated by the Commission after the war, dealing primarily with the bands above 30 mc. These allocations, like those which preceded them, had to be made without the benefit of much truly scientific planning.

New uses of VHF and UHF became established immediately upon the advent of technical means to generate, radiate, and receive frequencies of a higher and higher order. World War II accelerated this process. Thus many services became established at a time when it was not known whether the particular frequency band adopted was best suited for the service, and the large investments in facilities which followed made it difficult to consider reassignments on a more efficient basis. Furthermore, the importance of a new service could not be accurately predicted, and therefore its share of spectrum space had to be estimated in rough terms.

Several shifts were made between 1935 and 1946, at much inconvenience to the services affected. But, for example, when the time came to allocate bands for television service in the United States, beyond those which originally had been set out prior to the war, it was found impossible to provide for all the requirements in one continuous band located where the best radio-propagation conditions for television exist because of the already established wide uses by other important services, such as vehicular services and aids to air navigation.

To cope with the many expanding services, the general war-occasioned international disorder in the recording of radio-frequency assignments, and the need for agreements concerning newly developed areas in the spectrum above 30 mc, an International Telecommunications Conference was convened in 1947 at Atlantic City. The resulting agreement contained no fundamental alteration in previous allocations but made provision for additional exclusive frequency bands for aviation and international broadcasting. There also resulted a further blocking out of VHF by services, largely patterned after the scheme adopted by the United States for internal use.

A large part of this new allocation was to go into effect at such time as detailed utilization plans for the services could be established through further international collaboration. More orderly international administration of radio-frequency assignments was provided for by the creation of an International Frequency Registration Board. To give this Board a point of departure, the Provisional Frequency Board was appointed as a temporary body to prepare a master list of frequency assignments engineered to adequate technical standards. An Extraordinary Administrative Radio Conference was to make final the recommendations of the latter Board and establish the date when the Atlantic City frequency allocations would become effective.

1.6 THE PERIOD 1948–1951

In an effort to implement the Atlantic City frequency-allocation plan, many international meetings were held. The Provisional Frequency Board was in session for over two years, commencing in 1948, but failed to produce a workable frequency-assignment list. The countries of the world generally submitted requirements, including needs for the future, in excess of the capacity of the pertinent parts of the frequency spectrum to accommodate them.

Two conferences were held in 1949 and 1950 to prepare a plan for frequency assignments for HF broadcasting stations. These conferences also failed to agree on workable arrangements. An International Administrative Aeronautical Radio Conference met in 1948 and 1949 and adopted a plan for aviation which, however, cannot be made effective unless international agreement can be reached on a solution of the assignment problem for stations of other services in bands which aviation is to occupy.

Meanwhile disturbed world conditions initiated by the war in Korea followed by the mobilization activities of many important countries have intervened, imposing practical restrictions on effective international collaboration in telecommunications. Furthermore, because of an unprecedented growth of some services, particularly international broadcasting with its psychological warfare aspects, many countries of the world have found it expedient to derogate the international agreements already in effect and have assigned stations to frequencies outside the internationally allocated bands. The Extraordinary Administrative Radio Conference which began its meetings in Geneva in August, 1951, was not able to carry out its originally contemplated mission of approving a new complete master list of frequency assignments and found its definitive activities limited to such agreements as could be reached for promoting orderly procedures applicable to the period during which disturbed world conditions may continue.

Conferences of the CCIR were held in 1948 and 1951, respectively. They provided many technical recommendations which will aid further progress in frequency-allocation procedures.

In the United States under the auspices of the FCC, much progress has been made in the allocating of frequency bands and the assignment of frequencies to stations in the region above 30 mc, particularly in the fields of television and land mobile services. Because of the conditions previously described, the decisions of the Commission have had to be tailored to meet established spectrum occupancies. As before, it again proved impossible to give the new services the frequencies best suited for them even for those cases where the characteristics of the applicable frequencies and equipment technology are relatively well understood.

1.7 CONCLUSION

The radio-frequency spectrum has become occupied with useful services, almost always in advance of adequate knowledge of the behavior of the radio frequencies selected, commencing in 1898 with the first service for ships at sea. The frequencies adopted by the earliest services were determined by the limitations of the equipments and antennas then available. Subsequently, new services and the expansion of those already established encountered additional limitations by reason of having to avoid frequency bands already occupied and in use.

International conferences commencing in 1903 have contributed to the orderly administration of the frequency spectrum insofar as radio stations capable of producing international interference are concerned, on the basis of recognizing to a major extent that each service should have exclusive frequency bands. The same factors that have influenced the allocation of frequencies capable of causing intercontinental interference have affected allocations in the higher bands above 30 mc.

The existing radio-frequency allocations, therefore, have come about circumstantially and represent a combination of technical solutions with such factors as the pressures of economic and political forces and the heritages left by pioneering development. The results are not ideal. However, more technical information exists today than at any former time and the essential knowledge is accumulating rapidly. It should be possible, in making future studies of spectrum allocation, to proceed more intelligently than before. Procedures should be developed and adopted to lead to a correction of the errors that circumstances have created. The responsibilities upon the world's regulatory agencies in this regard are great.

Chapter 2

PROPAGATION CHARACTERISTICS OF THE RADIO SPECTRUM

2.1 GENERAL

Mode of Treatment of the Subject

Chapter 2 of this report is not a textbook for schools, not a handbook for engineers, not a treatise for scholars, not a history for posterity. Likewise it is not a treatment of the propagation basis for the assignment of frequencies to stations within allocated bands of frequencies, and it thus differs from the many other writings on the subject. This treatment is rather the summarizing of the major facts of radio propagation which need to be taken into account by persons concerned with the allocation of bands of radio frequencies to various uses.

In this treatment, words are used with the meanings as defined in the IRE Standards. The mks system of units is used where not otherwise specified.

Scope of Material to Be Compressed There are recurrent requests from well-meaning planners or users of radio frequencies that the outstanding facts of radio propagation be summarized in a brief statement of, say, one page or a few judicious sentences. This is impossible; nature did not so arrange the facts. That the facts are complex is not surprising when it is considered that the upper- and lower-frequency limits of the optical spectrum have a ratio of 2 to 1 while the corresponding ratio for the radio spectrum is over 10,000,000 to 1.

Efforts to summarize the facts in such a way as to aid frequency allocation have been made from time to time, and the resultant compendia have grown in length with the rapid extension of knowledge of the facts. The basic fact of radio-wave propagation can be compressed into a single mathematical formula on one line, but this is only a start and of no use at all to a frequency allocator. A partial list of the factors which determine what actually happens includes the distance of transmission, frequency, time of day, season, year, meteorological factors, location of transmission path with respect to land and sea and auroral zone, amount of penetration into various layers of the upper atmosphere, conductivity and dielectric constant of the ground and air, effects occurring on the sun and stars, (we must add) etc.

The International Radio Conference at Madrid in 1932 had a committee prepare a summary of radio propagation as then known; it was only seven pages long.[1,*] The International Radio Consultative Committee at Bucharest in 1937 set up a committee to do the same thing; this time it was 42 pages long.[2] In 1943, the Interservice Radio Propagation Laboratory prepared a handbook of only part of the subject (ionospheric propagation); it was 238 pages long and was considered as supplemented by monthly data pamphlets. In 1947 to 1950, efforts to compile the facts of radio propagation needed for their purposes were made by various international radio meetings (Atlantic City Telecommunications Conference, Mexico City and Florence Conferences on High Frequency Broadcasting, Provisional Frequency Board in Geneva); the resulting compendia of radio-propagation information are in part listed in Document 116 of CCIR study

* Numbered references appear under appropriate headings in the Bibliography.

group meeting in Washington, March, 1950; these papers amount to so many thousands of pages that they constitute a stack over 3 ft high.

The complex facts of radio propagation as here summarized represent the subject today; the knowledge of the facts changes rapidly as time goes on.

Treatment of Successive Frequency Ranges This chapter endeavors to present its compressed treatment of the major facts of radio propagation in successive sections dealing with different ranges of frequencies. This should aid allocators and users in localizing the parts of the radio spectrum that may be adaptable to their purposes. The differences of treatment in the various chapters reflect, in part, the differences of development of the subject and of emphasis in use.

There are no sharp divisions in nature such that one phenomenon stops abruptly and another becomes predominant when a certain frequency is reached. Nevertheless there are characteristic differences in many effects at different frequencies so that a rough division into frequency bands is useful. The particular frequencies used for the dividing lines between sections were chosen on this basis. There are overlaps of the effects characteristic of some bands into other bands, and these are explained in the pertinent sections.

The upper and lower limits, 10 kc and 300,000 mc, are the approximate limits between which useful radio transmissions are conducted, now and possibly for some time into the future. Even these are not strict limits. They are dictated in part by the fact that at frequencies below 10 kc it is difficult to radiate enough power to do useful radio work and, above 300,000 mc, it is difficult to produce radiated fields of relatively constant and coherent phase with sufficient power to overcome the severe attenuation caused by rain, oxygen, and water vapor.

General Nature of Radio Propagation

The electromagnetic field produced at a distance would be simply calculable if the transmitting and receiving antennas were in free space (*i.e.*, away from the earth and its atmosphere). But the medium between transmitter and receiver does in fact produce great effects and variations. Even transmission between airplanes at short distances may differ greatly from free-space transmission. It is essential to know something about what the medium is and what effects or phenomena occur in it. Unfortunately the medium is constantly changing in those very characteristics which affect radio propagation. There is no royal road to knowledge, and even when you have traversed the roads, royal or otherwise, you have to work to apply the knowledge to which they lead. A frequency allocation which applies at one time or place may have to be entirely different for another time or place. Nevertheless the more facts of propagation are heeded, the more sound is the resultant frequency allocation and the greater is the service obtained from the radio frequencies.

The Medium The ground and the air both affect the propagation of radio waves. Both introduce variations and departures from the uniform attenuation of the wave intensity with distance in free space. Because the conductivity and dielectric constant of the ground are different from those of free space, energy is lost from that portion of the wave which proceeds along the ground. The energy loss increases rapidly as frequency is increased. Thus ground-wave propagation is most useful at the lower frequencies. Despite the energy loss, the ground may assist propagation by acting as a reflector for waves which come down to it, *e.g.*, after having been first reflected from an upper layer of the atmosphere. Ground propagation is dealt with particularly in Secs. 2.2 and 2.3, and ground reflection in Secs. 2.4 and 2.5.

The air acts as a propagation medium, not only near the ground but also far above it because some of the radiation from an antenna is directed other than horizontally and because it is proceeding other than horizontally soon after it leaves the antenna as a result of the curvature of the earth. In the troposphere (0 to 10 km above the ground), variations in dielectric constant of the air, caused by variations of water vapor and temperature, change the direction (in the vertical plane) of propagation of the waves and thus increase or decrease the distance at which they may be received. When the medium is stratified, these effects persist; when it is turbulent, the propagation effects exhibit anomalies. These tropospheric phenomena are considered particularly in Sec. 2.5. Besides these effects of dielectric-constant variation, at the higher frequencies water vapor and other molecules interact with the waves and aid or hinder propagation; this is dealt with in Secs. 2.5 and 2.6.

At the levels so high that the air is very rare, it is electrically ionized by solar radiation. Where a radio wave passes through such ionized air, the electric force of the wave accelerates the ions and electrons, which take on a certain amount of motion at the wave frequency, this accelerated motion in turn giving rise to radiation. There is thus an interchange of energy between the ionized air particles and the radio wave, with a net effect of reflection or refraction of the waves downward, and the wave that might otherwise pass through the atmosphere to outer space is returned to earth. This is called the sky wave and is a major factor in radio transmission to great distances. It is dealt with particularly in Sec. 2.4, also to some extent in Secs. 2.2 and 2.3.

Because of their smaller mass, electrons are moved much more readily than ions; so it is electrons which control the behavior of the waves. The upper part of the atmosphere, in which the electron density is sufficiently great to reflect radio waves back to earth, is called the ionosphere. It extends from about 50 to 400 km (30 to 250 miles) above the ground. Because the ground wave is rapidly attenuated at the higher frequencies and may not be useful beyond a few tens of kilometers, there is often a zone around the transmitter in which no useful signal can be received. It is known as the skip zone. The ionosphere is stratified, and different radio frequencies are differently affected at different levels. The more important layers are called the D, E, F_1, and F_2 layers, respectively, in order of increasing height and increasing value of maximum ionization density. As we shall later see, the E, F_1, and F_2 layers are primarily a region of absorption. Little is known about the structure and location of the D layer except that its ionization density is low and it is located below the E layer between 50 and 90 km. (See Sec. 2.4 for a more complete description of the different layers.) The composition and the electron concentration of the several layers exhibit changes, some regular and slow, others sporadic and sudden. Besides the stratification, there are also irregular masses of ionized particles in the ionosphere which introduce additional effects upon radio-wave transmission. At times of special disturbance or storminess of the ionosphere the irregularities greatly increase and seriously interfere with radio propagation. The effects are very different at different geomagnetic latitudes.

The Basic Phenomena of Radio Propagation The propagation of radio waves is complex both because of diversity and variability of the medium, just explained, and because of the numerous physical processes which enter into propagation. These processes or mechanisms include wave refraction, reflection, diffraction, absorption, polarization, interference, and scattering. The intensity, angle of arrival, and other characteristics of received waves are further affected by the combination of waves propagated over multiple paths of transmission.

Refraction is the change of direction of propagation by a change of dielectric constant of the medium. The nature of this process in the ionosphere is explained above, and its results are treated in Sec. 2.4. In the troposphere, the diminution of density, and hence of dielectric constant, of the air with height above the ground results in a slight bending of radio-transmission paths downward, so that the waves go farther than they would without this effect. Under steady conditions, this increases transmission distances to approximately what they would be if the atmosphere were uniform and the earth's diameter were four-thirds its actual diameter. Local variations in the air produce far greater effects. Refraction through water wapor and temperature gradients in the troposphere at times greatly increase or decrease the distance of transmission. Further information is given on this in Sec. 2.5.

Reflection is change of direction of propagation by a discontinuity, *i.e.*, abrupt change, in the medium. Abrupt changes in conductivity and dielectric constant are the usual discontinuities. Thus the earth's surface and sharp boundaries of layers in the atmosphere may be effective reflectors. A receiving antenna receives a combination of the wave transmitter through the air and the wave reflected from the ground. At frequencies above about 30 mc (*e.g.*, in television) there are effects also from waves reflected from buildings and trees. The reflecting ability of most discontinuities is a rather complicated function of the frequency, angle of incidence, wave polarization, conductivity, and dielectric constant of the reflecting medium. Earth and water are moderately good reflectors of radio waves. Reflection is discussed further in Sec. 2.5.

Diffraction is a redistribution of wave energy beyond the edges of a region in which the conductivity or dielectric constant changes. In optics this gives rise to a slight bending of light around an opaque obstacle. In radio, it serves to bend waves over the horizon or behind buildings to areas beyond. Its effect varies with frequency; it is more important at the LF end of the radio spectrum than at the HF end. At optical frequencies it is still observable but not usually obvious.

The energy and intensity of a wave diminish as it is propagated because it spreads out over more space. There is further diminution of received energy, or of distance range for a given transmitter power, because some of the wave energy is dissipated in the medium by absorption in any substance or object in its path. The amount of ground absorption varies with ground conductivity; in general it increases as frequency is increased. Absorption occurs in the ionosphere because part of the energy of the waves is transferred to the electrons and other charged particles in random motion and thence to additional charged particles and molecules with which they collide. The amount of absorption increases with the ionization of the regions in which the waves are reflected or through which they pass. The amount of ionospheric absorption diminishes as frequency is increased. Wave energy is also absorbed by molecules of oxygen or water vapor in the atmosphere; this effect increases with frequency and becomes appreciable only in the frequency range dealt with in Sec. 2.6. At those frequencies absorption in raindrops may also be significant, although scattering (see below) by raindrops is more important.

The efficiency of propagation and reception of radio waves is affected by their polarization. A wave is horizontally polarized when its electric field is parallel to the earth's surface and is vertically polarized when its electric field is in a plane perpendicular thereto. At low frequencies, with the transmission along the ground, all waves are vertically polarized because horizontal components produce currents in the ground which rapidly absorb the energy of such components. At higher frequencies the ground transmission plays little role and the waves may have any polarization. Doublet antennas emit waves polarized in the plane containing the antenna and the direction of propagation. The direction of polarization may, however, be altered in the medium because of effects occurring in it. Received intensity is at a maximum when the receiving antenna is parallel to the direction of polarization of the received wave.

Waves arriving at the receiver over more than one path may exhibit the phenomenon of interference as in optics. This will result in distances or zones of greater and less received intensity. This occurs when elevated antennas (*e.g.*, mounted in aircraft) are used for the higher frequencies, because of interference of the wave propagated directly through space with the wave reflected from the ground. Another manifestation of interference is fading (discussed below) when caused by time variation of the relative phase of two or more of the waves arriving over different paths.

Radio propagation is further complicated by scattering. This is the reflection of radio waves by irregular masses as distinct from uniform layers or plane reflectors of any kind. In propagation by way of the ionosphere (dealt with in Sec. 2.4), scattering occurs from irregular concentrations of electrons in the ionosphere. Scattering may also be caused by ground roughness and irregularities including stormy seas, particularly at the higher frequencies. Scattering sometimes causes fluctuating, irregular received signals of unpredictable intensity. When the reflecting masses are numerous, the received signals merge and the resultant is fairly stable. This is true for tropospheric as well as ionospheric propagation and therefore applies throughout most of the spectrum.

These mechanisms are described more particularly in the chapters where their effects are of major importance.

Special Complications of Radio Propagation

The complexities of the medium and of the phenomena which have just been mentioned and their characteristic variations with frequency determine in large measure the utility of various radio frequencies for various purposes. But even if one had full data on these complexities, it would still not be possible to determine precisely the usability of particular frequencies.

A major additional complication is the existence of radio noise, which competes against the wanted signals in the radio receiver and which has many complexities of its own. Thus signal-to-noise ratio becomes an important quantity in radio engineering. When the signal is powerful enough to make the radio noise negligible, still another difficulty is faced: fluctuation of received signal strength. The fluctuation includes not only the variations from hour to hour and longer times, as the properties of the medium change from solar and other causes, but also the shorter time variations called fading. When radio noise and fading are both present, they are interrelated, for the combating of fading by automatic volume control is less successful the greater the radio noise intensity. Radio noise and fading are discussed further below.

Modern theoretical studies attempt to determine the amount of information receivable in the presence of given intensities of noise. Such theories are complicated by fading. Furthermore, when propagation is complicated by multiple fading and by effects which distort the signal in the medium, the problem is not completely solvable by existing information theories. It should be noted, too, that the existing data on the various vagaries of the medium are only partial and rough, so that existing statistical techniques are not suitable. It will doubtless be a slow and difficult process to develop genuinely applicable techniques. The utilization of propagation knowledge may therefore be a somewhat unscientific procedure for some time to come.

Another complication (not a difficulty) is the employment of directional antennas. Their functioning is not strictly an aspect of propagation, but the effectivenes of propagation over particular transmission paths and at particular frequencies is closely related to the question of the directivity of the antennas used. A simple vertical wire or steel mast used as an antenna usually radiates equally well in all azimuthal directions and is said to be omnidirectional. In the vertical plane, the power radiated from such an antenna is usually a maximum in a horizontal direction, decreasing progressively to zero as the angle of elevation is increased to 90 deg. In general the efficiency of a simple antenna increases as its vertical height is increased while remaining small compared with the wavelength. At the frequencies of Sec. 2.3, it is not only economically feasible to build antennas that are good radiators but it is possible to arrange several vertical antennas properly spaced and interconnected so as to enhance radiation in certain preferred directions at the expense of radiation in others. Under favorable conditions, elemental antennas may also be stacked one above another to divert power, that might otherwise go skyward, downward toward the horizon. Combinations of radiating elements are known as antenna arrays.

Among other advantages directive antennas minimize power required at the transmitter. The ratio of the power projected in the preferred direction by an antenna array, compared with that projected by an omnidirectional antenna operating under similar conditions, is known as the directive gain. Gains of this kind are available at both the transmitter and the receiver. The directive gain of most antennas is proportional to each dimension of the antenna array, measured in wavelength. Thus as frequency is increased, structures of practicable dimensions can readily provide very large gains. At the highest frequencies now used in radio, optical devices such as parabolic mirrors or lenses are often used in lieu of arrays of individual antennas.

At frequencies around 2,000 kc (Sec. 2.3) directive gains at each end of a radio link ranging from 2 (3 db) to 4 (6 db) are feasible. At frequencies of 30 mc (Sec. 2.4) the directive gain may be 100 (20 db) or more, while at the frequencies of 3,000 mc (Sec. 2.5) it may be 10,000 (40 db), and at 30,000 mc (Sec. 2.6) it may be 100,000 (50 db). At the lower frequencies used in radio, directivity cannot be relied upon as a means of avoiding interference with other stations, but at the higher frequencies it is very effective indeed.

Fading Radio propagation along the ground is stable and calculable, but transmission through the air is subject to many vagaries. These vagaries change with time, with the result that received field strengths fluctuate. Fading fluctuations vary from very rapid (less than a second) to very slow (as much as an hour). They are particularly rapid at the higher frequencies. Fading may be classified by its causes into five principal types: (1) interference fading, (2) polarization fading, (3) absorption fading, (4) skip fading, (5) selective fading.

Interference fading occurs when two or more waves arrive at a receiver over different paths and the phase varies in one or more of the paths; the phase variations may be due to the motion of the reflecting layer, body, or particle. When waves from a number of air paths combine, the random variations of phase tend to smooth out and the effect is a flutter of received signal. When, on the other hand, waves from a single air path in which the phase is fluctuating are received with strength comparable to that of the steady ground-propagated wave, the fading is very severe; this occurs, for example, at frequencies between 1,000 and 2,000 kc at distances of 50 to 200 miles.

Polarization fading is the result of fluctuation of the direction of polarization in one or more of the propagation paths of waves arriving at a receiver. Its effects are most noticeable in ionospheric propagation, treated in Sec. 2.4.

Absorption fading is a slower type and may occur along a single transmission path. It is due to variations in absorption somewhere in the path. The severe fade-outs associated with a sudden ionosphere disturbance are an extreme case of absorption fading.

Skip fading is a phenomenon of ionospheric propagation; it occurs at distances from the transmitter near the skip distance. Fluctuations of ionization density at the place in the ionosphere where the wave is reflected cause the skip distance to increase and decrease. The resultant changes in received field strength may be more than 100 to 1. This type of fading is most prevalent around sunrise and sunset.

Selective fading is a result of the quantitative variation with frequency of any of the other types of fading. The various frequencies in the side bands are received with varying amplitudes or phases, and the result is distortion of the signal. Selective fading is especially noticeable in broad-band communication such as telephony, where the deletion of some frequency components may greatly distort speech.

Radio Noise The disturbance to radio reception caused by received fields other than those from radio stations is not, in strict logic, a part of the subject of radio propagation. Its effects, however, are so intimately bound up with the characteristics of radio reception determined by propagation that both must be considered in determination of the utility of particular bands of radio frequencies.

Radio noise may be either man-made or provided by nature. Some radio noise is escapable, and some is not. Theoretically, all man-made radio noise should be escapable, but in fact some of it remains with which we must cope. Much of the natural radio noise can be escaped by selection of frequency to be used. One type, however, is an ultimate limitation on radio operations; this is the inherent irregular type of noise caused by electron motions in the conductors or electron tubes existing in the input circuit of receiving equipment. This type is important above about 20 mc and is the major limitation on the use of all frequencies above about 100 mc.

Some natural radio noise, such as local thunderstorms and precipitation noise, and most man-made types of radio noise are from sources which are nearby although outside the receiving equipment. Some natural radio noise, particularly that due to distant thunderstorms (called atmospheric radio noise), is propagated from a distance. At frequencies below 10 mc, the major characteristics of atmospheric radio noise are determined by the facts of radio propagation. Thus atmospheric radio noise is at its maximum at the lowest frequencies. For certain times and regions, at frequencies between 2 and 10 mc, it increases with frequency just as the intensity of all waves propagated via the ionosphere does for those times and regions. Above 10 mc, atmospheric radio noise becomes weak, falls to a very low value at 20 to 30 mc (the limit being different at different times, depending upon the state of the ionosphere), and is negligible at still higher frequencies.

At about 20 mc begin the effects of extraterrestrial radio noise. Radio noise from the stars is significant on frequencies above about 20 mc but diminishes with increasing frequency. The sun, too, causes radio noise of two kinds. A sporadic type associated with solar eruptions may exceed in intensity the noise from the stars around 100 mc, depending on directivity and orientation of antennas. At higher frequencies radio noise of a regular type from the sun is appreciable.

Throughout much of the spectrum, man-made radio noise disturbs reception. It is caused at relatively short distances by diathermy machines and other nonradio equipment using radio frequencies and by any sort of electrical apparatus in which sparks occur. At considerable distances from the sources of disturbance it is in general of little importance below 10 mc because of the larger effects of natural noise. Above that frequency the short-distance effects of automobile and airplane ignition systems and some other spark sources of radiation have to be taken into account. As the the frequency is increased, these effects again become negligible, partly because most electrical equipment produces little effect at such frequencies and partly because of the greater radio noise produced in the radio receiver itself.

Brief Summary of Usability of Particular Frequency Ranges

Here are summarized briefly a few of the main facts bearing on the adaptability of the several parts of the radio spectrum for various services. All conclusions are oversimplifications. The complexities of propagation preclude, in most cases, the stating of clear and simple conclusions. The reader must consult the succeeding sections for more definite information on the distance ranges, the times of serviceability, the differences with transmission-path locations, and the limitations due to radio noise, fading, multipath transmission, and other effects.

The lowest radio frequencies (10 to 200 kc) are characterized by the existence of a ground wave which is propagated to great distances and by relatively stable ionospheric phenomena; hence received signals are relatively stable and free from fading. On the other hand, in this frequency range atmospheric radio noise is stronger the lower the frequency; therefore great power must be used to override radio noise. Consequently the frequencies at the low end of the radio spectrum are suitable for commercial telegraphy or telephony for which the importance of the business justifies the cost of high-power transmitters and huge antenna structures. The low frequencies are relatively immune to ionospheric disturbances and are therefore particularly valuable as a standby for long-distance services carried on in the ionospheric frequency range (Sec. 2.4). For similar reasons the low frequencies are also suitable for long-distance navigation systems. The use of such systems by many ships or aircraft over large areas of the world may be found to justify the considerable cost.

In the portion of the spectrum between 200 and 2,000 kc occurs the transition from the predominance of ground-wave transmission to that of sky-wave transmission. At the low end of this range propagation in the daytime is by ground wave and good, stable signals are received. For transmission over sea water this is largely true even at the high end of this range. Throughout this range night propagation is characterized by sky-wave propagation to distances of hundreds of miles and by serious fading. Antennas are short enough so that direction-finding services are feasible in this range, although precautions against polarization changes are usually necessary. The lower end of this range has some utility for the same purposes as frequencies below 200 kc. The frequencies in this range are useful for audio broadcasting and mobile services, the day service areas, however, diminishing as frequency increases.

The frequency range from 2 to 30 mc is the one in which propagation via the ionosphere predominates. Distance ranges of thousands of miles are obtained with relatively low transmitter power. The lower frequencies of the band are in general used for long-distance nighttime service; the higher for daytime. These frequencies are suitable for long-distance telegraph and telephone communication. On account of the variation of usable frequencies at different times of day, season, and year of the solar cycle, it is generally necessary for each transmission path to have three or four frequencies available. The advantage of long-distance transmission carries with it the disadvantage of long-distance interference, so frequencies have to be assigned with their world-wide effects in mind. Use of these frequencies in polar regions, and also at times of ionospheric disturbance, is subject to interruption. The utmost reliability therefore requires the use of auxiliary means of communication for such areas and times.

Ionospheric propagation sometimes extends into the range above 30 mc and at certain times even up to as high as 80 mc. When the sky wave does play a part in this frequency region, it is more in evidence as a source of interference than as a means of reliable service. Except for the foregoing, propagation on 30 to 3,000 mc is, most of the time, limited to short distances. As frequency increases, the distance is progressively more nearly limited to the line-of-sight distance. At times, tropospheric and other irregularities greatly increase or decrease the distance. It becomes progressively easier to provide directivity as the frequency is raised, thus making possible the use of systems confined to a narrow path in space. The lower frequencies of the band, however, are better for omnidirectional transmission because the distance range is greater for a given power. Thus such frequencies are useful for ship and aircraft communication and for broadcasting.

The range from 3,000 to 300,000 mc is particularly useful for services in which high directivity may be employed. The antennas are so small and directivity so great that relatively little power is required. The high directivity and extreme definition available at these frequencies give radar some advantageous characteristics it does not have at lower frequencies. Point-to-point communication and navigational aids work very well. The distance range of a transmitter is little beyond the horizon distance. Long-distance communication by use of relays is effective and economically feasible on frequencies up to about 10,000 mc, beyond which a limitation is introduced by heavy rain. At certain frequencies (higher than 20,000 mc) distance ranges are extremely short because of energy absorption by atmospheric water vapor or oxygen molecules.

2.2 PROPAGATION CHARACTERISTICS OF THE SPECTRUM FROM 10 TO 200 KC

Description of General Propagation Characteristics

Propagation of radio waves in the range 10 to 200 kc presents special practical problems in addition to the complexities already discussed. Waves leaving the transmitting antenna may be radiated directly through space to the receiving antenna or may arrive at the receiving antenna after reflection by the ground or ionosphere or after various successive ground and ionosphere reflections. The result of all these, together with any radio noise received likewise, activates the receiving antenna. At frequencies above the range considered here, the energy arriving at the receiving antenna by many of these modes of transmission is negligible, and the practical problem is thus simplified. In addition, radio noise is generally much greater at these low frequencies and therefore causes more complication in reception.

Since transmitting and receiving antennas are close to the ground in comparison with ionospheric reflection heights, the resultant of the directly transmitted and ground-reflected waves is a wave which generally is guided by the ground, rapidly diminishing in intensity with increasing height above ground. The strength of this ground wave diminishes with distance from the transmitter, depending upon the dielectric constant and conductivity of the ground. Practically measurable signals by means of ground waves may be obtained at transmission distances as great as 1,500 km (about 1,000 miles).

Ionosphere reflection at these frequencies occurs at comparatively low heights (about 75 km for daytime, 95 km for night) which, for the lower frequencies in this range, correspond to distances of only a very few wavelengths. Although the wave penetrates into the ionized region, the penetration is small (generally very much less than one wavelength). Therefore it suffers little absorption and usually undergoes almost mirrorlike reflection when it encounters the comparatively weakly ionized D region or lower parts of the E region of the ionosphere.

At comparatively short distances from the transmitting antenna, it is possible to distinguish the ground wave and the sky-reflected wave from each other in the received signal. At great distances, this may not be possible, and the effect of the presence of many superimposed waves, transmitted by many modes of reflection between ionosphere and ground, is such that these reflecting boundaries (ground and ionosphere layer) serve as a waveguide for the transmitted signal.

Physical and Mathematical Basis of VLF Radio Propagation
No attempt is made here to give a mathematical treatment. Its basis is briefly indicated, and articles giving the detailed solutions are referred to.

Because of the low absorption characterizing both ground and ionospheric reflection at VLF, and because diffraction phenomena at these frequencies are more pronounced, the application of geometrical-optics methods to the solutions of problems in VLF propagation is generally not suitable. Rigorous mathematical solutions of the wave equations for the cases of practical interest are very complex.

When Marconi first transmitted radio signals across the Atlantic, Lord Rayleigh said that some kind of diffraction theory was needed to explain how the waves followed the curvature of the earth, since the plane-wave transmission theory was not sufficient to account for the phenomenon. A number of years elapsed, however, before a satisfactory solution was developed. A good bibliography of the early work, reported by Poincaré, Nicholson, MacDonald, Love, Rybczynski, and others, is provided by Love.[1]

Watson [2,3] extended the early method of solution to the case of wave propagation between two concentric spherical shells (the earth and a mirrorlike, sharply defined, ionospheric reflecting layer), each characterized by uniform constant dielectric constants and conductivities. His solution took approximately the same form as an empirical equation obtained by Austin and Cohen [4] from extensive observation over long transmission distances; it is given below under Field Strengths Received over Long Distances.

More recent work [5-14] takes account of actual conditions affecting the propagation of the waves. These studies recognize that the ionospheric reflecting layer is not sharply defined like a mirror, *i.e.*, the waves penetrate somewhat into the layer, and so the variation of ionization density with height is taken into account. The effects of the earth's magnetic field are examined and found to be of importance.

Methods of Estimating Received Field Strength

Ground Wave The basis of calculating the field strength of the ground wave was begun by Sommerfeld [15] with a theoretical treatment of the field produced by a short vertical antenna at the surface of a plane earth. This was carried forward by others.[16-31] Detailed computational procedures, with results calculated for a wide variety of cases, are provided by Norton [32,33,34] (a condensed survey of these being given by Terman,[35] Burrows and Gray,[36] and Bremmer [37]). For short distances, where the assumption of a plane earth is justifiable, field strengths are given by Burrows.[38] Computational procedures for transmission paths over composite terrain (such as paths partly over land and partly over sea) have been presented by Kirke [39,40] and by Millington and Isted.[41]

These computations of ground-wave intensity, checked by practical experience, show:

1. There is no pronounced "shadow" in reception as distance increases beyond the horizon.

2. With decreasing frequency, the logarithm of the received field strength tends to vary in a negatively linear manner with the logarithm of the transmission distance, departure from linearity appearing with increasing distance.

3. Better transmission is nearly always obtained over sea water than over land and over soil of high conductivity rather than soil of poor conductivity. An exception to this occurs at extremely low frequencies and very long transmission distances. For example, Bremmer (p. 121 of ref. 37) notes that, for 15 kc and a transmission distance of 2,000 km, both antennas near the earth's surface, the field strength over land is 4 per cent greater than over sea. Thus for great distances,

there exists an optimum conductivity σ for any frequency f in kilocycles, given by

$$\sigma = 1.675 f^{5/3} \times 10^{-16} \text{ emu}$$

4. With transmitting and receiving antennas near the ground, absorption of the waves by the ground is generally more important in decreasing field strength than is earth curvature. At very great distances, when the field has already decreased to such an extent that absorption cannot be important, the effect of earth curvature may be notable.

5. If the antennas are raised substantially above the surface of the earth, the effect at great distances is to multiply the field by a constant factor independent of the distance.

6. Effective phase velocity of the ground wave is slower than that pertinent to free-space propagation. It depends on frequency, ground constants, and distance from the transmitting antenna. This is notable, especially in the case of short transmission distances, with regard to VLF navigation systems based upon differential ground-wave phase measurement.[42,43,44]

Ground and Sky Wave Although ground-wave theory has been well developed and confirmed experimentally, so that ground-wave intensity can be computed, this is not true of the sky wave. The theoretical development of sky-wave reflection is in its elementary stages. At short distances, both ground wave and sky wave combine to form the received signal. Their relative importance in determining the received intensity varies with the reflection coefficient of the ionized layer in the ionosphere which reflects the sky wave back to earth as well as with the reflection coefficient of the earth itself.

Considerable interest therefore attaches to measurement of the reflecting-layer height and reflection coefficient at these frequencies. This is done either by the method of Hollingworth,[45] using the interference pattern formed by ground and sky wave, or by vertical-incidence pulse measurements, similar to those regularly made at ionosphere stations on higher frequencies (see Sec. 2.4).

Estimates of ionospheric reflection heights for the VLF, furnished by such experiments, are about 70 to 80 km for day and 90 to 100 km for night. Little, if any, significant change in reflection height accompanies changes of frequency within the limits treated in this chapter.

The logarithms of the reflection coefficients at vertical incidence, within this range, generally vary linearly and negatively, with the logarithm of the frequency. At night, for example, the reflection coefficient $R = 0.6$ at 10 kc and $R = 0.25$ at 200 kc, approximately; for winter noon, $R = 0.7$ at 10 kc and $R = 0.02$ at 200 kc, approximately; for summer noon, the change with frequency is even more marked; $R =$ about 0.1 at 16 kc and is less than 0.001 at 100 kc.[46]

Seasonal changes in R, at 16 kc, are almost opposite in phase for noon and night; night values increase from about 0.37 in winter to 0.56 in summer, while noon values decrease from about 0.27 in winter to 0.13 in summer. At 70 kc, $R =$ about 0.3 at night, with no marked seasonal variation, and is about 0.08 for winter noon, decreasing to negligible values for noon in summer.[46]

Diurnal changes, thus, are greater for summer than for winter and greater for higher frequencies within this range than for the lower frequencies. Both daytime and night values are fairly constant, transition taking place shortly before ground sunrise (sometimes accompanied by fluctuations in the reflection coefficient) and near sunset. It is interesting that, although the reflection coefficient begins to change about an hour before ground sunrise, the phase of the wave (indicating the reflection height) does not change until ground sunrise.

Reflection coefficients are greater for oblique incidence. At 16 kc summer daytime, $R =$ about 0.15 for transmission distances less than 300 km but is nearly double this value for distances between 500 and 800 km; at night, $R = 0.26$ at 170 km and 0.69 at 700 km. For frequencies near 100 kc, summer daytime R is less than 0.001 at vertical incidence but is 0.01 at 400 km, 0.04 at 700 km, and 0.055 at 900 km.[46]

It is interesting that for oblique incidence, on transmission distances of several hundred kilometers, both decrease of reflection coefficient and phase change of the sky wave take place about an hour before ground sunrise at the midpoint of the transmission path.

More than one reflection from the same ionospheric reflecting layer is sometimes observed, especially when the reflection coefficient is high. Reflections from layers of somewhat different heights have also occasionally been noted.

Field Strengths Received over Long Distances

The simplest practical working formula for VLF radio propagation over great distances is:

$$E = 1{,}256 \cdot \frac{fHI}{d} \sqrt{\frac{\theta}{\sin\theta}} \; \exp - \alpha d\left(\frac{f}{300}\right)^{0.5}$$

where $E =$ received field strength, microvolts per meter
$H =$ effective antenna height, kilometers
$I =$ antenna current, amperes
$d =$ transmission distance, kilometers
$\theta =$ transmission distance, radians (this formula and similar formulas are not applicable for distances near $\theta = 0$ or $\theta = \pi$)
$f =$ frequency, kilocycles
$\alpha =$ attenuation coefficient

This is essentially the empirically established Austin-Cohen formula,[4,48] given theoretical basis by Watson.[3] In some work, the exponent at the end of the formula has been found to be other values, varying from 0.5 to 1.25, but 0.5 is most commonly applicable.

Austin first gave the value of α, the attenuation coefficient, as 0.0015. Analysis of the observations of many workers,[49,50] has shown seasonal, diurnal, and other changes in α. These variations are discussed below.

Variation with Solar Activity The only sufficiently long-time series of data for significant study of year-to-year variations are those of Austin for the Nauen, Germany [0900 to 1000, 75° W time (EST), 1915–1933; 1500, 75° W time (EST), 1923–1933; 23.4 kc] and Bordeaux, France [1000 to 1500, 75° W time (EST), 1923–1933; 12.8, 16.2, 15.9, 15.7 kc], signals received at Washington, D.C. Yearly-average field strengths for Nauen (excepting those for 1930, a geomagnetically abnormal year) show positive correlation with smoothed sunspot number. The measurements on the Bordeaux signal showed no significant variation with sunspot number.

The effects of solar flares on the ionosphere (sudden ionosphere disturbance, or Dellinger effect) decrease the ionospheric reflection height for VLF by several kilometers, the decrease being approximately the same for all frequencies within this range. At vertical incidence or for rather short transmission distances, the amplitude of the sky wave is decreased. The decrease, for a given decrease in reflection height, is much more marked at the higher frequencies than at the lower ones in this frequency range. For example, for a decrease of 6 km in reflection height, the amplitude change at 16 kc is 6 db, whereas it is about 36 db at higher frequencies (30 to 113 kc). The relative change in amplitude $\Delta A/A$

varies linearly with log Δh.[46] At oblique incidence, on longer transmission paths, the effect of the sudden ionosphere disturbance is likewise to decrease reflection heights by an approximately equivalent amount. The field strength, however, is increased, in the frequency range considered in this chapter. Some experiments on radio noise [51] indicate higher attenuation for frequencies below about 8 kc during a sudden ionosphere disturbance.

The effect of ionosphere storms on LF transmission at temperate latitudes has been noted by many investigators. Austin [52] reported that night signals were weakened but daytime signals enhanced on long transmission paths. Wymore [53] likewise notes an increase of signal strength, reaching a maximum from 1 to 2 days after the onset of the storm and disappearing in 4 to 5 days, for transmission distances of 4,000 to 7,100 km. For shorter distances (250 to 450 km), the signal increased before the accompanying magnetic storm began, the increased signal being maintained after the magnetic storm reached its maximum. Espenschied, Anderson, and Bailey [49] note that ionospheric storminess tends to obliterate diurnal changes. More recent experiments [46] on 16 kc at vertical incidence indicate a violent phase and amplitude change, about 20 hr after the "sudden commencement" of a "great" magnetic storm, followed by a return to normal, then, 3 days later, the absence of diurnal change in the signal, with eventual return to normal in about 10 days.

Variation with Time of Day More pronounced diurnal variation occurs in the attenuation coefficient at the higher frequencies than at the lower within the range discussed in this section. Daytime values of attenuation coefficient are higher than night values, as shown by Table 2.1.[50]

Rydbeck [47] derived an expression showing positive variation of daytime α with the one-sixth power of the cosine of

Table 2.1 ATTENUATION COEFFICIENTS FOR VLF RADIO PROPAGATION

	Day		*Night*		*Transmission Path*			
f, kc	α	*Weight*	α	*Weight*	*Ground*	*Transmitter location*	*Receiver location*	*Observations by*
12.8, 16.2, 15.9, 15.7	0.59×10^{-3}	97			Sea water	Bordeaux, France	Washington, D. C.	Austin
17.13	0.66×10^{-3}	112	0.32×10^{-3}	48	Sea water	Rocky Point, N. Y.	New Southgate, England	Espenschied, Anderson, Bailey
22.9	1.49×10^{-3}	59			Land	San Diego, Calif.	Washington, D. C.	Austin
23.4	1.01×10^{-3}	97			Sea water	Nauen, Germany	Washington, D. C.	Austin
24.05	0.61×10^{-3}	93	0.25×10^{-3}	7	Sea water	Leafield, England	Belfast, Maine	Espenschied, Anderson, Bailey
24.05	0.80×10^{-3}	42	0.46×10^{-3}	2	Sea water	Leafield, England	Riverhead N. Y.	Espenschied, Anderson, Bailey
24.05	0.81×10^{-3}	52	0.44×10^{-3}	1	Sea water	Leafield, England	Green Harbor, Mass.	Espenschied, Anderson, Bailey
25.7	0.76×10^{-3}	104	0.29×10^{-3}	42	Sea water	Marion, Mass.	New Southgate, England	Espenschied, Anderson, Bailey
52	1.45×10^{-3}	29	0.60×10^{-3}	15	Sea water	Northolt, England	Riverhead, N. Y.	Espenschied, Anderson, Bailey
52	1.40×10^{-3}	75	0.84×10^{-3}	21	Sea water	Northolt, England	Belfast, Maine	Espenschied, Anderson, Bailey
54.5	1.49×10^{-3}	45	0.89×10^{-3}	30	Sea water	Northolt, England	Green Harbor, Mass.	Espenschied, Anderson, Bailey
57	1.48×10^{-3}	112	0.55×10^{-3}	48	Sea water	Rocky Point, N. Y.	New Southgate, England	Espenschied, Anderson, Bailey

the solar zenith angle, which is in general agreement with observation of very little change in α during times when sunlight is over all the transmission path.

At times when sunrise or sunset occurs along the transmission path, the values for α are generally intermediate between those for day and night but may, occasionally, become much higher than those for daytime, causing complete loss of signal for periods of several minutes. There has been found, so far, no simple relationship between these times of signal loss and the position of ionospheric or ground sunrise or sunset on the transmission path.

Variation with Frequency Attenuation coefficients for higher frequencies are greater than those for lower frequencies within this range, and their seasonal diurnal variations are more marked (see Table 2.1). Some radio noise studies [51,54] indicate pronounced attenuation on frequencies below about 8 kc.

Other Propagation Effects at These Frequencies

Polarization For short transmission distances (300 km or less) on all frequencies, a number of observers have found the downcoming sky wave to be approximately circularly polarized, with an anticlockwise rotation when viewed along the direction of propagation.[46] Some instances have been noted,[55,58,59] however, of linear polarization and of "split" echoes with components polarized at right angles to each other. These were noted at night or on frequencies of 310 to 340 kc.

For greater transmission distances (400 km or greater) on 16 kc, measurements have shown the downcoming wave to be plane polarized, the plane of polarization being 45 deg to the vertical plane of propagation.[46]

Cross Modulation Powerful transmitting stations sometimes cause cross modulation on transmissions from other stations.[58-68] Waves passing directly over the transmitter suffer more cross modulation than those in more distant paths. A station of 200 kw can so agitate the electrons in the ionosphere overhead that their collision frequency with molecules is appreciably changed; thus absorption of the medium for other radio waves changes with the modulation frequency of the transmitting station, and they are likewise modulated.

Cross modulation, occurring only on the sky wave, not on the ground wave, is most noticeable when the sky wave is relatively strong. In general, at very low frequencies, it increases with increased power and decreased frequency of the disturbing station, being most pronounced when both the wanted radiation and disturbing radiation are absorbed in the same ionospheric region. The transferred modulation will contain an octave component of the disturbing modulation but no higher harmonics. At higher frequencies than those discussed here, near gyrofrequency, abnormally high cross-modulation effects occur.

If E_w is the field strength of the wanted wave, p_w its angular frequency, and ω the angular modulation frequency of the disturbing wave, the field intensity of the wanted wave is given by $\bar{E}_w\,(1 + T_w \cos \dot{\omega} t) \cos p_w t$, where T_w is called the coefficient of transferred modulation. If this coefficient at zero modulation frequency is T_0, that at any other frequency T_f is approximately given by

$$T_f = T_0\left[1 + \left(\frac{f}{240}\right)^2\right]^{-1/2}$$

if

$$T_0 = \frac{T_0' \, P}{100}\left(\frac{140}{d}\right)^2 \frac{M}{100}$$

where P is the power of the disturbing transmitter in kilowatts, d is the slant distance in kilometers of this transmitter from the center of the transmission path, and M is the percentage depth of modulation. T_o' has a value of about 0.02 when both wanted and disturbing waves have VLF or when the wanted wave has VLF and the disturbing wave has MF. When the wanted wave is of MF and the disturbing wave is of VLF, T_o' is about 0.05. When the disturbing wave is near the gyrofrequency, T_o' has higher values. An excellent, detailed résumé of this subject has been given by Huxley and Ratcliffe [69] together with computations suitable for immediate practical use.

Directional Effects Aberrations in observed directions of signal arrival have been noted over very long transmission paths.[70,71] These occurred when the signal was received at a location nearly antipodal to the transmitting station. The signal is transmitted to the antipodal regions in all directions, so that more than one signal may be received. That coming over the path where ground and ionospheric conditions combine to offer the least attenuation will be the most prominently received.

Yokoyama and Nakai [72] reported that east-west transmission over long transmission paths, in fairly high latitude, suffers decidedly greater attenuation than does north-south transmission. Austin, Judson, and Wymore-Shiel [73] found that LF transmission was influenced more by magnetic activity when traveling across the earth's magnetic field than when traveling parallel to it.

Other directional effects noted are, more properly, diurnal effects. There are, for example, no typical sunset effects, such as those obtained on transatlantic paths, in observations made at Washington, D.C., on signals from Puerto Rico, the path in this case being nearly north-south.[74] Similar [75] is the lack of observed winter minima such as those observed on European stations, in Puerto Rico and Argentina signals observed at Washington, D.C., at 10 A.M. and on San Diego signals received at 3 P.M.

Variations in Delay Time Low-frequency reception of signals from several stationary transmitters is widely used for navigation purposes, the location of the mobile receiving station being determined by differences in time of arrival of signals from the stationary transmitters. When pulse signals are used, the path difference is measured directly as a time difference; when continuous-wave signals are used, the path difference is measured as a difference of phase.

Observed delay times of pulse arrival have generally been reported to be somewhat longer than those calculated for ground-wave arrival, possibly because the received signal consists of both ground-wave and sky-wave pulses, imperfectly resolved. With increasing intensity of the received sky-wave component of the pulse, the delay time increases. Since sky-wave field intensities vary seasonally, diurnally, geographically, and with solar activity, delay times may be expected to vary likewise. Since delay times depend upon the relative intensities of ground wave and sky wave, they also vary with the type of ground along the transmission path. Sufficiently detailed analysis to determine all these variations significantly has not been made.

Measurements carried out [76,77] on several experimental LF loran stations (180 kc) at various North American locations have, however, furnished sufficient data to provide practical corrections to measured delay times, with consequent notable improvement in accuracy. These corrections (the difference between mean time of observed signal transmission and the calculated time of ground-wave transmission) are given for day and night, for overland and oversea transmission paths, and for various distances. These increase from zero, at zero distance from the transmitter, to values of approximately 20, 40, 55, and 60 μsec for a transmission distance of 1,000 statute miles, for the cases, respectively, of daytime over sea water and over land and of nighttime over sea and over land. Similar values for a transmission distance of 2,000 statute miles are, respectively, 63, 74 (extrapolated), 84, and 133 μsec. Application of these delay-time corrections reduced estimated distance errors, roughly, by about 50 per cent for a typical case. Median daytime errors, remaining after these corrections were made, were about 8 miles, those for night being about 15 miles. Actually, distance error, in any particular case, depends upon direction from the location concerned, contours of equal error being probability ellipses about the location.

Navigation systems using continuous waves rather than pulses are dependent upon the measurement of phase difference of ground waves at rather short transmission distances and must correct their observations for the retardation of effective phase velocity of the ground waves. Interpretation of the phase of received sky waves must be made with reference to changes in effective ionospheric reflection heights.[78,79]

Variations in Radio Noise at These Frequencies

Effect of Solar Activity Austin's noise observations, a series accompanying his measurements of received field intensities, are the only series of measurements long enough to determine solar-cycle variations. These showed an approximately negative linear variation with increase of sunspot number, possibly caused by increased absorption with increasing solar activity.

Extensive observations [80,81] have been made on the effects of sudden ionosphere disturbances on radio noise at VLF. Sudden reinforcements of radio noise accompany solar flares, these being less notable at the lowest frequencies (below 17 kc) within this range. Several instances have occurred when a short reinforcement was observed before the fade-out for VHF was observed. Pronounced decrease in radio noise has been observed below about 8 kc during such occasions.[51,54]

Radio-noise Variation with Time of Day Generally speaking, received atmospheric noise is greater at night than day, because attenuation is less at night. Otherwise, it varies according to the diurnal variation of thunderstorm activity. Thus for most localities in the United States, high values are observed at night, low values in the morning, and rather high values during late afternoons in summer, since local thunderstorms are then most prevalent.[49,74,77,82,83]

Radio-noise Variation with Season Observations at Washington, D.C., show consistently higher daytime noise values for summer than for winter, this variation being less pronounced for morning than for afternoon. Ratios of monthly-average to yearly-average values for frequencies from 15 to 30 kc have been found to vary for 10 A.M. from about 0.7 in winter to 1.6 in summer; for 3 P.M. they vary from about 0.3 in winter to 2.3 in July–August.

Radio-noise Variation with Geographical Location Insufficiently long-time series of data at a large number of locations prevent accurate knowledge of noise variation with location. These variations may be inferred, to some extent, from our better information concerning thunderstorm occurrence and concerning radio-propagation characteristics. In general, radio noise tends to be negligible in Arctic regions,[84] fairly low in temperate regions,[49] except during times of local thunderstorm activity or when night conditions prevail over the transmission path between the station concerned and some noise center; and high in tropical regions.

Observed values of radio noise on 18.25 kc, approximately 150 cycles bandwidth, for Cabo Frio, Brazil, may be considered typical for a tropical noise center. For February, 1922, a diurnal minimum of about 36 μv per meter was observed at about 1800 local time, rising to a maximum of about 465 μv per meter at about 1600 local time. During relatively quiet periods in the early morning, the noise sources seemed largely located in northern Africa; the sources for afternoon noise seemed principally located in the interior of Brazil. Occasionally, afternoon noise values of more than 3,000 μv per meter were maintained for periods of several hours.

In long-distance signal reception, advantage is taken of the fact that such radio noise comes from particular noise centers; directional antennas are used to discriminate against the direction of the predominant radio noise and thus increase the signal-to-noise ratio.

Radio-noise Variation with Frequency Variations with frequency are determined by the nature of the generating atmospheric electrical disturbances, as well as the variations in their propagation characteristics with frequency. Throughout this frequency range, radio-noise intensity diminishes as frequency increases. There is a roughly linear negative variation of the log of noise field strength with frequency.

Utility of the Frequency Range 10 to 200 Kc

Radio frequencies of 10 to 200 kc are particularly useful for very long-distance transmission when sufficient transmitting power may be obtained and when good reliability is important. They are, thus, useful for message transmission throughout the range, although with decrease of frequency less information can be transmitted in a given time. The cost of high-power transmitting antennas for these frequencies also imposes economic limitations. Increased reliability, increased signal strength, and less diurnal, seasonal, solar-activity, and ground-conductivity variations are obtained with decreasing frequency throughout this range. Unfortunately, these benefits with decrease of frequency are accompanied, generally, by increase of radio noise, especially for receiver locations near tropical noise centers and at night and during summer afternoons in most temperate-zone locations on land. Recent experiments,[51,54] however, indicate pronounced decrease in both received field strengths and radio noise on frequencies below about 8 kc.

Frequencies in the upper part of this range are useful for fairly accurate navigation systems, covering large areas. It should be noted that suitable corrections should be applied to measured time delays in such systems. The phase stability on the lower frequencies within this range suggests their use also for long-range navigational aids.[78]

2.3 PROPAGATION CHARACTERISTICS OF THE SPECTRUM FROM 200 TO 2,000 KC

General

This is the frequency range in which occurs the transition from frequencies at which the ground wave plays an important part (at the lower frequencies) to frequencies at which the sky wave assumes primary importance (the upper frequencies). The ground wave and sky wave differ widely in their characteristics. Ground-wave propagation continues more or less uniformly throughout the day and night and ranges from what might be termed good in the lower end of this frequency range to rather poor propagation at the upper end, with average to poor soil conductivity. The propagation in the higher portion of the range permits only a relatively short-distance ground-wave service, especially over paths of poor conductivity. Over paths of good conductivity such as sea water, this disparity of propagation as between the high and the low portion of this frequency range is not so clearly marked.

Sky-wave propagation, though sometimes observable in the daytime, is conspicuous during the night hours. Being propagated by the ionosphere, it is subject to the great variations typical of the ionosphere. Received intensities fluctuate from minute to minute and also vary from hour to hour, day to day, season to season, and year to year. Though highly variable, the sky wave is nevertheless very useful, for it permits nighttime communication over hundreds of miles. Without it large areas of the world would receive no broadcast service.

The ground wave is generally of greatest importance at distances of less than several hundred miles, while the sky wave is of greatest importance at distances of hundreds of miles. At intermediate distances both components may be present in varying proportions, depending on the frequency, the time of day, the distance, the nature of the terrain, and conditions prevailing in the ionosphere. Because these two components of transmission, the ground wave and the sky wave, are so very different in nature, they are discussed separately below.

Ground-wave Propagation

Generalities with regard to the ground wave as set forth in the previous section hold also in this range, provided, of course, that due regard is given to the higher frequencies here. In this range the ground wave is more highly attenuated and furthermore its attenuation is markedly affected by variations in the conductivity and dielectric constant of the soil over which propagation takes place. It is also markedly affected by irregularities of terrain and by man-made structures such as steel buildings and wire lines. There is also marked difference between the attenuations of waves which are horizontally polarized and vertically polarized.

Calculated vs. Measured Ground-wave Data Field strengths for ground-wave propagation have been measured over a wide range of conditions and have been compared with theoretical calculations. The agreement is sufficiently good to warrant the use of such calculations as a guide to predicting ground-wave propagation generally, but subject to limitations discussed below.

Calculations of this kind have been made [1,2,3] for various distances and frequencies and representative soil conditions, assuming a homogeneously smooth earth. The results are shown graphically in Fig. 1.

It is assumed in this figure that the transmitting and receiving antennas each have a height of 30 ft and that the power at the transmitter is such that the inverse-distance field strength is 100 mv per meter at 1 mile (161 mv per meter at 1 km). This becomes the datum point from which subsequent levels are calculated. A conductivity of 5×10^{-14} emu and a dielectric constant of 15 have been assumed. The curves marked "*H*" apply to horizontally polarized transmission, while the curves marked "*V*" apply to vertically polarized transmission. Because of the excessive ground-wave attenuation of horizontally polarized waves in this frequency range, they will not be considered at greater length in this section.

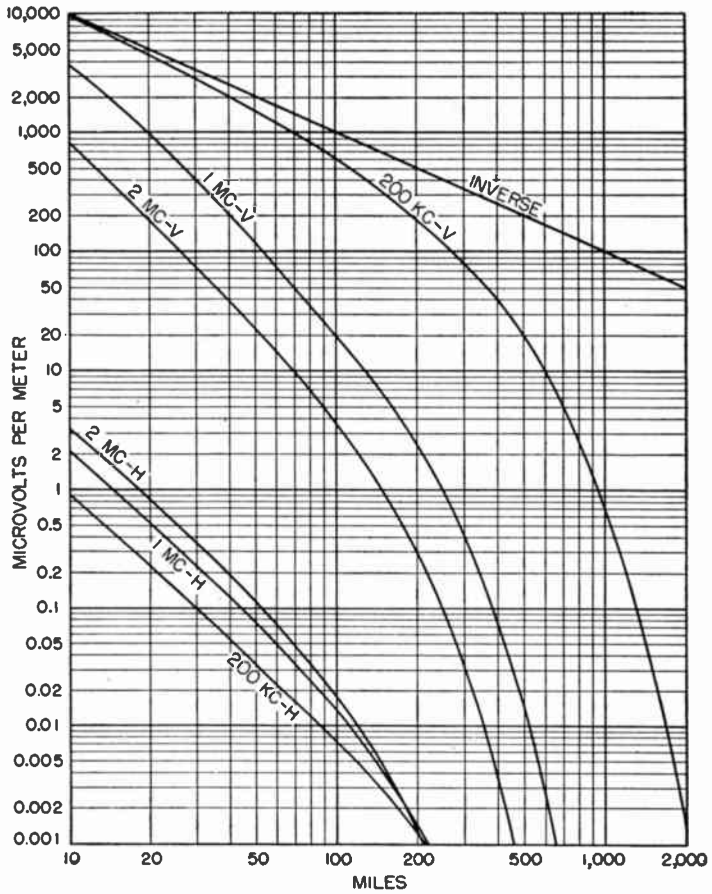


Fig. 1 Ground-wave field strength prevailing at various distances from a transmitter. It is assumed that the transmitting power is such that the field strength of 100 mv per meter prevails at a distance of 1 mile (161 mv per meter at 1 km) and that the soil has a dielectric constant of 15 and a specific conductivity of 5×10^{-14} emu.

Accuracy and Limitations Theories for the computation of ground-wave propagation assume the idealized condition of homogeneous earth throughout the entire transmission path. They further assume a smooth earth without structures or irregularities. The first step in the computation of a ground-wave signal is the choice of appropriate values of conductivity and dielectric constants of the earth. Since an adequate sample of earth cannot be measured by direct means, these values are determined in practice by measuring the attenuation of a ground-wave signal over the path in question and then matching this experimentally determined attenuation to one of a set of theoretically derived curves. These measured values are so made as to include a minimum of local effects such as structures and overhead wires. By this means it is possible to fix the effective conductivity and dielectric constant. (Such determination of ground constants is influenced to some extent by terrain irregularities and by the degree of homogeneity of the soil.) These constants are then used for computations at other frequencies. It has been found in practice that the ability to predict expected fields is satisfactory, although the accuracy is not extremely high when the transmission-path characteristics depart widely from the theoretical assumptions of a homogeneous and smooth earth.

When the field is produced by a number of sources such as from the radiators of a directional antenna and particularly in the direction of the suppressed signals, the effects of terrain irregularities as well as nonhomogeneous earth may result in considerable differences in the apparent conductivity and dielectric constant.

The deviations of the field due to irregularities tend to increase with the increasing frequency. Irregularities in terrain, structures, trees, and overhead conductors will generally result in a lower average field.

Frequently the transmission path will contain sections of different conductivity and dielectric constant. Several methods have been devised [4,5,6] to utilize theoretical curves derived for single-valued homogeneous earth. Some of these methods do not satisfy the usual concept of reciprocity in that transmission in one direction over a given path is not computed to be the same in the opposite direction.

Variations with Time Due to Changes in Conductivity Within moderately short distances, the ground-wave field strengths are relatively independent of ground conditions, such as the moisture content of the soil, and remain fairly constant from hour to hour and day to day. This, of course, applies where there is no sky-wave field or where the sky-wave field is very small in relation to the ground-wave field. There is, however, substantial evidence of temperature or seasonal effect [7] which results in less attenuation in winter or during periods of low temperature. At greater distances there are variations in field strength, the causes of which are not well established, but since they are small compared with variations in the sky-wave component, about to be discussed, they are of secondary interest.

Sky-wave Propagation

In this frequency range, waves are reflected mainly by the E layer (particularly at the lower frequencies) and are returned to earth at relatively short distances. As a result there is a considerable area around a transmitting station in which both ground waves and sky waves are received. This is most noticeable at night. In this inner area, conditions are favorable for wave interference and a considerable amount of fading and signal distortion may be expected. Outside this area, the sky wave predominates and acceptable, though somewhat variable, transmission is experienced. It is this region which is assumed in the discussion that follows.

Calculated vs. Measured Sky-wave Data Numerous attempts have been made to calculate sky-wave field strengths by assuming reasonable values for such pertinent factors as the height and reflection coefficient of the ionosphere. However, because these data are seldom known and because a large amount of measured field-strength data are now available, the latter are usually preferred. A particularly complete set of such data, representative of overland paths in North America, was collected between the years 1935 and 1946.[8] A large part of these data were taken in 1944, a period of low sunspot activity and hence a period when variations in the ionosphere were near a minimum. Though they apply particularly to the band 540 to 1,600 kc, they are believed to apply in a general way to the entire band covered by this chapter. Generalities based on these data follow:

1. Nighttime sky-wave field strengths may be a hundred or more times as great as the corresponding daytime field strengths. Daytime field strengths may, however, be sufficient for practical operation at great distances, provided sufficient power is transmitted and local radio noise conditions are favorable.

2. Sky-wave transmission in this band is affected by the latitude of the reflection point of the transmission path.

3. There is a tendency in this band for LF sky-wave field strengths to be greater than the corresponding HF field strengths, but such correlations are obscured by other effects such, for example, as the variation with latitude.

4. Fading conditions are such that the instantaneous sky-wave field strengths within any nighttime hour follow the so-called Rayleigh distribution. The constants for this case are such that, if E_m is the field strength exceeded 50 per cent

of the time, we may compute the instantaneous field strength E prevailing p per cent of the time by the relation $E = E_m \left[1.823 \left(\log \frac{100}{p}\right)^{1/2}\right]$. Calculations show that, for $E/E_m \geqq 2$, $p \doteq 6.2$ per cent and for $E/E_m \gtreqless 1/2$, $p \doteq 84$ per cent. That is to say, the field strength is greater than twice its median value * only 6.2 per cent of the time but it is greater than one-half this value about 84 per cent of the time.

5. Sky-wave propagation is subject to a diurnal variation typified by the following: Beginning approximately 3 hr before sunset and continuing for 2 hr or more after sunset, field intensities increase by a ratio of 10 or more. Except for the fluctuations already mentioned, these levels remain fairly constant until about an hour before sunrise, when they begin to fall. The fall continues until several hours after sunrise, when they regain their normal low daytime levels. The rate of increase appears to be affected somewhat by the frequency and also the length and direction of the path.

6. There is the suggestion of higher sky-wave field strengths in winter than in summer and even stronger evidence of 27-day and 11-year cycles of improved transmission. The latter suggest a relationship with sunspot activity.

Representative Sky-wave Field-strength Data Based on the above data, composite curves have been formulated in Fig. 2 to show the variation of field strength with distance for various latitudes in North America, each for three different conditions as follows: The upper group (*a*) gives the nighttime field strengths which were exceeded 10 per cent of the

* The median divides a group of data into two parts such that there are as many values greater than the median as there are values less than the median. Usually the median differs from the mean. Thus the median of the numbers 1, 3, 4, 8, 9 is 4. Their mean is 5.

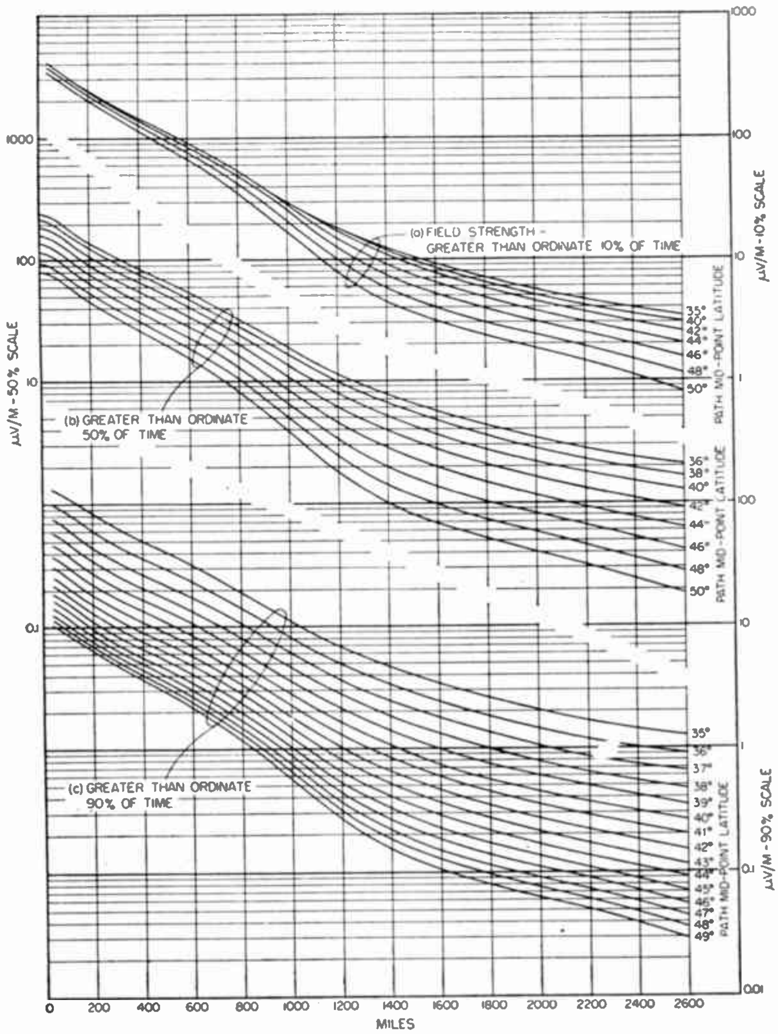


Fig. 2 Median hourly sky-wave field strengths prevailing, (*a*) 10 per cent of the year; (*b*) 50 per cent of the year; and (*c*) 90 per cent of the year.

time during a particular year. The second group (*b*) gives corresponding values exceeded 50 per cent of the time. The third group (*c*) corresponds to 90 per cent of the time. In this illustration, the observed data have been adjusted to an arbitrary power at the transmitter corresponding to 100 mv per meter at a distance of 1 mile (1.61 km), radiated at a vertical angle corresponding to one reflection from the ionosphere by a vertical antenna 0.311 wavelength long excited with respect to the earth.

Miscellaneous Propagation Effects

The ideal condition of a plane wave front with uniform polarization is seldom obtained. Departure from this ideal may be important in the performance of a service. Changes in the wave front or polarization result from irregularities, which may vary from path to path and with time.

Polarization and Directional Effects For some types of services, particularly direction finding by the use of loop antennas, the presence of a horizontally polarized field component results in erroneous readings. By the use of other types of direction-finding equipment, these errors may be reduced. The horizontal component occurs as a result of reflection from the ionized layer. In general this effect is most serious at the shorter distances and diminishes with increasing distance. The component is variable with time and location. For other types of services the presence of horizontally polarized components may be of little importance.

When the transmission path is nonhomogeneous and particularly when it is marked by variations in conductivity such as along a coast line, the wave front may be so shifted as to give the wave the appearance of arriving from a direction other than that of the transmitter. The effect is complicated by the angle the path makes with the coast line, the distance from the coast, and other factors.

When transmission is principally by sky wave, errors occur due to actual lateral deviation of the wave propagation path from that of a great-circle path.[9] For example, at 50 miles, bearing errors up to 30 deg may result, although the probable error is 7 deg.

Variations in Delay Time For some services such as loran, the reliability of the transmission time or delay time is very important and variation in this time may result in errors of appreciable magnitude. Variations in delay time are most common in sky-wave propagation, where transmission may take place by paths of different lengths. As a practical matter it has been found that services such as loran [10] can use frequencies within this band and that errors introduced by variations in delay time are not excessive.

Radio Noise

Of the various sources of radio noise prevailing in this band of frequencies, atmospheric noise and man-made noise are of greatest importance. As in other parts of the radio spectrum, so here, atmospheric noise is due to the integrated effects of all the thunderstorms occurring at the moment throughout the world. In the daytime, where only the ground-wave transmission prevails, only local thunderstorms are important. In northern latitudes these occur mainly in summer, often in the late afternoon. At night when the sky wave predominates, the effects of storms hundreds of miles away are added. The latter may be so great as to constitute an almost constant source.

Radio-noise Data The systematic survey of transmission referred to above included measurements of radio noise prevailing at numerous points throughout North America.[8] The data have been analyzed and have been reduced to an equivalent field strength, assuming that the noise is received at a frequency of 1,000 kc over a band 4 kc wide.

General conclusions based on this survey follow:

1. Atmospheric noise is greater in the summer than in winter and greater at night than in daytime. Sometimes the ratios are 15 or more to 1.

2. Atmospheric noise is markedly affected by geographical location. In North America, for example, daytime median values are a maximum at about 1.6 μv per meter in the vicinity of the Florida peninsula, decreasing progressively both to the North and to the West to values of perhaps one-twentieth this level in northern Maine and in central California. In northwestern California the noise level is even lower. Median nighttime values follow a similar pattern, but their levels are higher by a factor of about 5.

3. Atmospheric noise decreases with frequency to a greater extent in the daytime than at night.

4. The sources of man-made noise are particularly numerous and powerful in industrialized areas. Thus the man-made noise level is generally much higher in factory areas than in residential areas and is least in rural areas.

Summary of Uses of Frequencies 200 to 2,000 Kc

The lower portion of this band is useful for services, such as aural broadcasting, requiring some stability as well as moderately long-distance transmission during both day and night. Such services need to be capable of operation in the presence of considerable atmospheric noise; this requires substantial transmitter power. In the upper portion of this band, the ground wave is weaker but the sky wave prevailing at night is correspondingly enhanced. These upper frequencies may also be used for broadcasting; some of the finer qualities of sound reproduction are at times sacrificed for long-distance range. Within this band, the utilization of directional antennas with a moderate degree of directivity becomes feasible, with corresponding improvements in effective power and interference reduction. Directivity may be used to compensate in part for the severe attenuation of the ground wave. This frequency range may also be used for direction finding and for special location services such as loran.

2.4 PROPAGATION CHARACTERISTICS OF THE SPECTRUM FROM 2 TO 30 MC

For general information beyond that supplied in this brief survey the reader is referred to more comprehensive discussions such as the descriptive article by Dellinger,[1] the technical surveys by Mimno[2] and Mitra,[3] and the treatment of practical applications by Tremellen and Cox[4] and the National Bureau of Standards.[5]

The Ionosphere

The frequency range from 2 to 30 mc depends principally on the ionosphere for its propagation characteristics. The importance of ground-wave propagation is small compared with that of propagation via the ionosphere.

The ionosphere has four principal regions, or layers, which affect the propagation of radio waves. They are called the D, E, F_1, and F_2 layers, respectively, in the order of increasing height above the ground and increasing ionization density.

The E, F_1, and F_2 layers are primarily reflectors of radio waves. The D layer is primarily a region of absorption. It reduces the strength of waves which pass through it and are reflected from the higher layers, and it is located below the E layer between about 50 and 90 km (between about 30 and 55 miles).

In Fig. 3 is shown a typical distribution of electron density with height in the E, F_1, and F_2 layers, which illustrates their relative heights, thicknesses, and maximum densities. Note that these layers are not completely separated but overlap to some extent. Overlapping between the F_1 and F_2 layers varies considerably. The example in Fig. 3 is typical of summer daytime in temperate latitudes. During winter daytime in these latitudes, especially near sunspot maximum, the F_1 and F_2 layers are almost completely merged.

The maximum electron density in a layer and the angle of incidence of the radio wave upon it determine the maximum frequency of a radio wave which can be reflected by the layer. For reflection at vertical incidence this frequency is called the *critical frequency* of the layer.

The main features of the structure and the diurnal, seasonal, and geographical variations of the D, E, and F_1 layers are adequately explained in terms of the ionization produced by absorption of ultraviolet solar radiation and the rate of recombination of the ions.[6] For daytime, diurnal, seasonal, and geographic variations of electron density are simply related to the angle of the sun above the horizon. At night, recombination of the ions is the controlling factor.

The F_2 layer is much more complex. This layer exhibits strong solar control. The electron density builds up rapidly at sunrise, reaches a maximum during the day, and decays at night, but the density is not simply related to the sun's zenith angle and at night does not behave as though only simple

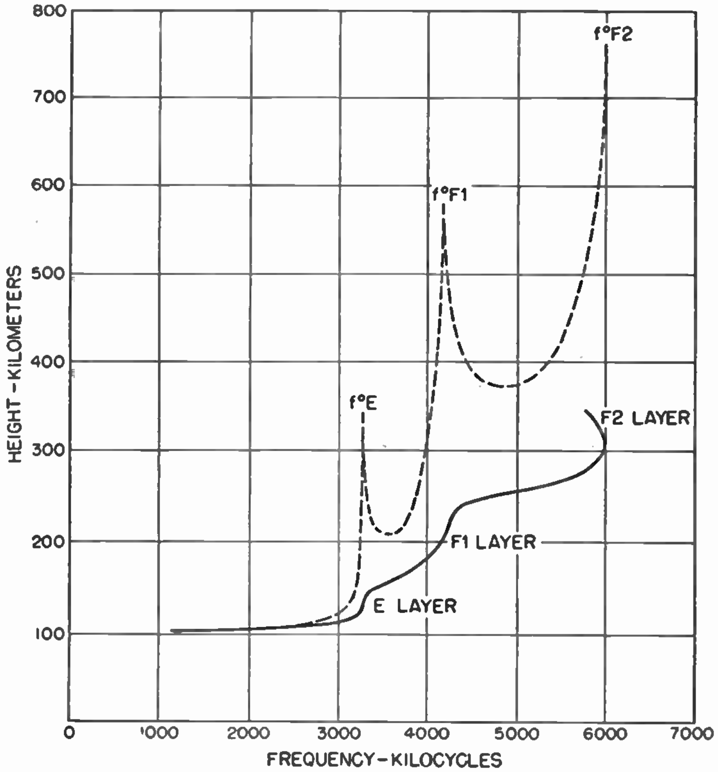


Fig. 3 Solid curve: Typical distribution of electron density with height above the earth's surface. The number of electrons per cubic meter is 1.24×10^4 times the square of the frequency in kilocycles. Dashed curve: Virtual height of reflection of the ordinary wave as a function of frequency.

recombination were controlling. Also, the earth's magnetic field exerts a strong influence on the behavior of the F_2 layer, as exemplified by radical variations in characteristics in the vicinity of the geomagnetic equator.[7]

All the layers show sunspot-cycle variations, those of the F_2 layer being greatest. Noon critical frequencies at Washington, for example, increase by a factor of about 2 for the F_2 layer and about 1.2 for the E and F_1 layers between sunspot minimum and sunspot maximum.

Besides the regular variations, the layers exhibit important irregularities, discussed later in this section. The type called sporadic E results in reflection of waves from the E region at frequencies above the normal-E critical frequency, at times even well above the F_2 critical frequency.

Propagation of Waves by the Ionosphere A greater electron density is required to reflect radio waves back to earth, the higher the wave frequency. If N is the maximum electron density in a layer of the ionosphere (per cubic meter) and f is the critical frequency, *i.e.*, the maximum frequency at which waves sent vertically upward are reflected back to earth (in kilocycles per second), $f = \sqrt{N/12{,}400}$. Waves of all frequencies below this value are reflected, but those of all higher frequencies pass upward through the layer.

This relation is a first approximation. Complication is introduced by the presence of the earth's magnetic field.[8] Upon entering the ionosphere, the wave is caused by the magnetic field to divide into two oppositely rotating elliptically polarized components, called the ordinary and extraordinary waves. At vertical incidence the level of reflection and the critical frequency of the ordinary wave are the same as though no magnetic field were present. The extraordinary wave is reflected at a lower level, and its critical frequency is somewhat higher.

The structure of the ionosphere and its wave-propagation properties have been explored largely by means of a radio pulse method first applied in 1925 by Breit and Tuve.[9] In this method short radio pulses or wave trains are transmitted vertically upward and received on a nearby receiving set after reflection from the ionosphere. The time required for the pulses to travel to and from the ionosphere is a measure of the virtual height of reflection. Because the wave is retarded along its path in the ionized medium, the observed virtual height is always greater than the actual height at which reflection takes place. Near a critical frequency the retardation and therefore the virtual height become very great. A typical curve of virtual height vs. frequency is shown in Fig. 3.

Oblique Incidence The upper limit of frequencies at which waves are reflected back to earth is greater for waves entering the ionosphere obliquely than for waves entering vertically. The oblique-incidence limit, called the maximum usable frequency (MUF) is approximately the vertical-incidence limit (the critical frequency) multiplied by the secant of the angle of incidence. Another form of the relation is $\text{MUF} = f^{\circ}(D^2/4h^2 + 1)^{1/2}$ where D is the distance from transmitter to receiver, h is the vertical height of the reflecting layer, and f° is the critical frequency. For great transmission distances, a correction is required because of the spherical curvature of the ionosphere.

The transmission distance corresponding to the MUF is called the "skip distance." It is the minimum distance over which that frequency is receivable. Thus, there is a zone around the transmitter in which that frequency is not receivable. In this zone, that or any higher frequency passes through the ionosphere layer instead of being reflected back to earth.

"Modes" of Propagation Radio waves which are reflected back to earth by the ionosphere are again reflected by the earth and may travel all the way around the earth by a series of reflections between ionosphere and earth, provided they do not encounter a region of the ionosphere for which the

skip distance is greater than the distance between successive earth reflections. Because of the earth's curvature, the limiting distance for a single hop is approximately 2,000 km for reflection by the E layer and about 4,000 km for reflection by the F_2 layer. Transmission between two points on the earth's surface may take place by several combinations of hops called "modes" of propagation. The minimum number is that for which the length of each individual hop is no greater than about 4,000 km. The maximum number is that for which the length of each individual hop is not less than the skip distance. Interference between waves arriving by two or more modes of propagation with comparable field strengths produces fading.

Maximum Usable Frequency

The approximate relation MUF $= f^\circ (D^2/4h^2 + 1)^{1/2}$ indicates the way the MUF depends upon distance D, virtual height h, and critical frequency f°. A typical variation of MUF with distance is shown in Fig. 4. It is based on the ionospheric layers depicted in Fig. 3. The MUF for 1-hop-E, 1-hop-F_1, and 1-hop-F_2 modes are shown. Note that in this example, although the F_2 layer controls the MUF at short and long distances, the E layer controls at intermediate distances. This is not always the case, however.

Since the heights of the E and F_1 layers are nearly constant, MUF variations for these layers at a fixed distance depend almost entirely on the critical frequency variation. The height of the F_2 layer, however, does vary considerably. At short distances the effect on the MUF is small but at large distances may be substantial. At Washington, D.C., for example, for a distance of 3,000 km the F_2-layer MUF factor $(D^2/4h^2 + 1)^{1/2}$ for undisturbed conditions varies between about 2.5 and 3.5 depending upon the time of day, season,

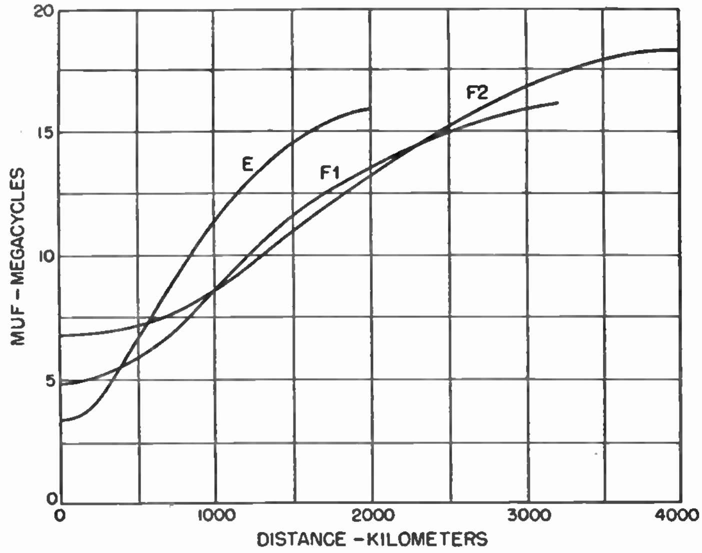


Fig. 4 Variation of maximum usable frequency (MUF) with distance for the layers shown in Fig. 3. Note that, whereas the F_1 and F_2 MUF curves involve the extraordinary wave, the E MUF curve is based solely on the ordinary wave. The extraordinary wave from the E layer is usually too greatly weakened by absorption to be usable.

and sunspot number. The factor is somewhat higher in winter than in summer and somewhat higher at sunspot minimum than at sunspot maximum. Diurnally, the highest values tend to occur near sunrise and sunset.

Although the true nature of sporadic-E reflections is not yet well understood, the MUF factor seems to be about the same as for the normal-E layer.

Regular Variations, E and F_1 Layers The regular variations of the E and F_1 MUF at fixed distances are almost entirely due to critical frequency variations. During daylight hours the diurnal, seasonal, and geographic variations of the latter are quite well represented by the function $f_o°(\cos Z)^{1/4}$ where

$f_0°$ is the critical frequency at the place directly beneath the sun $(Z = 0)$ and Z is the zenith angle of the sun. Typical diurnal variations for each of these layers are shown in Fig. 5. The critical frequency rises quickly in the morning, attains a maximum shortly after noon, and then decreases rapidly as sunset approaches. The F_1 critical frequency is not observed after sunset because the F_1 layer then merges with the F_2 layer. The E critical frequency is difficult to observe after sunset, but it has been shown that, after dropping rapidly during the sunset period to about 2 mc, it decreases slowly during the night, reaching a minimum of about 1 mc in summer and a minimum of about 0.5 mc in winter.

For a given value of the solar zenith angle the critical frequency is proportional to sunspot number R according to the relation

$$f_{ZR}° = f_{Z0}°(1 + 0.002R)$$

All the regular daylight variations of these layers are therefore represented by $f_{ZR}° = f_{00}°(1 + 0.002R)(\cos Z)^{1/4}$, where $f_{00}°$ is the value of the critical frequency for $Z = 0$ and $R = 0$. For the E layer $f_{00}°$ is about 3.5 mc, and for the F_1 layer $f_{00}°$ is about 4.5 mc.

Actually none of the characteristics of the ionosphere which vary with sunspot number correlate well with individual daily sunspot numbers. The sunspots are not the cause of ionosphere variations but are rather symptoms of solar activity which affects the ionosphere. Relatively long-term (yearly) averages of daily sunspot numbers are, however, good indicators of solar activity, and it is such averages that are implied by the symbol R. At the sunspot maximum of 1947, the highest in the history of reliable sunspot numbers, the yearly average number exceeded 150. For the average cycle the maximum is about 90.

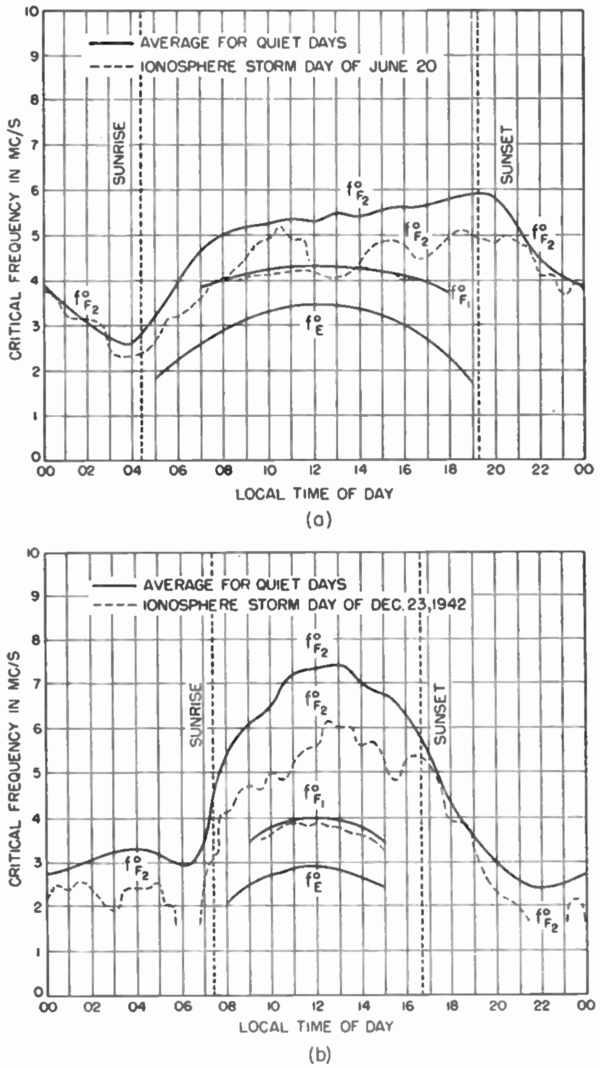


Fig. 5 Diurnal variations of critical frequencies observed at Washington, D.C. (*a*) June, 1942; (*b*) December, 1942.

During the last maximum the E-layer 2,000-km MUF for $Z = 0$ actually exceeded 21 mc. As far away from the equator as Washington, D.C., it exceeded 19 mc.

Regular Variations, F_2 Layer Although the variations in the virtual height of reflection of the F_2 layer affect the MUF somewhat, especially at the longer distances, the effect of critical frequency variations is far greater. During a day the critical frequency may vary by a factor of 3 or 4, and the over-all diurnal, seasonal, and sunspot-cycle variation may amount to more than a factor of 6.

The diurnal, seasonal, and geographical variations are markedly different from those of the other layers. Typical middle-latitude diurnal variations are shown in Fig. 5. Note that, in this case, night values of the critical frequency are lower in winter than in summer but day values are higher in winter than in summer.

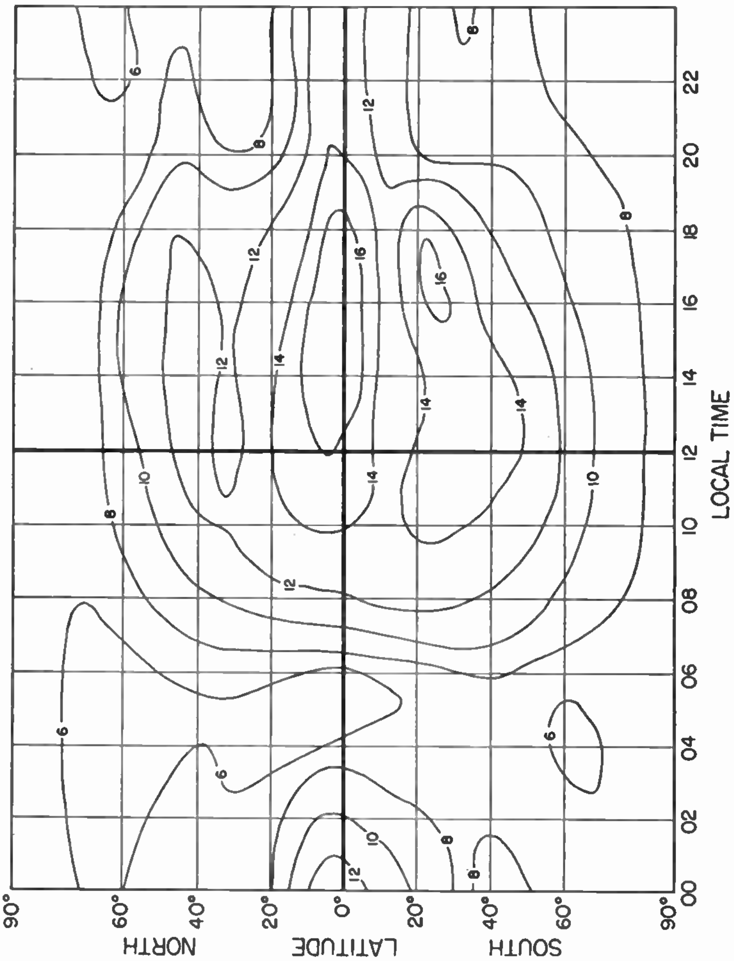
Unlike the E and F_1 layers, the F_2 layer is strongly influenced by the earth's magnetic field. In the Western Hemisphere at about 75° W longitude, the magnetic equator lies about 12 deg south of the geographic equator and on the opposite side of the earth lies about 12 deg north of the geographic equator. Along the same geomagnetic latitude the F_2 layer has similar characteristics, but these vary markedly from one latitude to another especially near the geomagnetic equator. At places having the same geomagnetic and geographical latitudes, the characteristics are almost identical.

The amount of variation of F_2 critical frequencies with sunspot number varies widely, depending upon the time of day, season, and geographic locations, from almost zero to more than a factor of 2 between sunspot minimum and maximum. In certain cases the combination of a small critical frequency variation and an inverse variation of the MUF factor results in a small inverse variation of the MUF with sunspot number.

To illustrate the complexities of the F_2-layer variations, predictions of zero and 4,000-km MUF for March, 1947, are shown in Fig. 6. These predictions refer to longitudes near 75° W. At other longitudes the contours are shaped differently, owing to the longitude effect associated with the earth's magnetic field mentioned above. Note that at sunspot maximum the 4,000-km MUF reaches 40 mc in middle latitudes and 50 mc near the equator. At sunspot minimum the 4,000-km MUF is limited to about 30 mc near the equator and to about 20 mc in middle latitudes.

Near the geomagnetic equator there is a strong effect of lunar tides on the F_2 layer,[10] which produces variations in critical frequency of as much as 30 per cent.

Day-to-day Variations of MUF Analysis of the trends of ionosphere characteristics measured over a number of years at many places on the earth has provided the basis for forecasts of the monthly average or median values of these characteristics. In the case of E- and F_1-layer MUF this amounts to a forecast of daily values, as their departures from the monthly values are usually insignificant. In the case of the F_2 MUF and sporadic-E MUF the daily departures are significant, but so far it has not been possible to forecast them accurately. The statistical dispersions have, however, been studied extensively. To a rough approximation, the dispersion of F_2 critical frequencies or MUF is such that during a month 10 per cent of the values lies below 85 per cent of the median and 10 per cent lies above 115 per cent of the median. A rough rule of thumb for sporadic-E reflections is that the frequency exceeded (at vertical incidence) on 90 per cent of the days of a month is 1 mc less than the value exceeded on 50 per cent of the days.



LOCAL TIME
(a)
00
02
04
06
08
10
12
14
16
18
20
22
90°
60°
40°
20°
0°
20°
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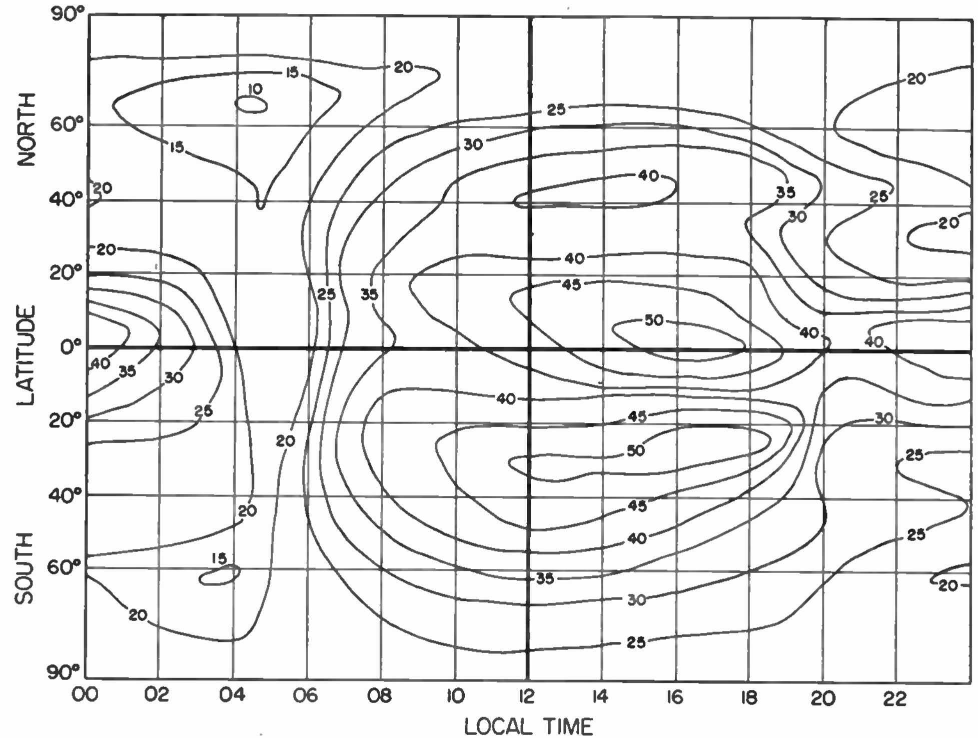
60°
90°
NORTH
LATITUDE
SOUTH



(b)

Fig. 6 F_2 layer MUF as a function of latitude and local time for longitude in the vicinity of 75° W, as predicted for March, 1947, by the Central Radio Propagation Laboratory. Numbers on contours give MUF in megacycles. (*a*) Zero distance MUF (vertical incidence); (*b*) 4,000-km MUF.

Predictions of MUF Maximum usable frequency predictions based on trends established by analysis of systematic ionosphere measurements made at a large number of stations throughout the world (the present number is about 60) are available in a regular service offered by ionospheric laboratories in several countries. In the United States the Central Radio Propagation Laboratory of the National Bureau of Standards publishes monthly predictions 3 months in advance, which are widely used by radio-communications companies, government users of radio communications, and amateurs.

Field Strength

The field strength of the downcoming sky wave is the resultant of the field strengths of all the separate waves arriving by different modes of propagation (single and multiple reflections, or hops). The waves arriving by different modes differ not only in direction of arrival but also in amplitude, phase, and state of polarization. The voltage available at the antenna terminals due to an individual mode depends upon the power radiated by the transmitter, the gain of the transmitting antenna in the direction of wave departure, the distance traveled by the wave (inverse distance attenuation), losses by scattering and absorption at ionosphere and earth reflections, diffraction caused by irregularities in the reflecting medium, focusing effects of ionosphere curvature, skip focusing near the skip distance, the polarization of the wave, and finally the gain of the receiving antenna in the direction of arrival of the wave. Varying irregularities in the medium cause fluctuations in the amplitudes and polarization of individual modes; this, together with interference between modes, causes fading of the received signal, discussed further under Fading, below. Absorption of the wave energy in the ionosphere is a major factor determining received field strength.

Ionospheric Absorption Absorption of energy from the radio wave takes place as a result of collisions between the molecules of the atmosphere and the electrons which have received kinetic energy from the radio wave. The degree of energy absorption is expressed by the "absorption coefficient," which is proportional to the product of the electron density and the collision frequency and approximately inversely proportional to the square of the wave frequency. At the lower frequencies during daylight hours, absorption is the principal cause of the attenuation of radio waves propagated by the ionosphere.

Most ionospheric absorption takes place in the D region. Here the electron density is not so high as in the E and F regions, but the atmospheric density and therefore the collisional frequency are much higher. Since the electron density in this region is simply related to the zenith angle of the sun, absorption has a similar relationship. For waves passing entirely through the absorbing region, the variation of the absorption is quite well represented simply by cos Z ($Z =$ solar zenith angle).[11] At night, absorption is small, and to a first approximation the field strength is independent of the frequency. The variation with distance is given by secant φ_D, where φ_D is the angle of incidence at the absorbing region. The solar cycle variation is given by the factor $(1 + 0.005R)$, where R is the sunspot number.

The following table of estimated median field strengths[5] in microvolts per meter for paths centered at 45° latitude will give an idea of the effect of absorption at different frequencies and distances.

The power is the equivalent of 1 kw radiated from an isotropic antenna. The paths are oriented east-west, and the time of day is noon at the mid-point of the path for the columns headed Day. The night field strength, which is approximately independent of frequency, is given in the column headed Night. The values given are for summer sunspot minimum absorption conditions. In order to show absorption variations, effects of skip at the higher frequencies have been ignored.

		Day				
	Night	3 *mc*	5 *mc*	10 *mc*	15 *mc*	25 *mc*
800 km (500 miles)	100	0.3	1	50	75	90
3,000 km (2,000 miles)	35	$<10^{-3}$	10^{-2}	5	15	25
8,000 km (5,000 miles)	8	$<10^{-3}$	$<10^{-3}$	3×10^{-2}	1	4

Day-to-day Variations of Field Strength Besides the regular predictable diurnal, seasonal, and solar-cycle variations of received voltage, there are irregular unpredictable day-to-day variations. The statistics of these variations and their dependence upon frequency, path length, time of day, and season have been studied by the Central Radio Propagation Laboratory. The data analyzed were hourly median values of received voltage recorded at Washington, D.C., during the year 1944 from transmissions by a number of stations varying in distance from 590 to 6,580 km and in frequency from 770 to 15,310 kc. The average ratio of the value exceeded on 10 per cent of the days of the month at a particular hour of the day to the value exceeded on 90 per cent of days was approximately 4. The variations of this ratio for different transmission paths, hours of the day, and months of the year were such that in 10 per cent of the cases the ratio was less than 2 and in 10 per cent of the cases greater than 8. However, the ratio showed no appreciable dependence upon frequency, distance, or time of day, except in the case of paths approaching the auroral zone for which the ratio was significantly greater than for other paths. The results for frequency and distance variations are not conclusive, because frequency and distance were correlated in the data.

Distance Ranges

Outside the skip zone the field strength decreases with increasing distance from the transmitter, and at some distance called the "distance range," the field strength becomes too low for useful communication. This distance depends upon many variables. It depends in part upon the radiated power; the higher the power, the greater the distance range. But the *rate of increase* of distance range with power depends upon the *rate of decrease* of field strength with distance. At night, when the rate of decrease of field strength with distance is small, a given increase in power results in a much greater increase in distance range than during daytime, when the rate of decrease of field strength with distance is great.

The distance range also depends upon the minimum required field strength, which is a function of the radio noise level at the receiving station and the type of service (radio telephone, radio telegraph, etc.). As with power, the effect of a change in the required field strength is greater at night than during the day.

The rate of decrease of field strength with distance is greater for low frequencies than for high frequencies, especially during the day. Consequently a given change in power, or in required field strength, produces a greater change in distance range at a high frequency than at a low frequency.

The distance range is thus a complicated function of the power and of all the variables which affect field strength and required field strength, *i.e.*, frequency, time of day, season, sunspot number, degree of ionospheric disturbance, orientation and geographical location of the transmission path, and the geographical location of the receiving station.

For a given power and required signal-to-noise ratio the variations of distance range may be summarized as follows:

1. Distance ranges increase with increasing solar zenith angle, being greater at night than during the day, greater in winter than in summer, and greater in high than in low latitudes (barring paths through the auroral zone and regions affected by ionospheric storms).
2. For transmitting stations located in intermediate latitudes, distance ranges are greater in directions away from the equator than in directions toward the equator.
3. Distance ranges decrease with increasing sunspot number.
4. Distance ranges increase with increasing frequency.

Limits of Usable Frequencies for Fixed Distances

The MUF constitutes the *upper* limit of the band of frequencies useful for communication over a fixed distance. This limit is practically independent of the power of the transmitting station. The *lower* limit, or lowest useful frequency (LUF), is the frequency below which the signal-to-noise ratio is less than that tolerable in the type of communication employed. Such a limit usually exists because the field strength of the desired transmission tends to decrease with decreasing frequency while that of atmospheric radio noise tends to increase or at least to decrease less rapidly. The lower limit is a function of the transmitter power, the required bandwidth, and the required signal-to-noise ratio. Specifically, it is a function of the ratio of the power to the product of the bandwidth and the required signal-to-noise power ratio. It is also a function of the directional pattern of the transmitting antenna and, to the extent that it controls the signal-to-noise ratio, of the directional pattern of the receiving antenna.

For a given power, bandwidth, and minimum required signal-to-noise ratio, the LUF varies over a wide range as a function of time of day, season, sunspot number, and geographical location, all of which affect both signal and atmospheric noise levels, and of transmission distance, which also affects the signal level. The LUF is typically higher during the day than at night, higher in summer than in winter, higher in low latitudes than in high latitudes, higher at sunspot maximum than at sunspot minimum, and, of course, higher at long than at short distances. Fortunately the MUF has similar variations, so that the range of useful frequencies does not fluctuate so much as the extremes.

On long east-west paths, the LUF may exceed the MUF at certain times of the day and thus make communication impossible. This is due to the fact that the MUF for the path is the least of the values of MUF for the individual hops along the path, while the LUF depends upon the integrated effect of absorption in all the hops. When the sun rises at the eastern end of the path, absorption and LUF begin to rise, but the MUF does not begin to rise until the sun rises on the westernmost hop. The LUF may exceed the MUF in this period. This situation may occur again near sunset, but the tendency is weaker because the MUF does not decrease so rapidly at sunset as it increases at sunrise.

A result of the diurnal, seasonal, and sunspot-cycle variations in MUF and LUF is that in most cases more than one frequency must be provided in order to maintain sky-wave communication between two points at all times throughout the day, year, and sunspot cycle.

Effects of Ionosphere Irregularities

Thus far the regular predictable variations of ionosphere and radio-propagation characteristics have been primarily discussed. Certain irregularities or disturbances which have important effects on radio communication will now be described. In middle and equatorial latitudes irregularities are secondary in importance to the regular variations. In the auroral regions, however, where disturbances are frequent and severe, the irregularities are the main features of the ionosphere and of radio propagation.

Sporadic E One of the most prevalent of the irregularities, which is not yet well understood, is the sporadic occurrence of a condition in the E layer which reflects waves at frequencies above the normal E-layer MUF. The character and prevalence of this condition vary widely. In low latitudes sporadic E is usually a relatively weak "partial" reflection which occurs mainly during daytime. At higher latitudes it is often more nearly a total reflection and occurs at night as well as during the day. It is especially prevalent and strong in the auroral zone, where its occurrence is correlated with general auroral-zone disturbance. Seasonally, sporadic E is at a maximum in summer.

Sporadic E accounts for sky-wave transmission up to higher frequencies than by any other means. Amateurs working in their 50-mc band occasionally are able to make contacts over considerable distances (up to the limit of 1-hop-E) by sporadic-E reflection. Because of its irregular nature sporadic E usually cannot be depended upon for reliable communication.

Scattered Reflections Irregularities in the distribution of ionization cause scattered or diffuse reflection of radio waves in contrast to the mirrorlike reflections obtained when the distribution is smooth. The strongest diffuse reflections known as "spread echoes" occur at F-layer levels, at times even obscuring the normal F-layer reflections. They are mostly observed at night, especially in equatorial regions, and during ionosphere storms. Scattering of much weaker amplitude occurs in the E region at all times.

Scattering may introduce large direction-finding errors. Consider, for example, a sharply beamed transmission aimed obliquely upward. A direction finder located within the skipped zone of the transmitting station would receive waves scattered from the area where the beam intersected the E region, which could be in a direction up to 180 deg from the direction of the transmitting station.

Sudden Ionosphere Disturbances Occasionally a sudden outburst of ultraviolet light on the sun, known as a solar flare or chromospheric eruption, produces abnormally high ionization densities in the D region which result in a sudden increase in radio-wave absorption, especially at the lower frequencies. It has negligible effects on the critical frequencies and heights of the reflecting layers, but the reduction of received field strengths may be enormous. This phenomenon is called sudden ionosphere disturbance (SID).[12] It often results in a complete loss of communications, and its effects may last for several hours in severe cases. Since the SID is produced by direct ultraviolet radiation, it never occurs on the dark side of the earth.

The frequency of occurrence of SID varies with the sunspot cycle, being greatest at sunspot maximum. The time of occurrence cannot be predicted in individual cases, but it has been found [13] that SID tend to occur in groups on the same day or successive days and to repeat at intervals of one or more solar rotations.

To give an idea of the nuisance value of the SID, the following data on SID observed at Washington, D.C.,[13] are presented. During the sunspot maximum year of 1937 SID were observed on 84 days. On 66 of these the SID was classified as intense, on 39 days there were more than one SID, and on 33 days the SID lasted more than an hour. In the sunspot minimum year 1944 the corresponding numbers were only 5, 3, 0, and 2. In the sunspot maximum year 1947 they were again high, 121, 104, 54, and 33.

Ionosphere Storms In medium and high latitudes, ionosphere storms are the most troublesome of the ionosphere irregularities. They may occur at any time of the year but have a noticeable preference for the equinoxes. They usually last for several days—several weeks in unusual cases—and their effects are felt during the night as well as during the daylight hours.

They are caused by charged particles from the sun. Such particles are continually bombarding the auroral zones (regions near the two poles of the earth), being guided in along the lines of the earth's magnetic field. The influx of such particles is irregular. When it increases greatly, the influence extends out from the auroral zones to lower latitudes; occasionally worldwide ionosphere storms result.

Except in the auroral zone itself, which expands during a storm, there is little effect on the E layer and only minor effect on the F_1 layer, but the F_2 layer is profoundly affected. It is greatly expanded and diffused, resulting in decreased critical frequencies and increased virtual heights. During daylight hours the F_2 critical frequency may even drop below the F_1 critical frequency (see Fig. 5). The MUF is, of course, decreased also. Increased turbulence of the layers results in rapidly fading or fluttering signals, and received field strengths are lower (absorption greater) than normal.

The following statements summarize the results (obtained by the Central Radio Propagation Laboratory, unpublished) of analyzing disturbed conditions resulting from ionosphere storms, for North Atlantic transmission paths, from data furnished by a number of radio users since 1944.

1. Disturbed days tend to occur on the average in groups of 2 to 3 days.
2. The percentage of the days of the year which are disturbed varies between 10 and 30.
3. The percentage of disturbed days does not vary significantly with sunspot number, but the character and distribution of disturbed days do so vary:
   a. Individual ionosphere storms are of greater intensity at sunspot maximum, but because of the greater range of useful frequencies, communication is not impaired for so long a period as at sunspot minimum.
   b. After sunspot maximum and extending into the minimum, disturbed days have a pronounced 27-day recurrence tendency and effects on communication are more lasting.

Fading The five types of fading mentioned in Sec. 1 are all encountered in sky-wave propagation in the 2- to 30-mc range. Most relatively rapid fading is the result of a combination of interference fading and polarization fading. Both occur even when only one mode of propagation is present, and both increase in rapidity with increasing frequency.

Besides the nuisance effects of fading, polarization variations may introduce large errors in direction-finder bearings. Special precautions in design and operation must be taken in order to avoid polarization errors.

The correlation between fading fluctuations of field strength received on two adjacent antennas decreases rapidly with increasing separation of the antennas, and the correlation of fading at two adjacent frequencies received on the same antenna decreases rapidly with increasing frequency separation. Fading may therefore be reduced by the use of multiple antennas and frequencies ("diversity" systems).

Radio Noise

The reader interested in comprehensive information and data on radio noise in this frequency range is referred to the survey published in 1947 by Thomas and Burgess.[14]

Of the sources of noise listed in Sec. 1, atmospheric noise is most important throughout the greater part of the 2- to 30-mc range, although extraterrestrial noise may become more important at the higher frequencies at times when the operating frequency is above the MUF for the paths between the receiving station and the atmospheric noise centers. As both atmospheric and extraterrestrial noise are of the random or fluctuation type, their nuisance effect is a function of bandwidth of the receiving set.

Below 30 mc radio noise from the sun is nearly always much weaker than galactic noise. The main source of galactic noise appears to be a region near the center of our galaxy in the direction of the Scorpio-Sagittarius region of the celestial sphere. Thus the received intensity at a point on the earth depends upon the position of the zenith in the celestial sphere. The intensity is also affected by ionospheric shielding and absorption. A typical value of required incident field strength for intelligible reception of radio telephony in the presence of galactic noise, using a receiving antenna with no more directivity than a half-wave dipole, is approximately 0.4 μv per meter between 15 and 30 mc.

Geographic, Time, and Frequency Variations The characteristic variations of atmospheric radio noise in the range 2 to 30 mc are:

1. Higher noise levels at low than at high latitudes, the difference being greater during the day than at night, especially at the lower frequencies.
2. Higher noise levels in the vicinity of land masses than over oceans.
3. Higher noise levels at night than during the day, especially at the lower frequencies.
4. Below the MUF limitation, noise levels tend to increase with frequency during the day, decrease with frequency at night.
5. In temperate latitudes noise levels are higher in summer than in winter.

These characteristics are consonant with the origin of atmospheric radio noise in thunderstorms and its propagation to great distances like other radio-frequency fields.

A method of estimating the required field strength for reliable radio reception in the presence of atmospheric radio noise is given in Chap. 8 of ref. 5. Because of limitations of available data on which the method was based, its accuracy is not great, but if not taken too literally, it offers useful indications of the general level and variations of atmospheric radio noise and required field strength.

To illustrate the levels and variations numerically, values of required field strength for radiotelephone reception in the presence of atmospheric noise, obtained by the above method, are listed in the following table. The values are given in microvolts per meter at Washington, D.C.

	Winter		*Summer*	
	Noon	*Midnight*	*Noon*	*Midnight*
2 mc	0.10	40	0.35	71
10 mc	2.2	4.5	4.0	10

Day-to-day Variations Radio noise levels at a given place, season, and hour of the day vary from day to day. It has been found that the logarithm of the hourly average noise field strength is approximately normally distributed during a month, with a dispersion such that the field strength exceeded on 10 per cent of the days is approximately 2.2 times that exceeded on 50 per cent of the days.

Communication Efficiency and Uses of Frequencies in This Range

The principal advantage of frequencies in this range is that useful long-distance propagation can be achieved with relatively low transmitter power. When the transmission path is in darkness and the ionosphere is undisturbed, all frequencies below the MUF are propagated to long distances, but when the path is in daylight, only the higher frequencies can be used for long-distance communication with low power.

Disadvantages of the band are:

1. Because of the continual variations of the limits of the band of frequencies usable for communication between two points, it is in most cases necessary to have available more than one frequency, often three or four, in order to maintain relatively uninterrupted communication throughout the day, year, and sunspot cycle. This increases the amount of spectrum space required.

2. A frequency which has a large distance range also has a large interference range. This severely limits the number of transmitting stations over the earth which may use the same frequency simultaneously without creating interference.

3. Long-distance communication in this frequency range, depending as it does upon ionospheric reflection, is at the mercy of ionospheric disturbances. Particularly in high latitudes near the auroral zone, a certain amount of lost time

during severe ionospheric disturbances is inevitable, and even during moderate disturbances, efficiency may be impaired. In low latitudes the effects of ionospheric storms are not serious, but sudden ionosphere disturbances during daylight hours cause some lost time.

4. Even under undisturbed conditions, there are fading and multipath effects which limit efficiency and the speed of intelligence transmission. Fading can be offset to a great extent by the use of diversity systems (multiple antennas and frequencies), but the latter, of course, require additional spectrum space. Multipath distortion can also be lessened somewhat by the use of optimum antenna directivity patterns and a frequency near the MUF. In the case of direction-finding systems, polarization effects, multipath effects, and non-great-circle propagation are serious problems. In navigational systems, accuracy suffers from changing delay times and the presence of multiple modes of propagation with a wide range of delay times. For such systems operating beyond the ground-wave range, the lower frequencies in the band which are propagated by E-layer reflections are probably best.

2.5 PROPAGATION CHARACTERISTICS OF THE SPECTRUM FROM 30 TO 3,000 MC

General

This very wide band of frequencies is the oldest of the entire radio spectrum; it was here that Hertz about 1885 produced the first man-made electromagnetic waves and it was here also that Marconi, a decade later, conducted his first experiments in "wireless." Old as this band is, its practical use is fairly recent, for it was little more than a decade ago that it came into general use. This band is distinguishable from others previously discussed in that it cannot in general be relied upon for transmission to great distances.* There are, however, numerous occasions, particularly at the lower frequencies, when it can be so used. More often, however, long-distance signals of this kind constitute potential sources of interference. Cases of transmission to great distances decrease rapidly with frequency and become negligible at a frequency around 80 mc.

At the higher frequencies of this band, atmospheric noise is relatively low. Also these frequencies permit the use of moderately high antenna directivities and the transmission of broad bands of communications. Together, these characteristics tend to make this band very useful, particularly where small or moderate distances are to be covered.

It was hoped in the early days of the exploitation of this band that, since the ionosphere played no very important part in propagation, transmission in this band would be very stable. While this is generally true, there are, as we shall later see, numerous exceptions. The mechanisms which lead to instability are discussed more fully below.

Mechanisms of Propagation Substantially all the mechanisms of radio propagation, reflection, refraction, diffraction, and scattering as well as guided propagation play a part in this frequency range. At the lower end of the range, the ionosphere is occasionally sufficiently dense to return waves to earth, particularly at great distances. This band therefore has properties in common with those covered by the two previous sections. Also at the lower frequencies of this band,

* Since this manuscript was prepared, numerous experiments have confirmed the occurrence of omnipresent signals well beyond the horizon such as those predicted by the scattering theory of Booker and Gordon. These tropospherically propagated signals appear to occur over almost the entire frequency range under consideration.

ground reflection is particularly important. It will be remembered that, for certain antenna heights, the ground-reflected wave tends to cancel the direct wave, while for others there is reinforcement, so that some antenna heights result in more efficient transmission than others.

It was pointed out in Sec. 2.1 that, on the average, the density of the earth's atmosphere and also its dielectric constant decrease with height above earth, with the practical result that radio waves in this frequency range tend to follow the curvature of the earth. The radius of curvature turns out to be about four times the earth's curvature. For this case the relative curvature is $1 - 1/4 = 3/4$. Facts are correctly represented if we assume rectilinear propagation over an earth whose radius is four-thirds of the earth's actual radius. This effect tends to make the range of a transmitter slightly greater than the horizon distance. The atmosphere that has this distribution of dielectric constant is called a "standard atmosphere" and the gradient is called a "standard gradient."

It is of interest that the properties of the earth's atmosphere do not always vary smoothly with altitude. As a result of an unequal heating or possibly to a failure of the air to mix freely, discrete layers are often formed with more or less definite interfaces between. If the change in properties in the interface is sufficiently rapid, the latter may become a reflecting discontinuity. At other times, there may be three-dimensional air masses having somewhat different dielectric constants from the surrounding air. There is evidence, too, that, on occasion, the dielectric constant of the air near the earth may be less rather than greater than that directly above. This effect is known as an inversion.

Deviations of the kind just referred to account for certain vagaries of propagation discussed in this and also in the succeeding section. One interesting example is the phenomenon of guided propagation, which may occur when the rate of change of index of refraction in an inversion is so great that waves are bent repeatedly back to earth for successive earth reflections. Radio waves may be propagated to great distances by this mechanism. This phenomenon will be discussed more at length later.

Deviation from standard gradient of the index of refraction does not always improve radio-wave propagation. For example, an abrupt change in the gradient can bend the waves in such a way that there are regions to which very little energy is propagated. Specifically when the direct wave between two aircraft in flight barely goes through this change in the gradient, there may be a reduction in the received field strength by as much as a factor of 10 (20 db).

Another type of deviation important in this frequency range is the irregular, though small, variation due to atmospheric turbulence. These fluctuations in the dielectric constant of the atmosphere are a cause of fading of the radio signal. Irregularities in the atmosphere may also scatter the wave. Sometimes small but nevertheless measurable scattering is observable at distances far beyond that at which any signal could otherwise be received.

The mechanism of diffraction plays its major role in this frequency range. At the lower frequencies (longer wavelengths) the bending of the waves into the shadow region of the obstacle (the earth) is sufficiently complete that a good approximation is to assume the earth's surface plane. At the higher frequencies (shorter wavelengths) the effect of diffraction is very much less, so that the bending of the waves into the shadow of the obstacle (the earth) is sufficiently slight that propagation beyond the radio horizon by this mechanism is relatively unimportant. In this frequency range, however, neither of these two extremes forms a good approximation to the actual propagation conditions, and the amount of bending resulting from diffraction must be determined by more exact means.

Some of the polarization effects prevalent at the lower frequencies are also present in the frequency range under consideration. The reflection coefficient of the ground (and objects in the propagation path) is greater for the component wave having its electric vector parallel to the reflecting surface than for the component having its electric vector perpendicular thereto. The angular distribution of energy scattered by atmospheric turbulence also depends upon the polarization, since the scatterer may be visualized as a dipole oscillating parallel to the electric vector of the incident wave whose reradiation has the directional characteristics of this dipole.

As throughout the frequency spectrum, so in this frequency range, there are phenomena which contribute to the distortion of the signal. Atmospheric turbulence is continually contributing to short-time variations of the signal amplitude. Also multiple-path transmission may produce fading in one part of a communications channel relative to other parts. This results in the transmitting medium not only attenuating the signal and introducing a background noise but also distorting the desired signal. When it is desired to transmit the maximum amount of information in any given frequency band in a specified time, this distortion may be an even more important limitation than the signal-to-noise ratio. Certain of these phenomena will be discussed further below.

Ground-wave Propagation

In this frequency range, it is common experience to find that the power radiated from an elevated antenna varies over a smooth terrain inversely as the square of the distance. The distances at which this applies depend on the frequency and antenna heights. At greater distances the rate of decrease rapidly becomes exponential. Well within the horizon, the interference between the direct and ground-reflected wave produces a series of maxima and minima. The field strengths in these regions are complicated functions of the conductivity and dielectric constant of the earth. Also actual terrain varies markedly from that assumed above. Thus the application of the science of propagation in this frequency region, like that in other regions already discussed, is rather complicated.

Attempts to calculate the field strength prevailing at a distance from a transmitter have met with varying degrees of success. All involve simplifications which at best are only approximated in practice. In one simplification the earth's surface is assumed to be a perfectly homogeneous sphere surrounded by a homogeneous atmosphere. Even this is complicated mathematically. It resisted attack for a period of a decade or so, until Watson [1] in 1919 took an important simplifying step by expressing the solutions as a rapidly converging exponential series. Later investigators introduced the effect of different electrical properties of the ground and the effect of the uniform decrease in the dielectric constant of the atmosphere with height.[2] A better understanding of this very difficult problem may be had by considering a series of idealizations of increasing theoretical complexity.

The simplest idealization is that of propagation between two vertical antennas above a perfectly conducting plane.[3] The effect of the plane is to introduce a reflected wave in addition to the direct wave. This reflected wave is the same as would be received from the mirror image of the transmitter, so that, for antennas in contact with the plane, the received field strength is exactly twice that from an antenna carrying the same current located in free space. As a result of the reaction between the image of the antenna and the antenna itself, its impedance is changed, so that the power transfer between two vertical antennas above a perfectly conducting plane is the same as that in free space. At sufficient distances it is possible to raise the antenna height while at the same time obtaining the benefit of the image of the ground as far as received field strength is concerned, so that the received power for vertical antennas whose height above the ground is large compared with the wavelength and whose distance apart is large compared with the antenna height is four times that for the same antenna in free space. The path difference between the direct and reflected waves may become of the order of a wavelength or more, in which case the interference pattern between the direct and reflected wave already referred to will occur.

The next degree of complexity is to consider the perfect reflecting plane to be replaced by one which has the same electrical properties as the actual ground.[3] When this is done, the field strength is still inversely proportional to the distance for short distances but becomes inversely proportional to the square of the distance for larger distances. The transition between these two relationships occurs at a distance which is equal to the complex dielectric constant of the ground times the wavelength divided by 2π for vertical polarization. For horizontal polarization the inverse square relationship starts in the immediate vicinity of the antenna. Some of the relationships described in this and the preceding paragraph are shown graphically in Fig. 7 below.

The next complexity to be added to the approximation to actual propagation conditions is to take into consideration the curvature of the earth. The shadow factor, which represents the quantity by which the field for propagation over an imperfectly conducting plane must be multiplied to obtain the field for propagation over a sphere, is a function of the distance, frequency, radius of the earth, ground constants, and polarization. Up to a certain distance the effect

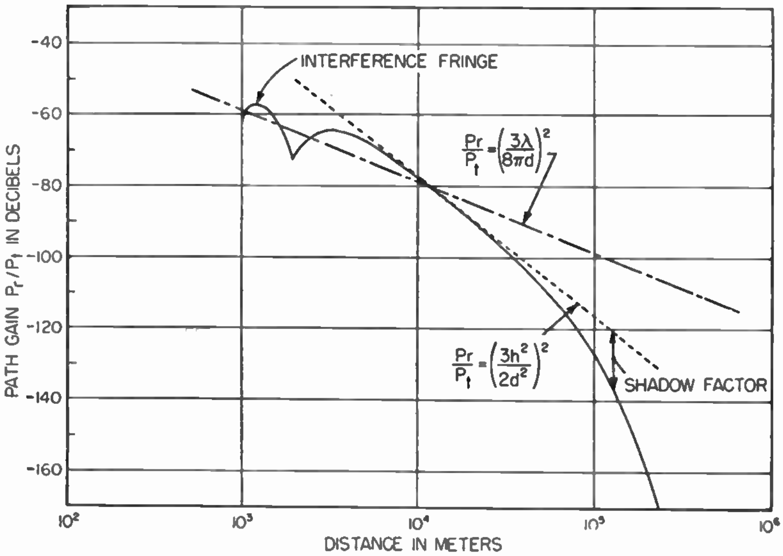


Fig. 7 Path gain as a function of distance for propagation on a frequency of 30 mc between two vertical antennas 100 meters above a smooth spherical earth with a relative dielectric constant of 4 and a conductivity of 10^{-2} mho per meter, under conditions of standard refraction.

of the earth's curvature is negligible. At greater distances the field drops off exponentially. For a more precise statement see The Effect of the Earth's Curvature on Ground-wave Propagation by Burrows and Gray.[4] The results of the above analysis are further summarized in the following sections.

If as a final complexity we introduce the effect of hills and other intervening objects, the problem becomes very complicated indeed. Irregular terrain, with no pronounced hills, may be approximated by fitting an average sphere to the actual terrain.[4] If there is a single intervening hill, an approximation may be had by assuming that the received wave is made up of several components, each accounted for by particular features of the terrain.[5] Other approximations have been formulated,[6] each quite useful in establishing magnitudes of expected results but hardly applicable to specific problems. In view of this situation the practical engineer confronted with a special problem will probably feel that it is better to exercise good engineering judgment followed by an experimental verification than to rely entirely on calculation.

Communication Efficiency

The ratio of the power received by an antenna, P_r, to that transmitted by a similar antenna, P_t, is a significant quantity called the "radio gain." [7] It is a measure of the communication efficiency. For two doublets located in free space (this is called the free space gain):

$$\frac{P_r}{P_t} = \left(\frac{3\lambda}{8\pi d}\right)^2 \tag{1}$$

where λ is wavelength and d is distance, both measured in the same units. This indicates that, for transmission in free space with nondirective antennas, the gain is inversely proportional to the square of the distance measured in wavelengths. The above relationship applies specifically to nondirective doublets. For directive antennas having an effective area A, Eq. (1) becomes

$$\frac{P_r}{P_t} = \left(\frac{A}{\lambda d}\right)^2 \tag{2}$$

As mentioned earlier, the formulas also apply to the paths between vertical antennas above a perfectly conducting plane. If the conductivity of the plane is not perfect, however, the inverse square of distance relationship merges into an inverse fourth-power distance relationship. This occurs at a distance which depends upon the ground constants.

Returning to doublet antennas as a reference, the radio gain is a function only of the transmission path, frequency and polarization and accordingly is called path gain. For antennas raised above a certain height which also depends upon the ground constants, there is a range of heights *h* and distances *d* for which the path gain is given by the following equation:

$$\frac{P_r}{P_t} = \left(\frac{3h^2}{2d^2}\right)^2 \tag{3}$$

This indicates that, in this range, the communication efficiency varies inversely as the fourth power of the ratio of height to the distance and is independent of frequency.

Figure 7 illustrates how these and other relationships calculated by the above-mentioned theory apply to propagation for one representative set of conditions. It illustrates the inverse square of distance relationship, Eq. (1), which holds for short distances. This is followed at a somewhat greater distance by the interference fringes that result from the interaction between the direct wave and that reflected from the ground within the line of sight. Further on there is the inverse fourth-power relationship, while at the extreme right there is the effect of the earth's curvature.

Equation (2) indicates that, for services where directivity is possible, the communication efficiency in free space increases with the frequency (inversely with the wavelength) for antennas of equal size. The advantage of the higher frequencies is increased still further when the effect of reflection from the earth's surface is taken into consideration. This suggests that, in order to take full advantage of these relationships, services requiring omnidirectional antennas such as broadcasting should be assigned frequencies near the lower end of this range, while services permitting the exploitation of highly directive antennas such as point-to-point communication should be assigned the higher frequencies in the range.

Modifying Effects

The above summarizations assume average transmission conditions. As already pointed out, there are various meteorological effects which may materially modify these conditions. A few that are of special importance are noted below.

Air Masses There is a form of fading which frequently occurs in this frequency range that can best be explained by assuming that the received signal arrives by two or more paths, as, for example, by ground reflection, and that the effective lengths of these various paths vary differentially with time. This leads to two or more components of the received signal, each varying in phase to produce at the receiver a resultant signal of variable amplitude. This type of fading can be caused by air masses of slightly different dielectric constant from the surrounding air passing through one or another of the several paths. Air masses of this kind are well known in meteorology. Fading of this type may be very rapid, but more often the variations may extend over several minutes or even hours. It can be mitigated by the use of automatic gain control at the receiver and corresponding increases of power at the transmitter.

Effects of Elevated Layers Besides the inversion layer that may on occasion be found near the earth to trap waves and propagate them to great distances, there may be elevated layers of air having dielectric constants appreciably different from the layers immediately above or below. The interfaces between these layers may provide a sufficient discontinuity to reflect radio waves in this frequency range. Under certain conditions an abrupt change in the vertical gradient of the dielectric constant of the atmosphere may result in a substantial decrease in the received field strength over an appreciable range of distances. This has been observed in the propagation between aircraft under such conditions that the direct path between the two craft barely penetrates the layer of the increased negative vertical dielectric constant gradient. Under these conditions there is a range of distances for which, on the basis of geometrical optics, no rays penetrate. This effect has been observed throughout the frequency range covered in this section.

Turbulence [8] Even a "well-mixed" atmosphere may not be entirely homogeneous. The very turbulence that produces the mixing provides deviations in the dielectric constant from the mean. The scale of these deviations is of the same order of magnitude as the turbulent eddies. Radio waves are scattered by the deviations from the mean of the dielectric constant which result from this turbulence. While the amount of energy scattered by a unit volume of the atmosphere is negligibly small, the total integrated effect produces a signal which predominates over the weak signal that would be diffracted around the earth's curvature under standard conditions at the greater distances. As a result of atmospheric scattering in the troposphere, the field that would cause interference with other services operating on the same frequency is not the field of the standard propagation but is greater than this as a result of atmospheric scattering. This scattered field comes from a direction somewhat above horizontal.

Ionospheric Scattering The scattering theory of Booker and Gordon [8] has been extended to the ionosphere by Booker.[9] His theory predicts long-range ionospheric communication at VHF up to ranges of 1,200 miles. Experiments [10] have confirmed the existence of such propagation at 50 mc per sec at a range of 780 miles. Signals are always present and *increase* during sudden ionospheric disturbances.

Atmospheric Ducts — Guided Propagation As already pointed out, special meteorological conditions may lead to a steep gradient in the dielectric constant gradient at points near the earth. This gradient may on occasion be so steep that the wave is repeatedly bent back to earth for a succession of reflections. This results in a small but very significant portion of the wave being trapped in a thin layer near the earth, through which it is propagated with relatively little attenuation. The phenomenon is not unlike that of wave-guide transmission, particularly the form in which waves are propagated through a dielectric slab.

Since in this case the earth provides one of the two guiding discontinuities and ground scattering may be appreciable at the higher frequencies, we may expect guided propagation to be more prevalent at 200 than at 10,000 mc. This appears to be the case. One rather interesting example of duct propagation was noted during World War II, when a radar station at Bombay, India, observed reflections from the coast of Arabia 3,000 km (1,800 miles) away. Although at this location duct effects were noted so frequently as to be almost consistent, there are many stations at which the phenomenon is almost unknown. Duct propagation has been observed at various times and places over a wide range of frequencies, even to frequencies of 10,000 mc. In general, however, it is so rare that it is not relied upon as a practicable medium of propagation.

Conditions favorable for duct transmission seem to be an increase of dielectric constant near the earth caused by a decrease in air temperature or an increase in moisture content, or both. This may occur, for example, when cool air blows over a warm sea as in a trade-wind belt. It may be caused also on clear quiet nights when the surface of the earth and nearby layers of air are chilled by radiation. Still another mechanism is subsidence inversion. This may occur where dry air for extreme heights merely settles to lower levels without acquiring heat in the process. Subsidence inversion is usually associated with areas of high atmospheric pressure.

Radio Noise

As in other portions of the radio spectrum, so in this band, noise plays an important role. The various components of noise, including atmospheric, ignition, resistance, and extraterrestrial sources, are discussed below.

Atmospheric Noise The atmospheric noise at any location is the integrated effect of thunderstorms throughout the world. The radiation from these natural transmitters is subject to the same laws of propagation as affect the desired signal. Since in this frequency band such waves are propagated only moderate distances, we may expect atmospheric noise to be generally low. This is the case. Such atmospheric noise as prevails is usually due to local thunderstorms and appears generally as sharp clicks. In general, atmospheric noise decreases with increasing frequency, becoming negligible at the HF end of the band.

Industrial Noise When currents flowing in ordinary circuits are interrupted, transients are set up. If conditions are favorable, as in ignition systems, power will be radiated as noise to become a potential source of interference. Other sources of such noise result from the turning on and off of motors and lights and from diathermy machines, X-ray equipment, and electronic equipment. Since ignition systems have resonances in the frequency range covered by this section, they may be expected to constitute one of the more important sources. This is particularly important, since mobile services such as those used on aircraft and automobiles are accommodated in this band. Their effects are usually minimized either by altering the steepness of the transient or by a suitable shielding. Most industrial noises decrease with frequency and are relatively small at frequencies of the order of 3,000 mc.

Receiver Noise In addition to the sources of noise just mentioned there are certain kinds of noise that arise within the receiver itself. One form, sometimes referred to as resistance or Johnson noise, arises in the early circuits of the receiver and is subject to any amplification that follows. This type of noise may be reduced by a suitable reduction of temperature, but it follows a law that makes cooling generally impracticable. This type of noise appears to set a limit of received power below which we may never pass. A second source of noise may arise in the first detector or first amplifier of a receiving system. In this band of frequencies this type of noise is somewhat greater than the corresponding thermal noise just referred to. Already considerable improvement has been made in its reduction, and further progress may be expected.

Extraterrestrial Radio Waves A third type of noise, particularly important at frequencies below 300 mc, is due to radio waves coming from the galaxy outside the solar system. The maximum of this noise comes from the vicinity of Sagittarius in the Milky Way. It is sometimes referred to as galactic noise. Certain measurements made with horizontal half-wave antennas located a quarter wave above the ground have shown that galactic noise is about 20 times that of the thermal noise in the receiver. Directive antennas may be used to discriminate against this type of noise, except, of course, under particular circumstances when the Milky Way lies in the path of transmission.

The sun emits radio waves as well as light waves. This type of noise is greater at frequencies of a few hundred megacycles than at higher frequencies and is much greater at times of sunspots than during quiescent periods. Its magnitude when received over moderately directive antennas pointed at the sun is somewhat greater than the noise prevailing in the receiver. Like galactic waves, solar waves can ordinarily be discriminated against by the use of directive antennas.

Utility of the Frequency Range 30 to 3,000 mc

At the lower edge of this frequency range reliable long-distance propagation appears possible by the mechanism of scattering from the turbulence of the ionosphere if somewhat greater than usual transmitter powers and antenna gains are employed. Since the number of long-distance communication channels could conceivably be increased a hundredfold thereby, it appears that this is the most important use to which these frequencies could be assigned. The lower frequencies in this band are also useful for transmission well beyond the horizon. This together with the fact that moderately high powers may be produced and wide bands of frequencies may be accommodated makes this range applicable to a number of possible local uses. Included are visual broadcasting and communication with mobile objects such as motor vehicles and airplanes. Also this region has important radar applications.

As we proceed toward the higher frequencies, primary power becomes more difficult to produce, diffraction effects are less pronounced, and receiver noise becomes appreciable, but these limitations are largely offset by low atmospheric noise and the possibility of obtaining greater directive gains. Also still wider bands of frequencies may be accommodated. The need to offset low power with high directive gain suggests the use of these higher frequencies for point-to-point services rather than for broadcast services. At the HF end of this band, high-definition radar becomes quite feasible.

2.6 PROPAGATION CHARACTERISTICS OF THE SPECTRUM FROM 3,000 TO 300,000 MC

General

This very wide band of frequencies is the newest to find practical use and also the newest to be explored as regards physical features. Indeed, it is so new that large portions are still uncharted. In contrast to lower-frequency bands, we find in this region little or no evidence that the ionosphere plays any important part in propagation. This leaves as the principal means of communication the directly radiated wave. Diffraction effects, which at the lower frequencies play such an important part in bending waves around obstacles and over horizons to serve areas beyond, are still present, but they are becoming progressively less important. Thus more than ever these higher frequencies are limited in their primary service range. Also, in contrast, we find in this new range, particularly near its upper limits, a very special feature which, though not exactly new, is of particular importance. It is the tendency for molecular aggregations of certain components of the earth's atmosphere to scatter and attenuate severely the transmitted signal.

It is of interest, too, that atmospheric radio noise, the principal source of noise below about 30 mc, is almost completely absent. Also extraterrestrial noise is so small as to be of little practical consequence. Ordinarily this low noise level would permit communication with extremely low powers were it not that the type of noise arising in the early circuits of radio receivers now predominates and prevents the complete realization of this very desirable situation. This particular aspect of the noise problem is currently being given a great deal of attention.

Special Techniques An important feature of this frequency band, quite unrelated to the transmission characteristics of the radio medium, is a relatively new circuit technique that makes it possible to carry out efficiently, in this upper register of frequencies, processes that were previously feasible only at much lower frequencies. More particularly it is possible to utilize new modulation, filtering, and amplifying techniques and to assemble as a closely packed radio band either several television channels or virtually hundreds of telephone channels and transmit the same over a single antenna structure. This new circuit technique has been used very effectively in communications work at frequencies up to 7,500 mc ($\lambda = 4$ cm) and in radar to frequencies of 10,000 mc ($\lambda = 3$ cm) or more. Beyond about 30,000 mc ($\lambda = 1$ cm) apparatus difficulties of one kind or another become increasingly serious. This, at the moment, is one of the more interesting frontiers of radio science.

An important feature of this new technique is a more effective means for producing sharply directed beams. The latter appears to be increasingly more feasible as frequency is increased. As already explained, the use of sharp beams tends to conserve power that might otherwise be wasted on areas in which no service is needed. At these high frequencies the gain is such as to enable a few watts of directed power to be as effective at the distant receiver as many kilowatts of undirected power. A similar gain may be obtained from the use of a directive antenna at the receiver. At the low-frequency end of this band, which is the portion most thoroughly explored, combined power gains, both at the transmitter and at the receiver, of a hundred million (80 db) or more are not uncommon. At the high-frequency end, it should be possible to provide very much higher gains. As might be expected, the use of highly directive systems tends to avoid interference with other stations operating in the same or neighboring channels. It will be readily apparent that high radio directivities have their greatest application in the point-to-point services and that their value in the forms of broadcasting now in general use is distinctly limited.

Considerations of Power The substantial power enhancements that accrue from the use of high directivity come as a fortunate compensation for other difficulties inherent at these frequencies. As already mentioned, noise arising in the radio receiver is a limiting factor. While there is some prospect that this may be reduced with further improvement, there is also in prospect a limit, apparently set by nature and known as resistance noise or theoretical first-circuit noise, below which we may not expect to pass.

Also the engineer finds it progressively more difficult to maintain the necessary signal-to-noise ratios to ensure a good grade of service. For frequencies in the lower part of this band, the upper level of sustained power now in current use in communications services lies between 5 and 20 watts. Often it is but a fraction of a watt. At the highest frequencies of the band, no adequate methods of producing and using wave power have been developed. Hence no limiting power level can be specified. It is reasonable to expect that with further improvements in techniques both the frequency frontier and the presently available power levels will be substantially increased.

One promising method of increasing the effective power and also of extending the frequency frontier consists of concentrating the available energy in short pulses each a fraction of a microsecond long spaced by relatively long periods each of perhaps thousands of microseconds. Methods of this kind are currently used in radar to produce peak powers of thousands of kilowatts, and considerable thought is being given to ways by which they may be used in communications.

Considerations of Directivity The directivity of a given antenna structure is directly proportional to each of its dimensions measured in wavelengths. In the case of the paraboloid, which is one favored form of antenna, it is therefore possible to obtain from a given structure a hundred times as much directive gain from the use of 30,000-mc waves as from the use of 3,000-mc waves. By the same token we find that, as we proceed toward the higher frequencies, the necessary radio antenna for a given degree of directivity becomes progressively smaller and accordingly it may be made more readily portable.

The combination of portability with beam sharpness has made this band very useful for radar as well as for communications. As applied to radar, the sharp beam makes it possible to resolve and note on a viewing screen details that otherwise might be lost. The degree of resolution increases with beam sharpness and hence with frequency. Thus there is a particular urge in radar to make higher and higher frequencies available. At the highest frequencies used in radar it is already possible to identify from aloft not only physical features such as rivers, islands, and bays but a considerable amount of fine detail as well.

Physical Properties of the Medium

This band of frequencies (3,000 to 300,000 mc) like that discussed in Sec. 2.5, is propagated mainly by the troposphere. The latter consists roughly of four-fifths nitrogen and one-fifth oxygen together with a sprinkling of argon, carbon dioxide, water vapor, and smoke particles. Also of appreciable importance in reflecting waves are insects, birds, and other air-borne objects. On rainy or foggy days there may be in addition substantial quantities of water particles of varying dimensions. Most of these substances play a part in one way or another in radio propagation.

Meteorological Effects It has been pointed out that, on the average, the density of the earth's atmosphere and its index of refraction decrease with height, with the practical result that radio waves tend to follow the curvature of the earth. This effect makes the range of a transmitter slightly greater than the horizon distance. It was pointed out also that the properties of the earth's atmosphere do not always vary smoothly with elevation. As a result of uneven heating or possibly of a failure of the air to mix freely, discrete layers are often formed with more or less definite interfaces between. These interfaces are believed to play a very important part in the fading phenomena observed in this band as well as in the band previously discussed. Also there are times and places, too, where the density and hence the index of refraction of air close to the earth may, temporarily at least, be less, rather than greater, than that directly above. These unusual effects, known as inversions, may conspire with a smooth earth below or another layer above to form a kind of guide for propagating waves from one point to another. These peculiar guiding effects, which are referred to as ducts, were a feature of the discussion of the previous band. They are prevalent also in this band.

Ground Reflections As at frequencies below 3,000 mc, so in those above, the earth and the various objects thereon play a part by reflecting radio waves. It turns out, however, that the earth's role in the two bands is rather different. In the range below 3,000 mc there may be a direct component between transmitter and receiver which follows the line of sight, and there may be one or more components that have left the transmitter slightly off beam and have been reflected by the earth at some intervening point. It was explained that, if, in this low-frequency case, the heights of the two antennas are properly proportioned relative to their separation and the earth is a good reflector, the second component may be of considerable amplitude and may arrive in such phase as to reinforce the first. If the heights are inappropriate, the two components will, of course, oppose and the corresponding signal level may be very low.

In the frequency range above 3,000 mc, it seldom happens that the earth is perfectly smooth but instead it appears, roughly at least, as though it were made up of an infinite number of very small mirrors, each a fairly good reflector and each facing a different direction. This leads to a diffuse reflection of incident radio waves. If in addition the earth is covered with vegetation, much of the incident radiation will be absorbed. Together, these two effects tend to make specular reflection a rare phenomenon. Thus very little reflected power reaches the distant receiver. It is evident that, in cases where the reflected component reaching the receiver is small, there can be no very strong signal due to reinforcement and no very weak signal due to wave interference. This condition is as though we had free-space transmission. In cases of this kind, antenna height is relatively unimportant as long as there is an adequate line in sight.

In so far as the inherent roughness of the earth and objects thereon tend to avoid multiple-path transmission and therefore fading, roughness is a virtue. Scattering is of further value in the case of radar. Because of this roughness, there is usually, on an object under observation, a sufficient number of reflecting facets facing the radar to return the necessary wave power for identification. As we approach grazing incidence on the earth, its returned wave power becomes progressively less important, and at that time elevated objects on the horizon become the principal reflectors. At these frequencies not only do tall buildings become discernible but so also do small objects, particularly when they may be contrasted to a non-reflecting background. Good examples are buoys and similar small objects floating on water.

Layer Reflections Though the roughness of the earth tends to reduce the particular kind of multiple-path transmission and fading associated with earth reflection, another very important type of fading remains. It is believed to be associated with multiple paths supported by discrete layers in the earth's atmosphere. If the length of any component path supported by these layers changes, there will be a shift in the interference pattern at the receiver and accordingly there will be fading. This type of fading, which was discussed more at length in the previous section, is believed to be particularly important in this frequency region.

Diffraction Effects Another very important characteristic of radio waves is diffraction. It relates to the extent to which waves bend around the edges of objects to fill the space behind. In general, diffraction becomes progressively less important as the frequency is increased, with the result that in the present range there is a tendency, more pronounced than ever, for buildings and man-made objects to cast sharp shadows. Likewise, smooth buildings tend to produce sharp reflections. It is of interest that, though the tall buildings of large urban areas tend to shield their streets from microwave signals, multiple reflections from their surfaces tend to offset this effect and give rise in the street to stronger signals than otherwise might be expected. In these cases, wave power seems to follow the direction of the street.

Rain Scattering At frequencies of several thousand megacycles, rain has a deleterious effect on radio propagation. This effect depends on the size of the individual drops as well as on the total number of drops encountered. It is of interest that, although pure water is transparent to visible light, it is rather opaque to radio waves, particularly in this upper-frequency range. Even more important, its index of refraction is very much greater than that of air. Hence the wavelength in water is correspondingly shorter. Since at these very high frequencies the wavelength is already short, this further reduction is such as to make the wavelength inside the drop comparable to the drop diameter. This leads to a kind of resonance which makes raindrops virtual traps for passing wave power. Experiments suggest that not all of this trapped energy is converted into heat. A very substantial portion is reradiated from the raindrop as a new center. It is significant that, though the exciting wave power may have arrived along a highly directed beam, it is reradiated in a wide range of directions. This phenomenon, known as scattering, is quite analogous to scattering in ordinary optics, the theory of which was worked out by Lord Rayleigh about fifty years ago to explain the blueness of the sky. This type of scattering has an attenuating effect on radio waves that is somewhat like that of diffuse earth reflections. Though absorption and scattering are fundamentally quite different phenomena, their practical effects in attenuating a transmitted radio signal are much the same. If the drop size is small compared with the wavelength, as might be the case with fog and relatively low frequencies, the loss is dependent only on the mass of water in suspension and accordingly is small.

Molecular Absorption Water drops are not the only centers that may absorb or attenuate radio waves. The molecules both of water vapor and of oxygen may also produce this effect.* The latter, however, occur at much higher frequencies. In the case of water vapor, absorption occurs around the frequency 22,300 mc ($\lambda = 1.34$ cm). The rate of attenuation depends on the amount of water vapor present and is such as to make the loss at this particular frequency rather serious in humid regions of the tropics. In this case the signal might be attenuated to one-half its initial value in traveling distances as small as 6 km (3.7 miles). For average conditions prevailing at sea, the corresponding distance is estimated to be as small at 16 km (10 miles). For average conditions prevailing over land areas in North America, these attenuations would probably be less. The attenuation in desert regions for this type of attenuation would presumably be very small.

Absorption due to oxygen molecules appears to be of greatest importance at frequencies of about 60,000 mc ($\lambda = 5$ mm). Indirect measurements suggest that at this frequency the attenuation may be such that the initial signal

* The locations of these absorption bands and the relative attenuations to be expected were calculated with considerable accuracy during the last war.[1] The results have been confirmed in a general way by experiments with small quantities of material under controlled laboratory conditions.[2,3] They are also supported by measurements on fairly long transmission paths.

power is reduced to one-half in traveling as little as 200 meters (220 yd). Theory indicates that there are other oxygen-absorption bands at still higher frequencies. The intervening regions are referred to as "windows." One absorption band that is believed to be even more deleterious than that just mentioned is calculated to appear at about 120,000 mc ($\lambda = 2.5$ mm).

It is to be noted in passing that the various losses just referred to fall into three rather different categories. For example, the importance of raindrops depends to a large extent on the frequency at which rains are encountered. Storms that may affect the lower frequencies are relatively rare. Those affecting the higher frequencies are far more prevalent. The importance of water vapor is similar, but since in most practical cases there is always a considerable amount of moisture in the atmosphere, these losses are somewhat harder to avoid. In contrast, the radio losses due to oxygen molecules are altogether unavoidable except possibly by a proper choice of frequencies. No losses due to nitrogen molecules have so far been cited. Theory indicates that they would not be serious, at least in the band of frequencies with which we are here concerned. Scattering by raindrops and by molecules of water vapor and oxygen is presumably not unlike that described in Sec. 2.5 and there ascribed to discrete air masses in the atmosphere. It is of interest that scattering phenomena described there extend into this frequency band.

Transmission Characteristics of a Typical Radio Path

Having discussed briefly the physical properties of the medium by which communication takes place, we shall examine more fully how these properties may affect in practice the over-all characteristics of the path.

Variation with Distance On the average, the power received from a transmitter located within the horizon distance varies inversely as the square of the distance. Thus, doubling the distance between the transmitter and receiver reduces the received power by a factor of 4. Accordingly the received field strength is reduced by a factor of 2. This relationship holds generally for all short distances, but at a range which corresponds roughly to the distance to the horizon, a new and more complicated relationship sets in. Beyond the horizon the signal decreases with distance very rapidly, and soon its level becomes too low for general use. As might be expected, the rate at which the signal power decreases in this fringe zone is a complicated function of terrain. Hence it is seldom possible to forecast in any detail its transmission behavior. It is generally true, however, that the signal level in this fringe zone falls off more rapidly for the higher frequencies than for the lower frequencies. Thus these higher frequencies are more than ever distinctly local both in their effect in producing a usable signal and in their effect in creating interference with other channels. In an effort to span greater distances, use is generally made of any natural elevations that may be present. This range is further augmented by the erection of suitable towers. As long as we stay well within the horizon distance and the characteristics of the medium remain constant, only a fraction of a watt of transmitted power is needed.

Modifying Effects In a properly aligned radio system, it is common experience to find that the signal level remains substantially constant for many weeks, but on occasion, it may vary through very wide limits and accordingly may produce considerable trouble. Often these variations take place during nighttime hours in summer and at times when there are few, if any, air currents. In a few cases where the phenomena have been examined rather carefully, it is found that not only does the level of the received signal vary but so also does its angle of arrival. Indeed, the signal may on rare occasions arrive from angles outside the region of maximum response of the receiving antenna. Thus it is possible for receiving antennas to be too sharp. These angular variations occur almost exclusively in the vertical plane. Usually the main component arrives from angles above the line of sight, but on a few occasions it has been observed arriving from angles below.

Available data strongly suggest that, in some cases at least, the received signal is a composite not only of two components, as already explained, but of numerous components, each of which has arrived by paths of different lengths and different angles to produce interference in the receiver. Path-length differences as great as 7 ft have been reported. These correspond to simultaneous fading at frequency intervals in the transmitted band as small as 150 mc. This phenomenon is referred to as selective fading. Angular differences of a few tenths of a degree are common.[4] Components arriving from angles below the line of sight suggest that the upper portions of the wave front have traveled more slowly than the lower portions and that, in the medium between, the more highly refractive (more dense) layers of air are temporarily located above less dense layers. These are presumably substantially the same phenomena referred to in Sec. 2.5 as due to inversion and will not be discussed further here.

A matter of great practical interest is the prevalence of these fading phenomena. Though this band is a new field of study and though the phenomena in question are relatively infrequent in their occurrence, sufficient data have already been accumulated to warrant important conclusions. On one particular path of about 25.5 miles mostly overland in northern Ohio on which the operating frequency was roughly

4,000 mc ($\lambda = 7.5$ cm), it was found that during the month of July, 1948, the signal power was at least one-half its calculated free-space value 72 per cent of the time. It was greater than one-tenth its free-space value nearly 98 per cent of the time and greater than one-one-hundredth this value about 99.7 per cent of the time. On systems of this kind single fades to one-one-thousandth (30 db) of their original power level are not regarded as serious. The troublesome periods centered around the early morning hours, but fading occasionally took place as early as 10 P.M. and as late as 5 A.M. During August of the same year fading was slightly more severe, but thereafter fading conditions improved until the end of the year, when measurements were discontinued. During the month of December the signal power was on the average at least one-half its calculated free-space value more than 96 per cent of the time, more than one-fourth the free-space value 99.6 per cent of the time, and greater than one-tenth the free-space value practically all the time. Somewhat similar data have been obtained on other paths in eastern United States.

In contrast to the above cases, which may be regarded as representative, it was found that, on a particular 29-mile path extending across a deep valley in an arid section of the West in which strong air currents prevailed, there was little or no fading. In another path, this time in California, fading was observed in daytime and also in winter. In still another very unusual and very interesting case, the path extended across a salt flat in western Utah. This path was unusual in that it combined typical desert climate with a highly reflecting earth that was almost mirrorlike in flatness. It was one of the very few cases in this frequency range in which it was found that specular ground reflection prevailed. It was found that, when antennas 135 ft high were used, fading was serious. Most of the fading difficulties were reduced to acceptable levels by making use of fortunately located elevations in such a way that successive repeater points were alternately high and low. This arrangement made it possible to operate on the first Fresnel maximum under conditions in which the effects of change of path length were a minimum. It is believed that, on most paths encountered in practice, the signal will be greater than one-tenth its free-space value 90 per cent of the time even during the worst months.*

Other observations made by Bell System engineers between 1943 and 1946 on a range of five frequencies between 710 and 24,000 mc indicate quite clearly that over this range difficulties from fading generally increase with frequency. This has been substantiated by measurements made by the Western Union Telegraph Company [6] at frequencies of 1,850 mc ($\lambda = 16.2$ cm), 4,200 mc ($\lambda = 7.1$ cm), 6,400 mc ($\lambda = 4.7$ cm), and 9,700 mc ($\lambda = 3.6$ cm). There is relatively little information about radio links similar to the above but operating at still higher frequencies. However, it is to be expected from known properties of the atmosphere that such fading will prevail throughout the entire band.

Rain Scattering Beginning as early as 1935, experiments were performed [7] to determine the impairment to a radio path resulting from scattering or absorption by raindrops. This was done at a frequency of 3,300 mc. No impairment was noted. Seven years later other tests were made at frequencies of about 10,000 and 30,000 mc.[8] Still later similar tests were made at about 50,000 mc.[9] These measurements have since been adequately verified.[10] They indicate that, with the better techniques now available, communications systems operating at frequencies of 10,000 mc ($\lambda = 3$ cm) are only

* The above data were taken from unpublished memoranda prepared by members of the Transmission Engineering Department of the Bell Telephone Laboratories. Early publication is planned.

slightly affected by rains of cloudburst proportions. At frequencies of 30,000 mc ($\lambda = 1$ cm) the cloudbursts that in the previous case were barely noticeable may now be rather serious, while rains of average proportions now become appreciable.† At 50,000 mc ($\lambda = 6$ mm) it is quite evident that even rains of average proportions will be rather serious. It is generally agreed that, since radar signals must pass through a rainstorm both before and after reflection from the distant target, radar is somewhat more vulnerable to rain than ordinary communications. In addition to contributing attenuation, rain may envelop the distant target and impair definition. A mathematical theory of rain scattering [11] which these experiments seem to support indicates that losses due to rain increase with frequency throughout this band. No attenuation attributable to snow has so far been reported. It seems doubtful that this form of attenuation will be of importance in this band of frequencies as long as the snow remains dry.

Losses due to rain scattering, like those due to fading, are of importance only if they occur frequently. Strangely enough, data on the frequency of rains of varying proportions, applicable to different parts of the world, are limited. However, such data as are available indicate that rains of cloudburst proportions are relatively rare, while those which might be characterized as merely average are much less frequent than might be supposed.

Conclusions based somewhat on general judgment and sense of proportion indicate that, for radio relay systems, transmission frequencies of about 10,000 mc would not be seriously hampered by rain * but, at some rather indefinite

† This has been further verified by tests over a 40-mile path described in ref. 5 of the Bibliography.

* This assumes a particular microwave system engineered to operate satisfactorily through fades to 1/1,000 of their normal power level. For systems operating on a lower power level, difficulties due to rain might be appreciable at somewhat lower frequencies.

point above this frequency, troubles may be expected. East-west systems seem particularly vulnerable in North America, since they lie along the path of heavy showers. In single-link radio communication systems where the path is relatively short or where reliability is less important, these higher frequencies may prove to be very useful. Also in radar systems where some reliability may be sacrificed for high definition, these higher frequencies may likewise be justified. These practical limits are by their nature rather indefinite.

Radio Noise

In the portions of this band that have so far been examined, both atmospheric noise and galactic noise are almost unknown. Moreover, solar noise is at such a low level and is so easily discriminated against by directional methods that it, too, can usually be neglected. This leaves the noise arising in the radio receiver as the principal limitation to the use of extremely low powers. Receiver noise consists of two distinct components. One is the noise that arises in the conductors forming the various circuit elements. The other arises in active electronic devices such as crystal detectors and amplifier tubes. The power in the first type of noise is a function both of the resistance of the early circuits of the receiver and of the bandwidth to which the receiver is adjusted. It is also a simple function of the temperature of the receiver, measured in degrees absolute. In this frequency range, receivers are usually broad-band devices such as to make this type of noise appreciable. The latter is sometimes referred to as theoretical first-circuit noise. Its level for a given bandwidth is relatively fixed and therefore constitutes a convenient datum * with which other low powers may be compared.

* For a receiver having a bandwidth of 1 mc, operated at ordinary temperatures, this is roughly 0.004 μμw (144 db below 1 watt).

The type of noise arising in electronic devices likewise depends on temperature and bandwidth. It also depends on other factors, some of which are under our control. Although improvements have already been made, the level of this type of noise is still several times theoretical first-circuit noise. Since a reduction of noise is quite as important in improving signal-to-noise ratios as an increase in transmitter power, this is a productive field of research.

Considerations of Adaptability

Because radio waves in this frequency range may be depended on only for line-of-sight distances, they might at first sight appear to have a very limited scope of application. It turns out, however, that these distance limitations are largely offset by the increased bandwidth that they provide. In addition, these extremely high frequencies make possible high directivities and a correspondingly low level of primary power. Thus it becomes economically feasible to transmit to the horizon and there retransmit to the next horizon beyond. This may be continued to distances of many hundreds of miles.

It also turns out that these very high directivities make possible high-definition radar. Best frequencies both for communications and for radar are usually compromises between increased directivity on the one hand and rain attenuation and fading on the other. Optimum frequencies for these services have not yet been arrived at. Radar and radio repeater systems represent the major aplications so far made of this frequency band, but being a relatively new range, other applications may be expected.

Future Development

The foregoing discussions strongly suggest that at some frequency between 6,000 and 10,000 mc rain becomes a factor which must be taken into consideration and at much higher frequencies it may become a serious limitation. At another frequency centering at about 22,300 mc ($\lambda = 1.34$ cm) further absorption results from water vapor. Still further on at 60,000 mc ($\lambda = 0.5$ cm) and again at 120,000 mc ($\lambda = 0.25$ cm) very substantial attenuation results from oxygen absorption. Together, these three sources of absorption might appear to be a formidable barrier to progress. But it should be remembered that, as radio has progressed to its present frontier in the frequency spectrum, other points have likewise been reached where the outlook was unpromising. It is significant that in each case radio adjusted itself to prevailing conditions and continued as a very useful medium of communication.*

Upon reviewing the history of radio, it is readily apparent that methods and techniques have changed enormously. Thus at the extremely high frequencies with which this section is concerned, the type of radio used is vastly different from that at the so-called VHF used in broadcasting television. Perhaps the next step in progress will likewise reveal another very different kind of radio (or at least of electrical

* About 1918 it seemed quite apparent that long-distance radio communications were becoming progressively more difficult with frequency and that beyond a particular frequency, perhaps around 1.5 mc, there might be little use for radio. Again about 1927 we seemed to be approaching a frequency of about 10 mc beyond which signals would not be propagated by the ionosphere, and again radio seemed distinctly limited. Still later, perhaps 1935, it appeared that, as we approached frequencies of about 1,000 mc, the necessary coils and condensers then used almost exclusively in radio apparatus were becoming vanishingly small and shortly there would be no technique for producing and utilizing the wave power then needed. It is to be noted that in all cases radio continued to use higher and higher frequencies.

communication). The nature of that step and the direction in which it will take us represent one of the more interesting developments that lie ahead.

One of the attractive possibilities for future communication is a scheme in which wave power is led from one point to another through hollow metal pipes. In such a pipe the transmission medium is sheltered from rain, conditioned for water vapor, and if necessary freed from oxygen. Thus the medium, which in the radio case is subject to all the vagaries of weather, would presumably now be largely within our control. It should be noted, however, that such a system will no longer be radio but will be a particular kind of transmission line. It is of interest that its success depends in no small measure on the use of a very special wave configuration, somewhat like a smoke ring in form, having the unique property of attenuating wave power progressively less as the frequency is indefinitely increased. The concept of a waveguide transmission line of this kind is not new. Indeed, research on such lines has been in progress for many years.[12] In fact, it was a by-product of this research which led to the critically important circuit elements and certain of the highly directive antennas that have made possible the extensive use of radio frequencies above 3,000 mc.

If the waveguide transmission line becomes a reality, as now seems probable, we shall have experienced the interesting evolution of electrical communications started by Morse more than a century ago using extremely LF waves guided by a wire transmission line, extending first to radio and much higher frequencies and later back to guided transmission, this time at frequencies far beyond any originally conceived.

Chapter 3

AN IDEAL APPROACH TO ALLOCATIONS

3.1 BASIC ASSUMPTIONS

The purpose of Chap. 3 is to prepare an ideal allocation table, based on present knowledge, present and prospective needs, and current trends, such as might be set up using the information presented in Chap. 2, on the assumption that no radio services or facilities exist and that the money which has been spent and the knowledge gained are now available to start a new radio industry. Furthermore, it is assumed that the world is peaceful and that all peoples are cooperating to make the best and most efficient use of available facilities; no consideration therefore has been given to political and military factors. The aim is to prepare an allocation table which will provide the peoples of the world with the radio services which they deem essential in the best and most economical manner.

It is fully realized that such an allocation is not practicable for world adoption today and that an ideal allocation can never be achieved. Nevertheless consideration of an ideal table of allocations yields interesting information and may be a useful reference source and guide to future planning.

Uses for Radio

Radio may be used for the following fundamental purposes:

1. Communication
2. Location and ranging
3. Industrial and scientific purposes other than 1 and 2 above

For use in this chapter these fundamental functions have been divided into the following classes of services:

1. Communication uses:
   a. Fixed services
   b. Mobile services
   c. Broadcast services
   d. Amateur service
   e. Special services
2. Location and ranging uses:
   a. Radio location services
   b. Navigation services
   c. Special services
3. Industrial and scientific uses:
   Industrial, scientific, and medical uses.

The succeeding sections follow the order of the foregoing list.

3.2 FIXED SERVICES

The fixed service is defined by international regulation as "A service of radio communication between specified fixed points." The word "specified" is included in the definition in order to establish the difference between fixed service and certain broadcast services, the intention being that the fixed service shall include all communication by radio between established stationary communication points and through relays along established communication routes.

The demand for radio service has always outgrown the useful spectrum space very soon after the technical means for using a given frequency range were known. For this reason international agreements and domestic regulations have subdivided most of the services in accordance with specific uses, giving priority to those considered to be the most important. At present, administrative and political considerations, theories of economics, and the inflexibility of statutes, rather than engineering factors, govern the allocation to a great extent.

The fixed service is divided into parts in accordance with a particular type of fixed service (aeronautical fixed, for example) or in accordance with the user or service with which the fixed operation is associated (marine relay, television studio transmitter link, etc.). These ulterior considerations have led to the establishment of multiple circuits between certain points, with the result in some instances of waste of valuable frequency space and high cost inherent in multiple staff and facilities.

A different type of a subdivision of the fixed service would provide greater efficiency and conserve frequency space, particularly in the HF range. A number of the present fixed services should be combined into a single system providing communication between major centers of population and carrying the normal government and private communication. Special circuits within this network should be available to large users, and priority afforded essential communications. Fixed service between points not regularly or effectively served by the integrated fixed system may be provided by separate systems used for a particular type of fixed communication. Where emergency traffic is being handled or the traffic load is heavy enough to warrant the use of exclusive frequencies, separate fixed services might also be established. In addition, suggestions are made in Sec. 3.7, Special Services, to provide for unusual and intermittent fixed operation in isolated areas or under particular circumstances.

Modern information theory indicates methods of transmitting and receiving greater amounts of intelligence in a given band in a given time. New techniques would not be closely related to presently operating systems. The time required to discover means of employing these new techniques in the fixed communication network cannot now be estimated, and therefore continued conservation of the HF spectrum is very important.

Within the next ten or twenty years overcrowding of the fixed service bands would be avoided in an ideal system by limiting the use of such frequencies to services which cannot be economically provided otherwise.

Super-high-frequency relay systems are capable of supplying the necessary bandwidth with good stability, and it is physically possible to establish such a relay to interconnect all the continents. While it is recognized that the system would be expensive and that there would be difficulties in installation and administration, a relay could be built from New York to the southern tip of South America and from New York through Alaska across Bering Strait into Asia, Europe, and Africa and via a chain of islands into Australia. The greatest overwater distance involved is approximately 90 miles. Alternate or basic circuits might be established over long water routes by aircraft relay, moored ships, or seadromes. A system of this kind would be capable of furnishing wide-band service for written, aural, and visual communication to all major population centers of the world. Because of the high directivity obtainable, additional circuits could be added along the same routes by selection of repeater locations and frequencies to prevent interference.

The HF part of the spectrum could then be devoted to communication between the major world land masses and offshore islands or to isolated areas where the communication requirement does not justify the bandwidth available in the SHF relay.

Even when conservation measures are taken and use is made of SHF relays, it will not be easy to fit the communications requirements into the HF band. The most difficult problems are faced in the 4- to 7-mc range. At the present state of the art, the required communication bandwidth does not increase markedly with increasing frequency up to 30 mc, so that the complement of frequencies in each range up to that limit need not be larger than the band available between 4 and 7 mc.

IDEAL ALLOCATION FOR FIXED SERVICES

4.25–7 mc
9.5–12 mc
15–17 mc
21–25 mc
2,500–8,000 mc
10,000–13,000 mc

3.3 MOBILE SERVICES

The mobile service is internationally defined as a service of radio communication between land and mobile stations and between mobile stations. The mobile services are subdivided into maritime mobile, land mobile, and aeronautical mobile.

Mobile services are similar to the fixed services with respect to the suballocations which have been made to specific users and with respect to the kinds of emission and types of traffic. The mobile service commands a priority in the allocation of radio frequencies, because radio is the outstanding (and often only) means of providing communication from and between mobile units and because communication is needed for the protection of life and property in the operation of aircraft, ships, and land vehicles.

The maritime mobile service is one of the oldest radio services. Its safety function is well established by domestic and international regulation as to both frequencies available and the procedures to be used. While radio is used for operational purposes in the maritime field, most of the communication is paid message traffic by telegraph and telephone and open to public correspondence. On the other hand, mobile communication in the aeronautical field is limited primarily to operational traffic because of the character of present demands for service, the lack of frequency space, and the great dependence placed on communication for aeronautical navigation and traffic control. In the latter service, both telegraph and telephone are used, with telephone predominating.

The aeronautical and land mobile services have expanded very rapidly. Because of this rapid expansion and the lack of sufficient frequency space, the kinds of communication in which these services are permitted to engage have been restricted. Until very recently, all the aeronautical and land mobile services were limited to operational traffic and not open to general public correspondence.

At present each user in a given type of mobile service operates his own communication system. Direct communication between the mobile services and direct communication between a mobile unit and other networks are technically possible but not as yet widely practiced.

As in the fixed service, improvement in frequency use can be obtained by the integration of a number of the present mobile services. Such a general mobile network interconnected with the fixed network where required would provide improved service to many of the present intermittent users and sufficient facilities for additional users. Large or essential mobile operations may require special facilities within the mobile network or a priority of use. There will remain mobile operations which should be conducted separately using their own system, the occupation of additional frequencies justified by the amount of traffic handled, the improved control of the system, or the greater dependability. Other types of mobile service for special purposes are discussed in Sec. 3.7, Special Services.

The mobile service must be provided with frequencies suitable for medium- and long-distance communication, for short-distance communication on land and to ships on inland waters or harbors, and for short-distance communication to aircraft. The medium- and long-distance communication requirements can be met on frequencies between 2 and 25 mc, the short-distance mobile service on frequencies beginning at approximately 60 mc, and the short-distance aeronautical service on frequencies adjacent to the 1,000-mc navigational band. Two bands should be provided in the VHF-UHF range for short-distance services, one near 60 mc for coverage of relatively wide areas over average terrain and one near 800 mc to provide service in large cities where multiple reflections may be used to fill in deeply shadowed areas.

It is assumed that an integrated navigational system for aircraft multiplexed to provide communication will reduce the separate operational communication requirement and that the aircraft use of these frequencies could be devoted primarily to meet future demand for public correspondence. Because of the very considerable interference range of high-altitude aircraft transmitters, VHF and UHF aircraft frequencies must be separated from land and maritime frequencies. Frequencies below 2 mc are not proposed for mobile service because of the limited bandwidth available and because of the inefficiency of antennas on mobile units in this frequency range. The present 500-kc safety operations would be transferred to 2 mc.

IDEAL ALLOCATION FOR MOBILE SERVICES

2–4 mc
7.5–9.5 mc
12–14 mc
17–21 mc
54–100 mc
770–900 mc

3.4 AURAL AND VISUAL BROADCAST SERVICES

The broadcast service, by international definition, is a radio service intended for reception by the general public. The auxiliary services such as studio transmitter links, remote pickup, etc., are included under the fixed and mobile services for allocation purposes. Where there are particular and unusual requirements, they would be satisfied in the bands available to the special services.

Broadcasting is by all odds the most widely distributed radio service. Many countries which have inadequate fixed and mobile communication maintain multiple broadcast services. The broadcast service is recognized as the most important means of mass communication ever devised.

Although the broadcast service has been limited by insufficient frequency space, its growth has been tremendous, and at the present time aural broadcast service is available by various means to most of the areas of the world. In the heavily populated areas, multiple aural broadcast services are provided; even in isolated areas as many as 40 different HF broadcast programs may be received during the early evening hours.

Aural broadcasting now occupies frequencies from 150 kc to above 100 mc. Governments in general place high importance on their broadcast service. Many government administrations have, in fact, departed from the international allocation table to improve or augment their own broadcasting. In the HF band, for example, monitoring reports show that more than twice as many broadcast channels are in use as have been allocated. Such operation outside the allocated bands is capable of causing serious interference to other services operating in accordance with international agreements.

The early development of broadcasting and the pressure to find room for a large number of broadcast stations have led to allocations having an unsound engineering basis and to operations which are improvident in frequency utilization. It is recognized that the tremendous public investment in broadcast service prevents radical changes in this service and that the determination of the number of programs which should be made available to any area is not an engineering matter. Nevertheless, the engineering factors which determine an efficient broadcast system should be examined in the light of present knowledge.

The economics of the present radio broadcast system are based on a very large expenditure by the public for receiving equipment compared with the expenditure for transmitting equipment. Recognizing this, broadcasting transmitters operate with much greater powers than do transmitters in any other service in order to simplify the receiving problem. From an engineering standpoint it is reasonably certain that this trend has not been carried far enough and that, in the future, material increases in transmitter power will provide better broadcast reception with greater freedom from noise and with less costly receivers.

In addition to the power required, the frequency band in which aural broadcast transmitters operate is important. It should be selected to provide high signal level over large areas, and the transmission should be as stable as can be attained. To meet these requirements ground-wave transmission, because of its stability, should be used to provide service to the majority of receiving locations. For the coverage of large areas, frequencies from 200 to approximately 1,000 kc are well suited. These frequencies, however, are not ideal because of the limited number of channels available and because they are subject to sky-wave interference, particularly at night, if the channels are duplicated within a region. Analysis of the demands of the various nations for broadcast service makes it amply evident that extensive duplication will be necessary, and therefore the nighttime range of stations operating in this band will be restricted.

In centers of concentrated population, where several different programs should be available, VHF sound broadcast stations can provide high field intensity and stable transmission conditions. If the frequency is above 50 mc, sky-wave interference over long distances does not occur for any appreciable percentage of the time. Other intermittent types of interference can be reduced bv sufficient geographical spacing.

If one assumes that there are no receivers in the hands of the public and that a sound broadcast system is to be provided on a good engineering basis, the VHF band should be used for multiple-program service in heavily populated areas and LF service should be provided for the large, sparsely populated areas. The LF transmitters should operate with very high power and should be so located that they provide optimum coverage of the area involved. It is recognized that the inherent higher cost of VHF receivers tends to retard the use of VHF frequencies for local coverage, but the better service rendered would appear to more than compensate for this additional cost.

High-frequency broadcasting (2 to 25 mc) is capable of providing an inferior broadcast service over very long distances. Even with extremely high power, the service is subject to wide variations over long and short periods of time, and regular changes of transmitter frequency are required in order to meet changing propagation conditions. With equipment of simple design, this requires the listener to keep track of such changes so that he can continue to receive programs. There are engineering developments, such as diversity reception, single side band, augmented carrier, etc., which could be employed to aid in overcoming some of the difficulties due to HF propagation. However, the limited and specialized audience of these stations makes it difficult from a production standpoint to provide superior receiving equipment at a reasonable cost.

High-frequency broadcasting is used for the interchange of cultural programs to supplement domestic broadcasting in countries where the area to be covered is great and the MF broadcast service is not well distributed or of insufficient power, to transmit programs from mother countries to colonies, and for the transmission of programs from a country to its nationals in other countries or on the high seas. High-frequency broadcasting is also extensively used for the transmission of propaganda by some countries. Under the peaceful conditions assumed in this chapter, there would be complete freedom of information among countries and the transmission, under arrangements which would be the subject of agreement, would be accomplished at great conservation of frequency space.

The transmission of cultural programs by means of HF broadcasting does not appear to be sound from an engineering standpoint because of the inferior quality of transmission by this means and because of the difficulty of capturing a large audience when high-quality domestic service is available to the majority of the listeners. Ideally the interchange of cultural programs should take place by means of program relay over high-quality fixed circuits or by electrical transcriptions or tape recordings subsequently broadcast over the domestic system of the country concerned. By this means the programs can be arranged to suit requirements of individual countries and the originating country can be assured of the greatest possible audience.

The domestic use of ground-wave transmission at high frequencies is unsatisfactory. Even in tropical zones it has been shown that high-power LF stations can provide more satisfactory service. (See Chap. 2 of the International Radio Consultative Committee, Study Group 10 report.) Some countries employ a special form of HF domestic sky-wave broadcasting wherein the government provides special receivers at public places in isolated communities for general listening. Such receivers can be enabled to make the best use of the unstable HF transmission. This service can be considered a multiple-address fixed service and might therefore occupy the HF bands with other fixed services.

High-frequency broadcasting would appear to be the only economically practicable present means of reaching the nationals of a given country on the high seas or in other countries. However, the number of such persons is small compared with the total number of people which radio must serve, and it is doubtful if a large amount of valuable HF space should be devoted to such a specialized service. Special arrangements can readily be made in the fixed and mobile service for the transmission of news and special events on occasions.

In view of the foregoing, an ideal allocation would not provide for the operation of HF broadcast stations for reception by the general public.

A major trend in broadcast service is toward maximum extension of the combination of aural and visual service (television) requiring wide bands and a stable transmission medium. This combination of requirements limits television broadcasting to frequencies above approximately 50 mc. Television should be allocated a continuous band.

Present growth of the television service indicates that a minimum of four television programs should be available to each major population center and that very large cities should have as many as eight. To satisfy this requirement in the United States, the band should be about 600 mc in width. Power of the transmitters should be of the order of 500 kw or more, and the transmitting antennas as high as feasible in order to provide a reasonable distribution of system cost between transmitter and receivers and further to improve the service.

A discussion of broadcast service would not be complete without mention of the several systems of distributing broadcast programs by wire which in many cases have rendered service in areas not adequately covered by the radio broadcast services. These systems have proved economical and also assure better reception quality.

In many parts of the world central receiving stations for aural programs have been established and the received programs are then distributed to the listener over the telephone network or a separate wire system.

In the United States a number of wired television systems have been developed recently to provide programs in areas where home reception is difficult because of the distance from the television stations or other factors. Some of these systems are designed to provide programs directly rather than by reception from a television broadcast station.

Demand for facsimile broadcast service has not developed at the present time to any great extent, probably because of the efficiency of other means of distribution of printed matter within heavily populated areas. It is quite possible that facsimile service for rural areas will become of importance, and apparently this can be most easily provided through the off-hour or multiplex use of aural broadcast stations.

IDEAL ALLOCATION FOR AURAL AND VISUAL BROADCASTING

0.18–1.2 mc	(aural)
100–700 mc	(visual and aural)
700–720 mc	(aural)

3.5 AMATEUR SERVICE

Amateur radio is a worldwide hobby embraced by over 100,000 persons in all walks of life having a purely personal interest in various phases of radio technique. The individual interests in amateur service are as varied as are the interests of the people engaged in this hobby. Some are concerned with the technique of communication by radio in its various forms, others in the technical aspects, and still others in scientific research.

The contribution of the amateur to the technical and practical development of radio is recognized by all, as is the fact that such a large group of citizens devoting their own time and money to the study of the various phases of radio operation constitutes an extremely valuable source of trained personnel. In case of disaster the equipment and capability of the amateur service are important in the preservation of life and property.

To encourage the continuation of this valuable hobby and to take into account the variety of interests represented, appropriate frequency bands in various parts of the spectrum should be provided. Provision should also be made for wide-band as well as narrow-band types of operation so that experimentation and investigation by amateurs will not be restricted.

The amateurs present a difficult allocation problem because of their numbers and because of the difficulty of weighing the importance of amateur service in a given frequency range as against other services which must occupy the same frequency range. As a result, the amateur bands have been reduced in size from time to time while the number of amateurs has increased. The resulting interference has, on the one hand, restricted those amateurs interested in communication and, on the other hand, encouraged the development of types of equipment capable of operating under the increasingly difficult conditions.

The ideal allocation for the amateur service would include a number of frequency bands in harmonic relation, where possible, the width of the band to be determined by the amount of space required in that region by other services carefully determined to have priority. Amateurs should be permitted to use the industrial, scientific, and medical bands, since some communication can be accomplished even in the presence of severe interference and in addition the amateur may well develop techniques which will help to overcome interference.

IDEAL ALLOCATION FOR THE AMATEUR SERVICE

Bands at:
3.5 mc
7.0 mc
14 mc
28 mc
50 mc
720 mc
2,500 mc
5,000 mc
10,000 mc
20,000 mc
30,000 mc

3.6 LOCATION AND RANGING SERVICES

Radio Location Services

Radio has been used for location and ranging, particularly in connection with navigation, for a great many years. Radio direction finding has been used in the maritime and aviation services almost as long as radio has been used for communication in these services. More recently, there have been developed pulse devices such as radar and loran and phase or frequency comparison systems such as FM altimeters and Consol. Radio location and ranging are used primarily as means of navigation, but radar systems and others are also used for the determination of exact locations over water or swamps where no other means are available. Other uses of radio location and ranging are to determine the location and direction of travel of unidentified aircraft and of storms and for scientific purposes such as ionospheric sounding.

Aeronautical Radio Navigational Services

Because of the ever-increasing speed and density of aeronautical traffic, the trend toward all-weather flying, and the lack of defined tracks in the three-dimensional medium traversed, the aeronautical service places increasing reliance on the use of radio for navigation and control purposes. Present-day air traffic is dependent upon a number of radio aids which have been developed gradually over the years. Although the requirements for a complete system of radio aids to aviation have been well formulated, the existence of serviceable equipment providing separate functions will necessarily impede implementation of such a complete system. It appears quite certain that the aeronautical aids required for overland flying may all be provided in a single band centering at about 1,000 mc. The requirement for long-distance aeronautical navigation can be met by a system utilizing low frequencies.

This determination assumes that a complete navigational service would be established in the 1,000-mc range for all overland aeronautical lanes where traffic is heavy and all-weather flying is permitted. It further assumes that the control of the system will be on the ground, where adequate facilities are available, and that no military, commercial, or private aircraft may be flown unless equipped with an essential minimum of radio equipment to ensure its safety and the safety of other aircraft. For off-route flying some of the same aids may be used. For particular purposes air-borne radar is desirable, for example, as a collision warning device in off-route flying. It could be operated in the 9,000-mc band which is suggested below for maritime radar.

The aeronautical service has been given the highest priority in the past because safety of life is involved in its operations and because it depends on radio for navigational functions. Therefore, a large amount of space has been devoted to aeronautical service and the space has been distributed throughout the frequency spectrum in order to encourage development. While the present trend is toward the integrated system previously noted, the industry is bringing into use new and radically different types of aircraft, and the requirements are certain to change in a short period of time. The ideal allocation should therefore provide for about twice as much spectrum space as is immediately needed in order to permit the simultaneous development of new system components to meet future requirements. There is no indication that the usefulness of frequencies between 500 and 3,000 mc is limited by propagation factors. Rather, in the present state of the art, equipment limitations appear to be the controlling factor. A high-priority service should operate at the lowest frequency at which sufficient bandwidth is available. In the case of the over-all aeronautical navigation system it would appear that the band should center at about 1,000 mc.

Maritime Radio Navigational Services

The present indications are that the maritime services require a long-distance radio aid for positioning with reasonable accuracy and a short-distance aid for use in restricted waters and near port where traffic is heavy. The long-distance requirements can be met through the use of the same LF, long-distance aid which aircraft uses when flying over water. For short-distance, shipboard radar with appropriately placed passive or active responders and in some cases land-based radar for harbor traffic coordination will be sufficient. The shipboard radar may be used as an anticollision device in the open sea. In certain instances for medium-range offshore operations it may be desirable to provide a radiolocation or navigation system for special purposes.

Land Radio Navigational Service

At the present time there is no indicated need for a navigation service for mobile units operating on land except in remote desert areas. Should such a need develop, it can probably be integrated with the navigation service provided for the aeronautical and maritime services. However, since no medium-range service is available over rough terrain in the frequency bands proposed previously, and since there is a requirement for a medium-distance radio location service, it would appear that a small band near 2,000 kc and one near 900 mc should be made available for either land-navigation or medium-distance location services.

IDEAL ALLOCATION FOR LOCATION AND RANGING SERVICES

0.12–0.18 mc
1.9–2.0 mc
900–1,900 mc
8,300–9,600 mc

3.7 SPECIAL SERVICES

There are a large number of existing and potential radio services which, because of their peculiar nature or particular need, are best treated as "special services." Some of these services are part of a regular service but have requirements sufficiently different from the general requirements to warrant separate consideration.

An excellent example is the standard frequency service which is a broadcast service, but not a program service. Other examples are meteorological services which include operations similar to those provided under other service designations but require special treatment because of the difference between meteorological requirements and other requirements for a comparable type of operation. Forestry and conservation interests require fixed and mobile service but, by the nature of their operations, need these services in areas where fixed and mobile services would not otherwise be provided.

There are numerous beneficial uses of radio for short-range communication and control which cannot be provided within the framework of the services previously discussed. Lower power transmitters might be carried by night watchmen, construction foremen on large construction projects, farmers, and even fishermen. Such communications do not require protection from interference and with a power limitation could be established in a reasonably small band. In a "citizens' radio service," for example, any citizen might be permitted to operate a radio transmitter for short-range communication on a party-line basis with no protection from interference by other users of the same service.

These special services are so varied that it is impossible to analyze all of them and difficult to discern their trend, except that more and more uses for such services are being considered daily. Frequencies throughout the HF band should be continued for the standard frequency service, and suitable frequencies provided for forestry and conservation. Other special services may be established in four parts of the spectrum, namely, 10 to 120 kc, 1 to 2.5 mc, 20 to 50 mc, and 1,900 to 2,400 mc. The middle two ranges are transition bands between basic types of propagation and as such are subject to serious sky-wave interference during certain times but are not useful for long-distance sky-wave transmission because of the relatively limited time that such transmission is effective. These bands would be devoted to the various types of low-power special service which can tolerate interference or which, because of the very short communication range, would not usually be subject to interference. The range 10 to 120 kc is useful for special fixed services in polar regions and for certain other fixed operations and is well suited to general broadcasts of information to be received over wide areas. Portions of the bands may be set aside for particular special services such as forestry and conservation.

In the special services, provision should be made for unforeseen uses of radio. It may be reasonably expected that most new uses will be within the basic service definitions and therefore could be included with the allocation to such services. Those which are completely new may be placed in bands not fully occupied by a regularly allocated service, or if they are of sufficient importance, a reallocation can be made. It is not believed desirable to leave portions of the spectrum open for experimentation or development of new services because neither the best position in the spectrum nor the width of the spectrum can be determined until the use to which it is to be put is decided upon. Experimental bands of frequencies have not proved ideally useful, and it is considered that experimentation should take place on the most appropriate frequency with provisions to prevent interference with established services.

In this brief discussion it is impossible to consider all the radio uses which may be included under the special services. A few examples will serve to indicate this approach to the problem and permit the reader to expand along the lines indicated. The meteorological requirements, for example, include fixed circuits which would be part of the regular fixed service and mobile circuits to aircraft and ships which would be in the mobile service. There may be other meteorological requirements which fit into the normal service patterns established, but in addition, frequencies are required for balloon radio sounding, radar storm tracking, and many other special types of radio operation. It is proposed that these special requirements be met in the special service bands either on a shared basis or by suballocation. Another unusual use is mobile pickup of television, not to be confused with the usual remote pickup, which would be carried by the fixed network. Television from a moving truck, aircraft, ship, or other conveyance where the pickup is made while in motion would be included in the special services bands.

IDEAL ALLOCATION FOR SPECIAL SERVICES

0.01–0.12 mc
1.2–1.9 mc
25–50 mc
1,900–2,400 mc
(Standard frequency bands at 2.5, 5, 10, 15, 20, 25 mc)

3.8 INDUSTRIAL, SCIENTIFIC, AND MEDICAL USES

In industrial, scientific, and medical uses, radiation is incidental to the primary purpose or, if radiation is essential, intelligence is not conveyed. The conveying of intelligence is, for the purpose of this distinction, broadly defined to include the kind of intelligence obtained in the case of radio location and ranging, telemetering, remote control of devices, as well as ordinary communication. The industrial, scientific, and medical uses are therefore confined to heating and other reactions which occur in substances because of the presence of rapidly varying electric fields.

The use of radio-frequency generators for heating is very old. Their use for the heating of the elements in vacuum tubes for the removal of gas is an outstanding example of this technique. In recent years many new processes have developed which depend upon the use of radio frequency for heating, and the present trend is toward the use of this means to speed and make more efficient many industrial processes.

It is certain that, with expenditure of sufficient money, incidental radiation from these devices capable of causing interference to the communication and radio location services can be suppressed. However, in the present state of the art the public interest requires that some of these devices be built cheaply and used in circumstances where control of the amount of radiation is not economically feasible. It appears desirable, therefore, to provide frequency bands in which such devices may be operated.

Certain frequency ranges are required to perform certain types of operation, the frequency being determined, for example, by the physical size of the material to be treated or the dielectric constant of the material. At the present time, frequencies throughout the spectrum are used for this purpose. If bands were provided for all these uses, there would be nothing left for the communication and radio location services. Since the only reason for not suppressing radiation from these devices is economic, one is faced with the problem of weighing the amount of spectrum space demanded against the cost of adequate shielding and other measures. These operations are not capable of interfering with each other and all units of a single type can operate on one frequency occupying very little spectrum space, provided the problem of maintaining adequate frequency stability is solved.

The ideal allocation would provide a number of bands in harmonic relation below 100 mc and several bands above 100 mc, the bandwidth being limited to reach a compromise between the cost of suppressing radiation and of maintaining adequate frequency stability.

IDEAL ALLOCATION FOR INDUSTRIAL, SCIENTIFIC, AND MEDICAL USES

5 kc at approximately 3.5 mc
10 kc at approximately 7 mc
20 kc at approximately 14 mc
40 kc at approximately 28 mc
60 kc at approximately 42 mc
10 mc at approximately 750 mc
30 mc at approximately 2,500 mc
60 mc at approximately 5,000 mc
120 mc at approximately 10,000 mc
240 mc at approximately 20,000 mc

Table 3.1 IDEAL ALLOCATION TABLE

Frequency bands	*Service (see Sec. 3.1 and Chap. 5)*
10– 120 kc	Special
120– 180 kc	Navigation (long range)
180– 1,200 kc	Broadcasting (aural)
1,200– 1,800 kc	Special
1,800– 1,900 kc	Special (forestry and conservation)
1,900– 2,000 kc	Navigation (medium range)
2,000– 2,490 kc	Mobile
2,490– 2,510 kc	Special (standard frequency)
2,510– 3,500 kc	Mobile
3,500– 3,750 kc	Amateur (industrial, scientific, and medical shares 3,622.5–3,627.5 kc)
3,750– 4,250 kc	Mobile
4,250– 4,990 kc	Fixed
4,990– 5,010 kc	Special (standard frequency)
5,010– 7,000 kc	Fixed
7,000– 7,500 kc	Amateur (industrial, scientific, and medical shares 7,245–7,255 kc)
7,500– 9,500 kc	Mobile
9,500– 9,990 kc	Fixed
9,990–10,010 kc	Special (standard frequency)
10,010–12,000 kc	Fixed
12,000–14,000 kc	Mobile
14,000–14,990 kc	Amateur (industrial, scientific, and medical shares 14,490–14,510 kc)
14,990–15,010 kc	Special (standard frequency)

Frequency bands	*Service (see Sec. 3.1 and Chap. 5)*
15,010–17,000 kc	Fixed
17,000–19,900 kc	Mobile
19,990–20,010 kc	Special (standard frequency)
20,010–21,000 kc	Mobile
21,000–24,990 kc	Fixed
24,990–25,010 kc	Special (standard frequency)
25,010–28,000 kc	Special
28,000–30,000 kc	Amateur (industrial, scientific, and medical shares 28,980–29,020 kc)
30– 43.47 mc	Special
43.47– 43.53 mc	Industrial, scientific, and medical (amateur operation permitted)
43.53– 50 mc	Special
50– 54 mc	Amateur
54– 100 mc	Mobile
100– 700 mc	Broadcasting (visual and aural)
700– 720 mc	Broadcasting (aural)
720– 770 mc	Amateur (industrial, scientific, and medical shares 740–750 mc)
770– 900 mc	Mobile
900– 1,900 mc	Navigation
1,900– 2,400 mc	Special
2,400– 2,500 mc	Amateur (industrial, scientific, and medical shares 2,435–2,465 mc)
2,500– 4,800 mc	Fixed
4,800– 5,000 mc	Amateur (industrial, scientific, and medical shares 4,870–4,930 mc)
5,000– 8,300 mc	Fixed
8,300– 9,600 mc	Navigation
9,600–10,000 mc	Amateur (industrial, scientific, and medical shares 9,740–9,860 mc)
10,000–13,000 mc	Fixed
13,000–19,200 mc	Future assignment
19,200–20,000 mc	Amateur (industrial, scientific, and medical shares 19,480–19,720 mc)
20,000–28,800 mc	Future assignment
28,800–40,000 mc	Amateur

Chapter 4

A CRITIQUE OF THE PRESENT ALLOCATIONS

4.1 GENERAL

Despite the shortcomings in the frequency allocations now in effect, radio is performing all over the world in effective fashion, and a better situation exists than might have resulted in view of the many difficulties. The present state in radio has been reached in spite of frequent revolutionary discoveries and changes in the basic factors. Consequently, it has not been possible to set up an allocation plan which would be satisfactory for more than a few years. Only within the last decade has sufficient information been available to permit a comprehensive view of the entire spectrum. Quantitative and reasonably exact knowledge is available about all parts of the spectrum except the extreme upper end. Chapter 2 of this book gives evidence of the exactness and the extent of this knowledge.

The high degree of accomplishment in frequency allocation has been attained in large part by international cooperation, which has continued steadily since its astonishingly early beginnings in 1903 through such agencies as the conferences of the International Telecommunications Union (ITU), the newly formed International Frequency Registration Board (IFRB), the CCIR, the International Scientific Radio Union (URSI), and the Department of National Defense (DND) (Canada). In this country, the FCC, CRPL, IRE, and other organizations have made major contributions. Even with such cooperation, present allocations have been largely the result of unplanned growth, with expediency often dictating decisions and assignments. Especially in the region above 30 mc, assignments have been made in advance of certain knowledge of their suitabilities, some cases turning out well and others unfortunately. Furthermore, this region was "staked out" at a time when its technical characteristics were little known and when government and military services headed the list of priorities because of war or approaching war.

Introduction of changes in allocation resulting from technological progress must necessarily lag behind new developments and new possibilities in use of the spectrum. The introduction of these changes must be timed nicely; herein is one of the great problems of allocation. If changes are made too soon, mistakes may be made or development penalized; if too late, implementation and operational introduction become more difficult and more costly. Nevertheless, the application of wisdom and good judgment can bring about realization of the benefits of technological progress toward an ultimate goal pursuant to such planning as that described in Chap. 3.

It would help enormously if adequate propagation research were conducted in advance of service use. Usually, propagation-research programs are not sufficiently extensive to produce adequate results, because both government agencies and industry are handicapped in financing such activity. Adequate propagation studies usually are made only after a new service has provided convenient technical facilities, and even then the studies are too often conducted as a byproduct in the regular operation of the new service.

The problem is complicated by the fact that knowledge of the propagation laws is often acquired simultaneously with the development of new services. The desire to introduce a new radio service has almost always appeared before full knowledge was available concerning the behavior of the spectrum segment involved. Under these conditions, it is inevitable that misfits should occur.

A limitation on improvement in allocations exists in the reluctance of some users to adopt technological improvements because of the consequent expense of replacing old equipment with new. For example, in spite of the demonstrated practicability of ship-to-shore communication for over ten years beginning in 1900, it was not until after the "Titanic" disaster in 1912 that large passenger vessels were equipped with radio and manned throughout the day.

Later, in spite of the readily demonstrated superiority and greater efficiency of continuous-wave systems over the early spark method, displacement of the latter was not accomplished until it was compelled. Even now, a few spark transmitters are in operation.

At the present time, in spite of the obviously high value of electronic navigational aids, such as radar and loran, well known for over five years, there is reluctance on the part of certain maritime operators to equip their ships with navigational equipment.

The reluctance to install a new service is usually accompanied by continued resistance against replacing equipment with improved types, even after a reasonable period of use and obsolescence. This tendency arises largely from the circumstance that amortization of most equipment other than radio is based on a rather long useful life. Radio, being in a state of rapid and continuous technical development, frequently makes available improvements and refinements which represent a considerable change in a period of less than ten years. Such a length of time often seems to operating managements to be too short a period to justify replacement of apparatus with improved types. When the improved equipment would permit beneficial allocation changes, such changes are delayed.

4.2 PRESENT USE OF THE SPECTRUM FROM 10 TO 200 KC

As indicated in Chap. 2, on propagation, this frequency range is useful for long-distance transmission by ground waves and sky waves. It is allocated primarily to the fixed, mobile, radio navigation and (in Europe) broadcasting services. The first uses were for transoceanic fixed communication and long-distance maritime mobile communication. After the development of HF techniques and their utilization in the fixed service, LF facilities were maintained for stand-by use during the ionospheric conditions when high frequencies were erratic.

The use of this range for fixed service is limited by the small amount of frequency space available, the noise level in certain regions, and the large, expensive, and difficult-to-maintain antenna structures required for effective radiation. Its use for mobile communication is limited by the same considerations plus the fact that highly efficient radiating systems on board ships and aircraft are impracticable.

Recently various long-range radio navigational systems have been developed and proposed for use in this frequency range because of its relatively stable propagation behavior. A universal long-range navigation aid will unquestionably be established below 200 kc. One characteristic of propagation in this range is particularly advantageous in navigation aids; namely, waves at these frequencies travel over land with only slightly more absorption than over sea water. This makes it possible for one navigational aid system to serve both surface craft and aircraft and gives greater freedom in locating the stations.

In the European region, the range 160 to 200 kc is used for broadcasting. Since these frequencies have low ground absorption and are effective for relatively long distances over land, they are well suited to the requirements of broadcasting to rural areas. Unfortunately, the number of channels possible in the range is very small, so that this service, in a realistic allocation, must extend into the region of the spectrum considerably above 200 kc.

4.3 PRESENT USE OF THE SPECTRUM FROM 200 TO 2,000 KC

Most of the frequency range 200 to 2,000 kc is used for broadcasting throughout the world. The international allocation for broadcasting is 535 to 1605 kc, and in the European region the ranges 150 to 255 kc and, to a lesser extent, 255 to 405 kc also are used for broadcasting. Frequencies above 535 kc were allocated to broadcasting, not because the band is most suitable from a propagation standpoint, but because it was the only available band at the time broadcasting began. The location of this service would be better if it were somewhat lower, because greater area coverage would be provided.

However, the space allocated to sound broadcasting served the basic requirements of this service sufficiently well to enable it to continue its rapid growth into even wider use. These basic requirements are:

1. High-grade signals day and night over short distances (approximately 50 miles)
2. Moderately good signals at night over distances up to a few hundred miles

An unfortunate condition of propagation in this band is the discontinuous nature of the nighttime service area from the station to the limit of the range. The coverage area is broken into inner and outer zones, separated by a fading zone extending about 50 to 75 miles in radius. This phenomenon is caused by interference between the ground and sky waves, which have about equal strengths in this critical zone. Beyond this zone, the ground wave disappears and such fading as is present is comparatively free of distortion.

In spite of the reasonably satisfactory allocation to aural broadcasting in this band, the service actually rendered has become degraded seriously throughout the world by the assignment and operation of a technically excessive number of stations. For example, in the United States of America, 106 channels are being used by more than 2,100 stations. Some duplication of stations on a channel is permissible, with appropriate attention to geographical separation, but the interfering range of stations is so much greater than the service range that duplication cannot be carried very far in any one area. Duplication has, in fact, been carried too far in many areas, with the result that good sound broadcasting service outside cities and suburbs has largely disappeared. Even urban-area service has been degraded; many stations which give good service in the daytime to a radius of 50 miles or more find their service range reduced at night to 5 or 10 miles.

Under the existing crowded condition of the spectrum, it is difficult to effect a major improvement in aural broadcasting allocation. Studies of the subject should differentiate clearly between local and distant service areas, because an improvement in one may degrade the other. An expansion of VHF broadcasting will improve local broadcasting but cannot affect rural service if the nearest stations are a few hundred miles distant. Lowering the allocation from 535 to about 200 kc would greatly improve the rural service, provided assignments were made properly and appropriate power were used. In fact, considerable technical improvement over the present situation is possible without changing the allocation, merely by limiting the number of stations on the same channel and increasing power to appropriate levels.

Aeronautical, maritime, and land mobile services throughout the world occupy portions of this frequency range. The band from 400 to 550 kc has been used for many years for maritime mobile service and to some extent for aeronautical service. The frequency 500 kc is established by international agreements for distress and emergency traffic. This allocation was made before there was very extensive knowledge of propagation or equipment. Although attempts are now being made to transfer these mobile services to more suitable ranges, the large amount of equipment and the consistent use of this band over many years continue to impede the transfer to other frequency ranges.

Radio navigation services, primarily aeronautical but including maritime radio direction finding, occupy frequencies between 200 and 415 kc. In the American region extensive use is made of this band for aeronautical radio ranges. These ranges are now being replaced in some countries with VHF ranges. Maritime radio beacons used for direction finding are still in extensive use after many years of service. The maritime field is noted for its reluctance to adopt new radio methods and equipment, but it seems certain that the present beacons will eventually be replaced by newer navigation aids.

Above 1,600 kc the band is used throughout the world for fixed and mobile services, primarily for coastal shipping in the European region and land mobile services in the American region. These frequencies are well suited to medium-distance maritime mobile communication, and antennas of reasonable efficiency are practicable on most ships. They are not well suited to land mobile service except in areas where the ground conductivity is exceptionally high. The land mobile services in this range are seriously limited at night by sky-wave interference. As a result, the short-distance land mobile users are rapidly converting to VHF systems, and it is probable that in a reasonably short time this frequency range can be allocated to medium-distance maritime mobile services and other services for which it is best suited.

The band 1,800 to 2,000 kc is allocated to the loran system of navigational aid which is operated extensively in the North Atlantic and Pacific Oceans. The principles of operation of this system and the service range desired require that it operate either in this part of the frequency spectrum, where certain sky-wave reflections are sufficiently stable for the purpose, or in a much lower part of the spectrum, where ground-wave absorption is sufficiently low so that ground waves can be used to the necessary distance, which may be more than 2,000 miles. The present system was largely installed during World War II by the United States.

Better performance and simpler operation can be achieved in the LF range, and the loran system or some other long-range system should be established in that portion of the spectrum as soon as it is feasible to do so. This would give some additional space in the 1,800- to 2,000-kc band for needed expansion of the maritime mobile service.

4.4 PRESENT USE OF THE SPECTRUM FROM 2 TO 30 MC

First operations in the frequency spectrum above 2 mc began at about the time of World War I. A few naval systems were operated during that war on frequencies near 3 mc. Strange to say, in the light of present-day knowledge of propagation, the naval equipment was intended for very short range, communicating over a few miles only. That its range was limited to a few miles was the result of very low power rather than of propagation limitations as was thought at the time. In the years immediately following World War I, knowledge of the propagation characteristics of this part of the spectrum increased rapidly, and the theory and practice of long-distance radio communication was revolutionized.

The range 4 to 30 mc was found to be well suited to long-distance transmission, both day and night, although subject to variations and peculiarities because the transmission was entirely by sky-wave reflections. Study of these variations has been conducted intensively for the past 25 years, and now they are understood sufficiently well so that advance prediction is feasible. The operation of long-distance commercial communication circuits can now be conducted with efficiency under all but rare and most extreme conditions.

Because of the effectiveness of this band in long-distance communication, many services desire to use it. These include transoceanic telegraphy, telephony, and broadcasting; maritime telegraphy and telephony; aeronautical and amateur communication; and navigational and meteorological aids. In consequence, this band has become the most congested part of the spectrum.

There is considerable difference in performance between the two ends of this band of the spectrum. The low end of the band is more useful during the low part of the sunspot activity cycle, while the upper part of the range (above 21 mc) is more useful during the highly active part of the cycle. Most of the long-distance services do not require frequencies below 3.5 mc, and therefore the range of 2 to 3.5 mc is devoted throughout the world to short-range mobile services, including maritime mobile telephone and aeronautical. Some short-distance fixed circuits are operated below 3.5 mc, and some frequencies have been allocated to tropical broadcasting. These services are moving gradually to VHF, where they can obtain equivalent performance and where they will cause less interference to other services at greater distances.

The fixed stations in this region are generally of low power and operate intermittently; while the frequency range is not particularly appropriate, many of them will continue for a number of years. Broadcasting in tropical zones was established on the assumption that the signal-to-noise ratio in tropical regions would be more satisfactory at frequencies between 2 and 4 mc. Subsequently it has been found, for areas of average or even high ground conductivity, that the ground-wave signal at these frequencies decreases so rapidly that the signal-to-noise ratio is not so good at distances of 10 to 30 miles as it would be at a lower frequency. The existence of receivers in the hands of the public will require maintenance of a "tropical broadcasting" allocation for some time, although it is certain that better service generally can be provided below 1,500 kc and a much better service above 50 mc.

The frequency range above 3.5 mc is devoted to long-distance service, including maritime and aeronautical mobile, fixed, broadcasting, and amateur. Each of these services has a series of bands throughout this range to permit selection of optimum frequency, which depends upon the distance involved, the time of day, and the solar activity. Because of these variables, several frequencies are required for each station. During low sunspot activity, all the services in the HF bands except amateur and other intermittent operations must have frequencies between 3 and 7 mc in order to maintain communication. During high sunspot activity higher frequencies can be used, since the total amount of frequency space available is then greater and the range of frequency which can be used to maintain a given circuit is greater. As a result, during periods of high sunspot activity, operation of the various services is fairly satisfactory. During low sunspot activity, on the other hand, congestion and resultant interference are great.

During the high-activity portion of the solar cycle, these services must have frequencies above 7 mc. Since more channels are available above 7 mc than below it, the congestion and interference problem is not so serious above 7 mc as it is below it. Below 7 mc the problem is extremely difficult and there appears to be no wholly satisfactory solution at present. Future improvement in techniques may permit reduction in bandwidth with consequent increase in number of channels available or allow some users to move to other parts of the spectrum.

In maritime coastal and inland waters telephony, allocations are in the MF-HF and VHF regions of the spectrum,* but most of the present use is in the band 2 to 3 mc. The number of users has increased enormously during the past few years, so that congestion, interference, and traffic delay are excessive. The use of this band is increasing steadily, and this trend promises to continue for several years.

The MF-HF region allocated is suited to the user requirements and in fact is essential to the great majority of communications required. Some of the traffic is over distances

* See the table at end of the Introduction which defines these terms.

short enough to utilize VHF frequencies; such a shift in allocation can relieve the MF-HF congestion. A test survey at one U.S. coastal harbor station, under average conditions, showed that about 40 per cent of the total traffic with all types of vessels could be effected by VHF.

While VHF has not had much use in this field as yet, chiefly for lack of equipment and the reluctance of users to install additional equipment, it is obvious that VHF service should be used wherever practicable to relieve congestion in the 2- to 3-mc band. Even when this change is put into effect, it appears that congestion will continue to be severe because of the continued growth of the service requirements.

In HF international broadcasting, bands are distributed through the range 6 to 25 mc to provide for service under the wide variety of propagation conditions. However, the bands are greatly overcrowded with transmitters. Congestion is especially severe in the lower bands (6 to 9 mc) during the evening hours in the three principal reception areas (Europe, the Americas, the Far East). In the 6-mc band, at 1,800 to 2,200 GMT, transmitting stations are operating in or near Europe on nearly every 5-kc channel, and in some cases two or three transmitters operate on the same channel. Other transmitters operate above and below the allocated limits of the band.

Even in the absence of interference, the quality of reception in HF international broadcasting is not good because of the propagation vagaries of high frequencies and the relative inefficiency of receiving antennas in home installations. Consequently there has been a trend away from HF broadcasting in areas where other broadcast services render good service. For example, in the United States, the public generally has lost interest in HF broadcast reception, and as a result very few receivers with provisions for the reception of HF bands are now marketed. Contributing to this condition is the fact that especially noteworthy international events are picked up by the various networks, using special equipment and antenna systems, and rebroadcast on the standard broadcast frequencies, with consequent better quality than direct reception in the home could achieve.

The present situation in HF broadcasting is that more and more transmitters are being used, creating additional interference, while there is generally less and less listening to HF broadcasts. The public interest would appear to require a reduction in the total frequency utilization. The transmitters which can be justified should operate at still higher power with selective programming directed to the best listening hours in the area to be served.

The worldwide interference capability of HF transmission, the heavy pressure for space in this part of the spectrum by governments and private services, and the uncertainty of the degree of future growth of all these users make the problem of allocation exceedingly difficult to solve. Two international conferences, during the past three years, have failed to arrive at an acceptable solution.

In the fixed services, 37 bands are allocated between 2.25 and 29.99 mc. Allocations cover the required range of the spectrum fairly well, although some higher-frequency bands could be used advantageously during one extreme of the solar cycle. Hope for improvement of the present unsatisfactory situation seems to lie less in the obtainment of more frequencies than in the reduction of the number of circuits (by elimination of unnecessary duplications) and by the introduction of apparatus and system improvements already known to be practicable.

The aeronautical services also have allocations scattered throughout this range. Some of these, involving communication to aircraft, could utilize the VHF range instead of the HF, because the altitude of aircraft permits greater working ranges on VHF frequencies, and such transfer to the VHF region would lessen congestion in the HF region. However, the problem of conversion is not easily solved, as is usual when a service has become established solidly in one part of the spectrum. The economic factors involved probably preclude complete transfer from the HF region for some years to come.

The total spectrum space now available for aviation communication appears to be adequate, and any new requirements likely to arise in the near future can be met by apparatus improvements based upon techniques already known and available. For example, much of the apparatus now in use does not have high performance in frequency stability, whereas practicable performance approaches 0.001 per cent. Additional channels are therefore possible within existing allocations to accommodate future requirements.

In the evaluation of aeronautical communication requirements, it is important to take account of certain special operational conditions. In both domestic and international air-to-ground communication, voice is the principal method of modulation and is increasing in extent of use. Because of such factors as the language difficulty in the international field, the duplicated transmissions of identical requested weather information to aircraft, and the requirements of traffic control, a relatively large amount of communication takes place in proportion to the intelligence conveyed.

4.5 PRESENT USE OF THE SPECTRUM FROM 30 TO 3,000 MC

The 30- to 3,000-mc range is well suited to short-distance communication of all kinds, except that the low portion of the range (below about 50 mc) can produce serious interference at long distances under some conditions of the ionosphere. Since the band is effective for short-distance communication, it is used extensively by the fixed, mobile, broadcasting, navigation, and amateur services. In the aeronautical mobile service, the utility of this frequency range is affected adversely by the long distances at which interference can be caused by transmissions from high-flying aircraft.

The most extensive use of the range is found in the American region, particularly in the United States, where VHF sound broadcasting and television broadcasting have built up large new services. Mobile communications in this range have been adopted by many new users. Over 300,000 mobile transmitters are now licensed for operation in the United States, and additional ones are being licensed at a rate of 12,000 to 15,000 per year.

The frequencies in this range of the spectrum are high enough to permit efficient wide-band modulation of transmitter carrier frequencies. Therefore such wide-band applications as television and FM telephony can utilize this range, whereas they cannot modulate efficiently in the lower-frequency ranges. Since this range of the spectrum does not provide reliable long-distance transmission, these applications must be built up commercially and economically on a short-distance basis.

The availability of techniques and equipment suitable for commercial operation in this range burst upon the radio world rather suddenly (about the year 1935), and various services were introduced and accompanying frequency allocations set up before the propagation behavior of this range of the spectrum was thoroughly understood.

The band 30 to 60 mc has effective ground-wave transmission considerably better than that of slightly higher frequencies. Therefore this portion of the range is more efficient for vehicle-to-vehicle operation in the mobile service, where low-power transmitters and low antennas must be used. However, the transmissions are subject to shielding by obstructions such as buildings and rough terrain. The greatest disadvantage of the 30- to 60-mc range is sporadic transmission to great distances, which causes serious interference to other transmissions. It appears advisable, from the international allocation standpoint, not to establish critical or high-power services below about 50 mc, because serious interference can be expected during at least the high part of the solar cycle.

According to presently available data, the aeronautical mobile service is not adversely affected by propagation conditions in its air-to-ground communication anywhere in the range up to 3,000 mc. This service has numerous allocated bands from 100 to 3,000 mc, allocated originally on a basis of equipment availability.

The allocations to aeronautical navigation service are somewhat unwieldy because many of them were set up individually as the requirements appeared. The requirements arose sequentially during the period when propagation in the HF, VHF, and UHF regions was little understood. Simplification of the allocations is desirable. In the United States a plan (known as "RTCA SC-31") has been developed and a transition program under the plan is being implemented. It is intended to complete the ultimate program by 1963.

The heart of the SC-31 system is the band 960 to 1,215 mc. Since these higher frequencies are usable in air-to-ground service and have the advantage of small antennas particularly suitable for aircraft, the relinquishment by aeronautical services of frequency space now occupied elsewhere is a future possibility.

The land mobile services have allocations in the neighborhoods of 40 to 60, 150 and 450 mc. The 60-mc band is subject to shielding by obstacles such as buildings and mountains and to sporadic interference. The 150-mc band is excellent in practically every respect for land mobile communications. While this band is closely limited to "line-of-sight" operation, reflections from obstacles fill in the "shadows" behind other obstacles. The 150-mc band covers less distance than the 60-mc band under conditions of smooth terrain or under other circumstances where advantage cannot be taken of the multiple reflections from intervening obstacles. Consequently, the 150-mc band is preferred for urban and metropolitan mobile services. It should be noted that the property of "filling-in" shadows, which is prominent at 150 mc and above, is not wholly effective in any system which must transmit information at a high time rate as, for instance, television. In such systems, the reception of multiple reflections from which the property is derived results in distortion, multiple images, etc. In telegraphy and telephony other than high-fidelity sound broadcasting, the distortions are not serious enough to outweigh the advantages.

The 450-mc band, for lack of equipment, has not been used extensively as yet in the mobile services. It promises to be effective for urban and metropolitan services. The degree of utility will depend upon the adequacy of the engineering standards set up to control assignments to particular users. The matters of channel width, frequency stability, receiver design, and various other system standards, if correctly determined initially, will assure most effective use of the band. Sound engineering standards in allocation and assignment of both the 450- and 150-mc bands are necessary if the very rapid growth of mobile systems is not to result in intolerable congestion and interference in the near future.

Very-high-frequency aural broadcasting as assigned at present in the United States can be said to have adequate space and a satisfactory location in the spectrum.

In the future, when the relationships of urban and rural listening, and the relationship between aural and visual broadcasting have become more definitely established, some other region of the spectrum may be more advantageous for aural broadcasting, either higher or lower in frequency. Higher regions could utilize either FM or AM. Lower regions (LF) would necessarily use AM. Studies of VHF broadcasting should take account of the fact that it cannot give, in large countries such as the United States, the extent of nationwide coverage which is given by stations in the MF part of the spectrum without an uneconomic number of stations. Medium-frequency (standard broadcast) stations can serve an urban area and a large rural area simultaneously. This fact made possible the rapid and wide use of sound broadcasting, even in areas unable to support a station because of sparse population.

Television broadcasting has worldwide allocations, varying somewhat in the several regions, as follows: 54 to 72 mc, 76 to 88 mc, 174 to 216 mc, 470 to 960 mc. In the United States the allocations are 54 to 72 mc, 76 to 88 mc, 174 to 216 mc, 470 to 890 mc.

Present American television operations are of large magnitude, although only 107 stations are in operation and are to date confined to the first three bands listed above. The channel width assigned is 6 mc, which has proved satisfactory for current black-and-white techniques. After considerable testing experience, this channel width has been found to be sufficient to accommodate foreseeable future developments, including color television. The basic requirement of television broadcasting is the same as that of sound broadcasting, namely, to reach all people in a given area requiring service regardless of their particular locations, with stations so located that the service area of each includes enough listeners to support it. Television unfortunately cannot use that part of the frequency spectrum which made it easy for sound broadcasting to serve both short and long distances with one station, because its channel-width requirement is too great. Television must operate in the VHF region or higher, with resulting limitation in range and area which each station can serve. Consequently it appears that special attention must be given to the problem of certain areas having sparse population, insufficient to justify erection and operation of television stations, which cannot have television broadcast service except perhaps by some special arrangements such as community distribution by wire or relay transmitters.

The minimum bandwidth of a channel is 6 mc. Several scores of channels are necessary for good service in a large country, so that the space in the spectrum required for television broadcasting totals many hundreds of megacycles. The present allocation provides this amount of space, but it is broken up into the four bands of contiguous channels listed above, some of which are widely separated. This arrangement imposes considerable penalty on apparatus design and performance, especially receivers. Apparatus can always be simpler and less costly if the frequency bands it uses are contiguous. In addition, system-operating problems are simplified if the frequency range is not so great that dissimilar behavior among stations is produced by different propagation characteristics. The present allocation, extending from 54 to 960 mc, covers the tremendous range of 906 mc, yet only 572 mc of this space is allocated to television. The maximum and minimum frequencies are in the ratio of over 16 to 1, a serious handicap in the design and performance of apparatus. If the same amount of spectrum space were made continuous, as from 54 to 626 mc, the ratio of the limiting frequencies would be only about 11 to 1.

The present situation resulted from an insufficient allocation made at a time when knowledge was limited as to the eventual needs of the service and when knowledge of propagation characteristics was meager.

In the United States, the current service reaches somewhat more than one-half of the entire population and is established in the 54- to 72-, 76- to 88-, and 174- to 216-mc bands. Future expansion is contemplated for the 470- to 890-mc band. This choice seems unfortunate in that operation would be much more efficient in the region immediately above 216 mc. This region is now occupied by services which could operate effectively in a higher part of the spectrum.

Most of the bands allocated to industrial, scientific, medical, and miscellaneous noncommunication devices are in the region above 30 mc. Two bands are below it, and an additional one is desired in the vicinity of 6 mc.

Allocations were made to these devices because it appeared to be impracticable to construct them in such manner that they would not radiate sufficiently to cause interference to radio communication services. Minimum interference is caused if they are assigned specific bands and required to operate within those bands. This condition still exists but has lessened since allocations were made originally. There is now general agreement among manufacturers of these devices, based on experience, that it is frequently more practicable to provide shielding of the devices sufficient to prevent troublesome radiation than to provide means for holding frequencies sufficiently constant to stay within the allocated bands. Consequently, manufacture is tending in this direction, and successful shielding is being achieved. In the United States, only a few complaints have been received during the past year, and these were due to failure to follow manufacturers' instructions. However, it should be emphasized that radiation from industrial devices, like smoke abatement and the prevention of the pollution of water supplies, is a matter which is best checked at its inception.

It is likely that many existing and new devices will have to be frequency-controlled within allocated bands until sufficient knowledge of shielding methods is acquired to control radiation under all circumstances. It may well be that certain devices, because of their very close proximity to receivers with which they may interfere, will never be adequately shielded and must always operate in allocated bands.

Medical diathermy equipment is especially difficult to control, and present practice utilizes both shielding and frequency control methods. However, good results have been obtained. Mr. George Sterling, Commissioner of the FCC, has stated [1,*] that medical diathermy equipment now has "generally good records of noninterfering operation."

It appears that the present frequency allocations in this field meet adequately the needs of the industry and of the radio communication services and that the allocations will continue to be required for some time, although there is hope that eventually they may be eliminated.

4.6 PRESENT USE OF THE SPECTRUM FROM 3,000 TO 300,000 MC

This region of the spectrum is still largely experimental in nature, since established commercial services have had experience only with frequencies near the lower limit. The first utilization of this region was by military radar, which began operational use in 1943. Since then military radar has expanded greatly in this region.

Maritime radar and relaying for various purposes have been the only commercial uses of appreciable scope. Some

[*] Numbered references appear under appropriate chapter headings in the Bibliography.

authorities believe that radio services, as known today, will never find useful application on frequencies in the upper part of this region. On the other hand, others now hold that there is a possibility of finding in the upper part of this region new phenomena, perhaps capable of producing biological effects, as well as new radio services.

Another interesting possibility of the extremely high frequencies arises from the fact that the physical dimensions of associated radiating elements are so small that very high directivity of the radiation is feasible. With wavelengths of the order of 1 mm (300,000 mc), concentration of high power in very small area beams becomes possible. Such concentration of electric power in high-energy density beams may have other applications than communication, as, for example, the drilling of holes or other mechanical operations. Such considerations are wholly speculative at this time, and practical use and conclusions are confined at present to the lowest portion of this range. Conclusive findings of conditions and possibilities in the upper part of this region and above cannot be stated at this time.

Maritime radar has present allocations as follows:

3,000–3,246 mc
5,460–5,650 mc
9,320–9,500 mc

The second of these is used little at present. The first and third are widely used, and opinion is divided as to their merits. The 9,000-mc band is preferable with respect to resolution, minimum range, and antenna size, and the 3,000-mc band is preferable with respect to stability and ease of manufacture. Operation on the 9,000-mc band is affected by heavy rainfall, if this covers a considerable part of the path between instrument and target, but this condition occurs so rarely that it is outweighed by the advantages mentioned. Use of the 9,000-mc band is increasing rapidly as installation of radar extends to smaller ships and boats. British ships are required by law to use this band.

Interference is not a problem in maritime radar at present and probably will not become one until the number of installations in use is very much larger than at present. In general, the allocation situation in maritime radar is satisfactory.

It is important to note that, while the absorption caused by rain in the transmission path begins to be appreciable at frequencies in the vicinity of 5,000 mc in radar operation, it is not equally appreciable in radio communication operation until frequencies of 20,000 mc or higher are reached. This is because radar utilizes very weak reflected signals.

Relaying and point-to-point transmission of wide bands of communications, as in television and multiplex telephony and telegraphy, have reached a stage of rather general use, especially in the regions of 4,000 and 7,500 mc. Higher frequencies will undoubtedly come into general use.

Certain properties of frequencies in this region make them especially well adapted for use in long-distance relaying. The feasibility of highly directive antenna systems and the property of high attenuation beyond the horizon, with consequent freedom from interference beyond the intended receiving point, make feasible relaying without the use of much frequency spectrum space. A chain of relay stations can repeat the same frequency with only moderate distance separation, especially if zigzagging of station locations is employed.

A highly developed form of relay system is being introduced currently in the United States by the Bell System, and transcontinental operation began in September, 1951. This is capable of transmitting four television channels simultaneously both eastward and westward and telephone traffic for the total distance of more than 3,000 miles (4,800 km).[1,2]

Comparable relay facilities in private service are being installed extensively throughout the United States and abroad.

In this system, more than one hundred relay stations are involved. Tests indicate that there is no substantial degradation in signal quality. The wide band of frequencies employed, the high antenna directivity, and the low power of transmitters combine to make such use of this region of the spectrum advantageous.

A second network operating in this band of frequencies is being installed in the United States by the Western Union Telegraph Company.[3] It is reasonable to expect that these systems are the beginnings of extensive networks which ultimately will cover most of North America as well as other large continental areas. It is clear that, as systems of this kind develop and expand, allocation problems will increase also and there will be need for substantial frequency space.

In addition to the telephone and telegraph UHF networks open to public correspondence in the United States there is now an increasing number of private operators of UHF or SHF relay systems for particular purposes. Pipe-line companies transporting oil or gas are large users of microwave relays, some systems extending as much as 1,840 miles, and a number of other relays are in regular operation.

Chapter 5

DYNAMIC CONSERVATION OF SPECTRUM RESOURCES

5.1 PAST LESSONS AND PRESENT PROBLEMS

In the past, extensions of the upper-frequency limit of the radio spectrum have provided room for the expansion of established services and the introduction of new ones. The useful limit was once thought to be 1.5 mc, but during the past three decades there have been extensions to 30, 300, 3,000, and most recently 300,000 mc. Measured in frequency space, this represents the discovery and occupation of a spectrum 200,000 times as large as was initially envisaged. Such an expansion, as visualized in 1925, might have taken care of all foreseeable requirements.

For many reasons this vast extension of the spectrum has not relieved the congestion of existing services. The new regions display technical properties not suitable for many existing services. Operators have in other cases been unable or unwilling to invest in new equipment. Even in cases where considerable expansion has occurred, as, for example, in the land-mobile services from the initial allocation at 2 mc to new bands above 30 mc, the old bands have been retained.

Even if full advantage is taken of the newly available space, a limit must ultimately be reached. In fact, the end of the extension of the useful radio spectrum seems now in sight, in view of the difficulties of transmitter power generation, the high attenuation at certain frequencies, and poor receiver sensitivity encountered at frequencies above 100,000 mc. These difficulties may be overcome in time, but it is unwise to depend on such an eventuality in laying down plans for the next decade.

The present congested situation can be remedied only in small measure by the transfer of services to higher frequencies. We are confronted, therefore, with an economy of scarcity in spectrum allocation; we may expect that the demand for spectrum space will increasingly exceed the supply. If the HF and VHF regions appear congested today, we can well imagine the state of affairs 10 or 20 years hence as current trends continue.

The radio spectrum is, then, a public domain of limited extent. When it becomes clear that a natural resource is thus limited, the evident course is to establish a program of conservation. When the end use of the natural resource is stabilized, as it is in forestry, water power, and certain forms of mineral wealth, a static policy of conservation may suffice in which the trend of past consumption is plotted against the known reserves and the resources disposed accordingly.

No such static policy will suffice in the conservation of the radio spectrum. One cannot extrapolate on the basis of past demand, because new forms of service appear with disconcerting regularity. Many of the newer services, particularly in the field of aural and visual broadcasting, consume amounts of spectrum space tens or hundreds of times greater, for each station, than is needed in the older services. Moreover, the nature of the natural resource is not perfectly understood; we still have much to learn concerning propagation and interference effects, for example, on frequencies above 100 mc. Without such knowledge, it is futile to set up a fixed plan of administration. What is needed, rather, is a program of *dynamic conservation* which sets up a procedure for changing allocations as new services of great value appear and as older ones lessen in relative value. This procedure must be equitable, and it must be based on sound technical and economic principles.

Such a dynamic program of conservation, courageously and wisely administered by all the nations of the world, would ensure the efficient use of spectrum space for the maximum benefit of the world's population. It would provide a method of arbitrating among the conflicting demands and requirements of different services and competing users of the spectrum. It would accommodate new services as their value is established and close out or restrict older services as their value wanes. It would take account of advances in the knowledge of propagation and improvements in apparatus which lead to more efficient and more conservative use of the spectrum. It would exploit the benefits of competition, while avoiding the excesses of competitive zeal on the one hand and the static tendencies of monopoly on the other.

The purpose of this chapter is to explore the implications of such a dynamic conservation program and to state some of the technical and economic measures necessary to put it into effect. As a starting point, in the following section the ideal condition of spectrum utilization is expressed in terms of a definition of full occupancy of the spectrum with respect to frequency, time, and geography. Various factors—technical, economic, and sociological—which tend to prevent attainment of full occupancy are then discussed. The extent to which these limitations are *real, i.e.*, inevitable in technical fact or inherent in the social structure of our times, is then considered. The extent to which such limitations are ***artificial, i.e.***, subject to technical improvement or to correction by the application of sound economics, provides the avenue of progress now open to those who administer the use of the spectrum. The final sections discuss specific measures, technical and economic, which may be used to implement the proposed program of dynamic conservation.

Throughout this book it should be realized that the broad point of view taken tends to obscure the intrinsic values involved in the utilization of the radio spectrum. It is necessary, for example, to discuss the radio services in broad categories, such as fixed, mobile, broadcast, amateur, special, location and ranging, and industrial and scientific applications. But these terms give little information, except to those whose professional life is very close to the allocations problem, concerning the actual *end uses* of radio as they affect commerce, industry, and the public welfare. In order to orient readers more concerned with such end uses than with broad categories, the accompanying table has been prepared. It comprises a list of some 80 different applications of radio, arranged according to the broad classifications mentioned above and patterned after the terminology used by the FCC. While this list has a formidable appearance, it is worthy of more than cursory inspection. Only in terms of such specific applications can the general problem of spectrum allocation be visualized concretely as an urgent reality, involving every channel of commerce, the operation of every form of transportation, protection of life and property, and the education and entertainment of hundreds of millions of people. So visualized, optimum utilization of the spectrum is no academic matter. It deserves the close attention of everyone engaged professionally in radio engineering, not merely those whose duties take them to administrative proceedings and international conferences.

Table 5. END USES OF RADIO

Communication Purposes

1. *Fixed services:*
    - Aeronautical fixed
    - Remote pickup
    - Studio-transmitter link (standard broadcast)
    - Studio-transmitter link (FM broadcast)
    - Studio-transmitter link (television broadcast)
    - Television intercity relay
    - Television pickup
    - Citizens' radio
    - Miscellaneous common carrier
    - Fixed public (international)
    - Fixed public (domestic)
    - Forest products
    - Motion picture
    - Power
    - Petroleum
    - Relay press
    - Special industrial
    - Highway truck
    - Intercity bus
    - Railroads
    - Urban transit
    - Fire
    - Forestry conservation
    - Highway maintenance
    - Police
    - Special emergency
    - State Guard
    - Government
2. *Mobile services:*
    - Aeronautical advisory
    - Aeronautical land
    - Aircraft
    - Airdrome control
    - Flight test stations
    - Flying schools
    - Remote pickup
    - Television pickup
    - Citizens' radio
    - Domestic public mobile

Miscellaneous common carrier
Forest products
Low-power industrial
Motion picture
Power
Petroleum
Relay press
Special industrial
Automobile emergency
Highway truck
Intercity bus
Railroads
Taxicab
Urban transit
Coastal harbor
Coastal telegraph
Coastal telephone
Ship telegraph
Ship telephone
Fire
Forestry conservation
Highway maintenance
Police
Special emergency
State Guard
Government

3. *Broadcast services:*

Developmental broadcast
Educational (FM) broadcast
Experimental facsimile
Facsimile broadcast
FM broadcast
High-frequency (international) broadcast
Standard broadcast
Television broadcast
Experimental broadcast
Government

4. *Amateur services:*

Amateur

5. *Special services:*

Special service bands are not allocated. However, a number of government and nongovernment services would logically be placed in such bands within the terms of the Atlantic City definition for this service.

Location and Ranging Uses

1. *Radiolocation services:*
   Radiolocation

2. *Navigation services:*
   Aeronautical radar
   Shipboard radar
   Government

3. *Special services:*
   Government

Industrial and Scientific Uses

1. *Industrial, scientific, and medical uses:*
   Medical diathermy
   Industrial heating
   Miscellaneous.

5.2 IDEAL AND ACTUAL CONDITIONS OF SPECTRUM OCCUPANCY

The ideal condition of spectrum occupancy may be defined as follows: The limit of spectrum occupancy occurs when all portions of the spectrum are fully, continuously, and uniformly utilized and each frequency assignment is employed by many stations so arranged that their service areas are adjacent but do not overlap. This criterion, academic though it is in terms of the actual occupancy of the spectrum, emphasizes the three ways in which the spectrum can be occupied: in frequency, in time, and in geographical location. It states without ambiguity the limit beyond which we can never hope to go. Another way of stating the proposition is this: Full occupancy of the spectrum exists when every differentially spaced frequency within the spectrum is found to be occupied with useful carriers or side-band signals of sufficient strength to override interfering signals and noise, no matter where on earth or at what time the investigation is made.

It may be objected that it is pointless to define spectrum occupancy in this manner, since full occupancy would imply no distinguishing features among the side bands and no intelligence can be communicated under these circumstances. This fact is recognized in the following discussion. The foregoing definition of spectrum occupancy has, nevertheless, the advantage of simplicity and definiteness. A more realistic definition would involve explicit assumptions concerning the modulation methods and might lose generality as new modulation methods are introduced.

Full occupancy, so defined, can be approached, but it can never be reached for many technical, economic, and sociological reasons. Among the technical deterrents to full occupancy are:

1. Portions of the spectrum must be reserved, in the form of "carrier tolerances," to accommodate unavoidable variations in carrier frequencies. The amount so required varies from a thousandth of a per cent of the carrier frequency to about 1 per cent, depending on the frequency and the state of equipment development. Space so reserved serves only to avoid interference; it does not otherwise contribute to the transmission of intelligence. In most cases the carrier tolerance is a small portion of the channel width, so the loss of occupancy thus incurred is not great. But the loss is one which can be reduced by purely technical means, provided only that sufficient incentive is offered to justify the cost.

2. All known methods of modulation involve concentrations of energy at particular regions of the channel occupied. This fact is a fundamental postulate of the theory of infor-

mation transmission and cannot be circumvented. Consequently no station can occupy its channel continuously and uniformly, as full occupancy would require, if it is to convey useful intelligence. There are, nevertheless, wide differences among methods of modulation regarding the density of the side bands. In some services, side-band density can be increased, with resulting improvement in occupancy, by suitable choice of modulation method. The proposal for "frequency-interleaved" side bands in color television is an example, of particular interest in view of the wide channels required for this service. The loss of occupancy due to this cause is very great; it is largely, but not wholly, unavoidable.

3. The theory of information transmission also indicates that the signal-to-interference ratio, for intelligible transmission, must exceed unity by a substantial amount. While this requirement is not fundamental (signals may be perceived through overwhelming interference if sufficient time is available for correlation of the signal components), it is sufficiently true in practice to constitute a valid basis for allocations planning. As a result, even under perfectly uniform conditions of propagation, the area over which a station causes interference is appreciable larger than the area over which it renders service. The service areas of two stations assigned to the same frequency can, therefore, never be adjacent, as full geographic occupancy would require. Rather the service areas must be separated by a zone within which interference is so prominent as to preclude service.

4. The service and interference areas vary in size with the condition of the atmosphere, particularly of the ionosphere at frequencies below about 50 mc and of the troposphere at frequencies above 50 mc. These variations are usually of great magnitude, may be sporadic or periodic, and are almost impossible to predict in detail. Two results of these phenomena are of paramount importance: in the first place, the occa-

sional *interference* range of a transmitter, during exceptional conditions of long-distance transmission, is very much greater than the reliable range of *service*, which must depend on normal propagation. This effect forces much wider geographical separation of stations than would otherwise be necessary (under the conditions outlined in 3 above) and sharply reduces the geographical occupancy of the spectrum. In the second place, periodic (diurnal and seasonal) variations in propagation require the assignment of several frequencies to many classes of station, only one of which is in use at a time, depending on the time of day (or season) and the distance to be covered. The frequencies assigned but unused at a particular time can be used by other stations only if a carefully coordinated program of sharing frequencies is instituted. While technically possible, such sharing is difficult to administer beyond the confines of a single operating organization. The net result is a frequency and time occupancy of the spectrum far below that which would obtain under steady conditions of propagation. Little can be done about this, beyond continued studies of propagation looking toward better prediction methods. Even with perfect prediction, large blocks of spectrum space would have to be used to accommodate unavoidable changes in service and interference ranges.

5. In nearly all classes of stations, except broadcast stations and microwave relay stations, the interference sector (angle from the station over which interference is caused) vastly exceeds the service sector. This is particularly true of stations (maritime and aeronautical mobile stations, for example) which cannot conveniently use directive antenna systems and consequently cause interference in all directions while communicating predominantly in one direction. The geographical loss of occupancy thus incurred is beyond calculation. Directional antennas can be used much more widely

than they are at present; this is, in fact, one of the most promising technical approaches to improved occupancy.

6. A related problem arises from the fact that many classes of stations (maritime and aeronautical) are mobile and travel over distances which are great compared with the service and interference ranges of the transmitters carried. A large allowance in geographical occupancy for each such station is required compared with that for an equivalent station at a fixed point. Since the very mobility of these stations is the primary justification for radio as a means of communication and guidance, this fact must be accepted as an unavoidable attribute of these classes of service.

Other limitations on full occupancy spring primarily from economic causes:

7. The need for radio communication evidently varies, in the great majority of services, with the time of day, to a less extent with the season, and is subject to major changes in accordance with the state of business activity, condition of war or peace, and similar social circumstance. Continuous operation of such services serves no purpose.

8. Variations in population density require great concentrations of service in and near cities, whereas in deserts, ocean areas, and polar regions, terminals of communication either do not exist or are widely scattered. Full geographical occupancy evidently serves no economic purpose in the latter regions. The areas of greatest population density are in general the limiting factor in geographical occupancy. In most classes of service, the rule is: "Allocate for the cities and terminals and you allocate for all."

9. Occupancy of the spectrum, in any event, occurs only when an economic purpose is served. Economic situations traditionally develop, even in the best planned of societies, in haphazard fashion or at least in a manner which cannot be

predicted accurately. When the plan for occupancy of a given region of the spectrum is first laid down, therefore, changes must be anticipated. A reasonable procedure must be set up for correcting such inequities and inefficiencies as may appear as the new terrain is settled and the direction of economic forces becomes manifest. Many of the errors now evident in allocations have been recognized for years but have been perpetuated for lack of such a corrective procedure or by the unwillingness of particular administrations to adhere to one.

Consideration of these nine limitations upon full occupancy shows that progress toward better spectrum utilization can be made in certain directions through the employment of better techniques and rational administration. Progress is blocked, in other directions, by the facts of nature and of social organization.

It is, perhaps, hopeless to expect that the restrictive postulates of information theory or vagaries of radio-wave propagation can be circumvented, particularly insofar as they cause the interference area of a station to exceed its service area by a substantial amount. It is equally hopeless to overcome the effects of nonuniform distribution of population. These limitations must be accepted. What remains is to take concrete action in those directions admitting improvement.

5.3 TECHNICAL MEASURES TO IMPLEMENT DYNAMIC CONSERVATION

The limitations governing spectrum occupancy discussed in the previous section suggest a number of corrective measures, some rooted in the design and operation of technical equipment, others in the administration of allocations. The technical measures comprise the early adoption of methods contributing to spectrum conservation, with due regard for the benefits and costs involved. The administrative steps involve applying sound doctrine in comparing the economic and social values of competing services.

In adopting these measures, great care must be exercised to avoid foreclosing future developments. The cornerstone of the conservative program should be the encouragement of and, as far as possible, advance provisions for new services having more extensive or comprehensive values than the old. Such unborn methods and services may have, in fact, at least as important claims on our natural resources as the services currently occupying the spectrum. The evaluation of the relative importance of the old and the new is, in fact, the most delicate task in the administration of the spectrum.

The following suggestions are offered, therefore, on the assumption that necessary steps have been taken and are in continuous effect to encourage experimentation with new services throughout the spectrum. The suggestions apply in particular to services which have passed the experimental stage and have entered or are about to enter regular operation.

On this basis, the following measures are indicated:

1. Experimental authorizations to develop new services should be granted in all regions of the spectrum, subject to reasonable safeguards to prevent interference with existing services. When a radio service performs a function which can be performed by nonradio equipment (*e.g.*, wire lines), the permanent establishment of the radio service, beyond the developmental period, should not take place until the comparative costs and values of the radio and nonradio services have been assessed and compared and a determination made

of other demands on that portion of the spectrum. Unless the costs of the radio service are appreciably less or their value appreciably greater than the corresponding costs and values of the nonradio service, conservation of the spectrum requires that nonradio services be used.

2. The frequency tolerances applicable to carrier emissions should be a suitably small fraction of the channel width. In most cases "suitably small" implies as small as the state of the art permits, without incurring undue penalties in size, weight, or ease of operation and maintenance. Such penalties are not usually the controlling factor. The principal deterrent is cost. After a reasonable period to amortize the cost of substandard equipment has intervened, it should be replaced by equipment meeting a reasonable standard of carrier stability.

3. Off-frequency operation and pirating of frequencies represent a gross derogation of the principles of spectrum conservation which must be brought under control by improved methods of international cooperation.

4. The use of guard bands to accommodate apparatus deficiencies (such as excessive carrier-frequency tolerances, improper or inefficient transmitter modulation, or inadequate receiver selectivity) should be curtailed.

5. The use of the most efficient modulation methods, with respect to uniform frequency occupancy of the assigned channel, should be encouraged, particularly in the wideband services such as FM and television broadcasting.

6. Every practical method of restricting the extent to which the interference area of a station extends beyond its service area should be employed. Specific measures include restriction of transmitter power to the level required for adequate service, suppression of harmonic emissions, synchronization of carriers where practicable ("offset carrier" in television broadcasting), and the employment of directional

antennas. Where the cost of such measures is substantial, a suitable amortization period should be allowed.

7. Services occupying regions of the spectrum not particularly adapted to their needs and capabilities should be transferred to other regions, in accordance with the dictates of full spectrum occupancy, and outmoded services deleted. Economic resistance to such shifts can be overcome by announcement of the impending change with a statement of the technical and economic advantages to be obtained, sufficiently in advance to permit old equipment to be amortized and to allow new equipment to be procured and installed. As knowledge of propagation and equipment improves and becomes stabilized, it should be possible to establish in advance the basis for such transfers over periods as long as 25 years, although shorter periods should suffice in most cases.

8. Frequency assignments should be shared to the fullest practicable extent. Time sharing of frequency assignments is looked upon with disfavor by nearly all users of the spectrum and by many of its administrators, largely as a result of unfortunate experience. Geographical sharing is common in many services, including all forms of broadcasting, but is uncommon in others, as, for example, between military and civilian services. The difficulties of shared operation are mainly administrative. While not belittling the problems, we must recognize that the increasing congestion of the spectrum will eventually force greater reliance on shared operation. The time is already past when a local assignment made under a military administration should preclude a similarly local assignment at a distance made under a civilian administration, when interference does not occur and is not anticipated.

5.4 ECONOMIC FACTORS IN DYNAMIC CONSERVATION

The corrective measures taken in the economic sphere are influenced to a great degree by two fundamental philosophies with respect to the distribution of facilities, which may be loosely labeled "competitive" and "monopolistic." The distinction between competition and monopoly is not confined to radio allocations, of course; it is deeply ingrained in economic theory and systems of government. While forms of government and principles of regulation differ, the plans of spectrum administration must be expected to differ in like degree. It is hopeless to expect that so fundamental a conflict will be resolved in radio allocations, but it is of value to examine the two patterns of administration as they affect measures of spectrum conservation.

The monopolistic position in radio allocations is based on the following reasoning: Full occupancy of the spectrum is fostered by rigid control of frequency use, by the elimination of duplicate facilities whose combined capacity exceeds the demand for service, by strict coordination of shared frequency assignments, by narrow tolerances on carrier frequencies and strict observance of channel limits. It is argued that these requirements are most easily met when the equipment is operated by a single organization, having cognizance of the need of spectrum conservation and being competent to put the necessary measures into effect.

Public broadcasting and common-carrier radio services in the majority of countries are currently operated in general conformance with this monopolistic principle. Domestic radiotelephone and radiotelegraph services, open to public correspondence, are customarily operated by the post offices in European countries. Broadcasting services in the great majority of nations are operated by a government department or by a government-sponsored corporation which has a monopoly on this class of service.

The alternative approach to the distribution of facilities—regulated competition—is exemplified by the system of broadcasting in the United States. The administration of the spectrum is in the hands of a government body (the FCC) which determines allocations, assignments, and standards of engineering practice. The ownership, operation, programming, etc., are in the hands of private companies which are, except in the case of certain telephone service, prevented by government regulation from obtaining a monopolistic position.

Under this competitive system, regulations concerning frequency stability, channel occupancy, standards of fidelity, noise, distortion, etc., are set by the government, in conformance with treaty agreements where applicable, and the private operators are required to adhere to these regulations and standards under penalty of losing their licenses to operate. In this respect, the quality of emissions under the competitive system is not inferior, and in some cases is superior, to that of stations operating in a monopoly.

The difference between the competitive and monopolistic systems arises not so much in the operation of individual stations as in the number of stations permitted to operate. In the standard broadcasting band, for example, the number of stations assigned to each channel is vastly greater in the United States than elsewhere in the world. This condition follows from the action of the FCC, under the Communications Act of 1934, in granting licenses to any qualified applicant who may appear, upon proper showing that a public service will be rendered without causing undue interference. The fact that 10 or 20 broadcast stations may already be serving the people of a given area is not considered reason for withholding permission for an additional station to operate, provided a channel can be found on which established levels of interference will not be exceeded. The basic principle followed is that as wide a choice of programs should be made available as will be supported by the public, subject to the limitation that additional programs shall not unduly reduce the service areas of existing stations.

The first advantage of the competitive system, in the field of broadcasting, is that the allocations and assignments tend to follow the will of the people as that will is evidenced in the economic support of the stations. Second, competition between program sources forces the adoption of a programming policy in accord with public taste and appetite.

The disadvantage is that the pressure for additional stations requires the government regulatory body to act with particular wisdom in finding the proper balance between the numbers of stations (with consequent wider choice of programs) on the one hand and the quality of the transmissions, as influenced by interference, on the other. If this balance is destroyed, the tendency is toward overpopulation of the broadcast spectrum. Many argue that such overpopulation has already occurred in the standard broadcast band in the United States. Certainly it is true that interference-free service is to be found at night only within a few tens of miles of the great majority of standard broadcast stations. Longer distance service is available on certain clear-channel stations, but these constitute only about 50 out of more than 2,000 such stations now operating in the United States. When such overpopulation occurs, it should be noted, the fault is not in the *principle* of competition but in the *method* of regulation.

Another set of conditions obtains in the administration of nonbroadcast service, notably systems open to public correspondence. In domestic common carrier operations, it is customary to set up a governmental monopoly or to grant a limited monopoly to a private organization. In the international communications field, there are often several organizations in apparent competition. But this situation does not necessarily represent true competition, since a common rate structure governs each organization. Thus if the facilities of the several organizations are increased until they are more than ample to carry existing traffic, the cost per message increases. This causes the operators to apply to the rate-making authorities for increases in rates which, if granted, constitute a loss due to competition rather than a benefit derived therefrom.

These examples of the tendencies of competitive and monopolistic allocations are cited because they constitute one of the most important conflicts to be resolved in assessing the economic and social value of radio services. If it is decided that the absolute minimum of spectrum space must be used in each service, the monopolistic approach is indicated. Carried to its logical conclusion, this approach leads to a greater variety of different types of service but to a smaller choice of facilities within each type. The benefits of true competition traditionally considered valid (lower cost, greater variety, more rapid development of improved methods, and more rapid correction of mistakes) are lost.

If, alternatively, it is decided that spectrum space should be made available to several organizations in competition within each service in order to gain the benefits just mentioned, fewer classes of service can be accommodated but a greater variety in each becomes available.

It is pointless to argue that spectrum administrators must adopt one course or the other. The proper method of allocation depends on the situation in the particular country, including its system of government. But it can be argued, with some point, that the excesses of both approaches must be avoided in allocating so congested a domain as the radio spectrum. The public must not be deprived of the type of service it wants and needs merely to satisfy an abstract concept, be that concept competitive or monopolistic. To take a concrete example, the optimum method of allocating the standard broadcast service presumably lies somewhere between the British monopolistic system, with good coverage but restricted choice of program, and the American competitive system, with comparatively poor coverage per station but considerably greater choice of programs.

When the appropriate economic basis of allocation has been established, in line with the foregoing discussion, the conservation methods thereafter adopted depend on the economic and social values of the various services. Without a measure of such values, it is difficult to arbitrate for or against the admission of new services or the enlargement of established ones at the expense of other services. It is necessary to measure, at every stage in the introduction and establishment of a new service, its actual and potential value relative to the older service it tends to displace.

This measurement takes the form of an assessment of certain costs and values, some of which can be expressed simply in terms of money, others of which involve such intangibles as the general public welfare, protection of life, national defense, and the prejudices and desires of the individuals collectively served or protected.

In purely commercial and industrial radio services, like those used in the operation of transportation systems (excluding the safety services), the cost of the radio service (the equipment, its operation and maintenance) can be compared directly with the money value of the products transported. If the ratio of cost to value is low, it is economically sound to subject such services to reallocation of channels or even to removal from the spectrum when other means will serve.

In the safety services, the value of the service rendered (protection of human life) is so great that the cost of rendering it is, with wide limits, immaterial. But this fact does not imply that safety services should have unlimited access to the spectrum. Quite the contrary. To ensure that distress calls can be answered and other safety requirements met on the broadest possible basis, a high degree of standardization is required in these services. Such standardization impedes the adoption of new methods and equipment. Here again, a sufficiently long interval between the announcement of intention to adopt new safety systems and the actual shift in allocation will bridge the gap. The resulting improvement in the safety services is evidently worth while.

In services where the public investment is large and widely distributed, as in the various forms of broadcasting, the cost of the equipment is relatively high in relation to the value of the service. Shifts in the broadcast allocation structure should be approached more slowly than in the commercial and industrial services. But sight must not be lost of the fact that broadcast receivers do become obsolete (more rapidly, for example, than shipboard receivers). Shifts in broadcast allocation are feasible, therefore, when properly conceived and executed over a suitably long interval.

5.5 SPECIFIC EXAMPLES

In conclusion, several examples of prospective shifts in allocation may be cited which illustrate the technical and economic trends discussed above. In the location and ranging services there is a definite trend away from aeronautical beacon service now occupying the band 200 to 415 kc and toward consolidation of these activities in the UHF above 900 mc. Maritime beacons in this band may continue to be used for a decade or more, but the present availability of more accurate navigation means on higher frequencies points to the eventual evacuation of this band by the location and ranging services. Aural broadcasting, as stated elsewhere in this book, could use this vacated space to advantage.

Aeronautical beacons now operating in the band 108 to 118 mc and air-to-ground communications in the band 118 to 144 mc are planned for transfer at an early date to higher frequencies, and the space thus vacated is vitally needed by the land-mobile services.

The land-mobile service at 2 mc can operate better on frequencies in the VHF range whereas maritime medium-distance stations in this band can use more space effectively. The land-mobile safety services now operating in the 30- to 50-mc range, such as fire and police, are subjected to long-distance interference during periods of high sunspot activity. These vital services should be transferred to higher frequencies which are free of such interference, leaving more space for other land-mobile services which can cope better with these propagation characteristics.

The maritime mobile service should consolidate its communication requirements, making use of advanced types of equipment and methods of handling traffic. Such a consolidation might take the form of transferring the telegraph service from the frequencies below 500 kc to HF telegraph bands starting at 2 mc and including 4-, 8-, 12-, and 16-mc bands. Fewer telegraph bands and advanced transmitter design and systems of handling additional traffic should greatly improve the efficiency and economy of this service. The maritime mobile telephone service should be expanded in the 2-mc range but limited to those users requiring a communication range greater than that obtainable on VHF. Short-distance maritime mobile communications, capable of being handled on the VHF should not operate on the congested HF bands. The maritime safety service, including a standardized automatic alarm system, might well be established in the vicinity of 2 mc and combined with a similar safety operation in the aeronautical field.

In the broadcast services, extension of the standard broadcast band downward in the direction of 200 kc, in the areas of the world not now using this space for broadcasting, would appear a worth-while long-term objective. Particularly to provide coverage of rural areas in implementing additional broadcast space, the aim should be to furnish interference-free service over the areas served by these frequencies in order to provide the best possible reception in large sparsely populated areas. This means that in most countries there should be no additional broadcast stations authorized in the LF and MF bands. Rather, the actual number of aural broadcasting stations should be reduced in order to obtain sufficient cochannel and adjacent channel separation. Those stations which provide a purely local service should be moved to the band 88 to 108 mc, thus providing a superior short-range service.

Within 20 years it should be possible to provide long-distance coverage of most of the world by MF and LF stations and to supply multiple service to all areas of concentrated population by VHF. This plan should also provide sufficient channels and freedom from interference so that the bands above 2 mc, which are subject to serious sky-wave interference, will no longer be required for domestic service. Implementation of such an allocation plan for broadcasting accomplished gradually does not present insurmountable social and economic difficulties. The problem is one of developing and publicizing sound long-range administrative plans, accompanied by industrial efficiency in providing low-cost transitional receivers.

The HF broadcast bands should not be used for domestic coverage which could be accomplished better in the MF or VHF bands, and the number of HF transmitters per country should be materially reduced in order to accomplish selective programming with less interference to the benefit of all. Furthermore, for the reasons outlined in Chaps. 3 and 4, every effort should be made, as soon as international conditions permit, to reduce international and intercontinental HF broadcasting by encouraging the transmission of programs by transcriptions or by the use of high-quality fixed circuits and rebroadcasting the programs over the LF, MF, and VHF broadcast services.

Finally the use of VHF and UHF point-to-point relays for fixed radiotelephone and radiotelegraph circuits is indicated as a measure to relieve congestion on the MF and HF bands.

These changes in allocation are typical of the action required under the proposed program of dynamic conservation. Resistance can be expected from those required thereby to make changes in equipment and operating procedures. But if the changes can be shown to be technically sound and to have inherent ultimate benefit, they are in the public interest and are beneficial to private and government interests as well. When this benefit is recognized, and when the transfer is made in such a way as to avoid undue financial hardship, the resistance can be transformed to cooperative participation in the program of spectrum conservation.

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Chapter 2

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APPENDIX

JOINT TECHNICAL ADVISORY COMMITTEE

Radio-Television Manufacturers Association Engineering Department — Institute of Radio Engineers

Ad Hoc Committees — Consultants

SOURCES OF TECHNICAL INFORMATION

Broadcasting

IRE Technical Committees:

Audio Techniques
Facsimile
Information Theory & Modulation Systems
Radio Transmitters
Receivers
Television Systems
Video Techniques
Piezoelectric Crystals
Subcommittees of above

RTMA Eng. Dept. Committees:

FM Systems (FM)
Television Systems (TS)
AM BC Transmitters (TR2)
FM BC Transmitters (TR3)
TV BC Transmitters (TR4)
Transmitter Components (TR9)
BC and SW Receivers (R3)
TV Receivers (R4)
FM Receivers (R6)
Radio Interference (R15)
FM and TV Test Equipment (ETE2)
Audio Facilities (TR10)
Receiver Components (CEX)
Committees of above

NARTB Engineering Department

Frequency Modulation Assoc.

FCC Bureau of Engineering

Other organizations concerned with broadcasting

Common Carrier

IRE Technical Committees:

Mobile Communications
Radio Transmitters
Receivers
Information Theory & Modulation Systems

RTMA Eng. Dept. Committees:

Communication and Marine Aids (TR6)
Microwave Relay Systems (TR14)
Aeronautical Radio (TR7)

FCC Bureau of Engineering

Other organizations concerned with common carrier service

Safety Services

IRE Technical Committees:

Navigation Aids
Mobile Communications

RTMA Engineering Department:

Communication and Marine Aids (TR6)
Aeronautical Radio (TR7)
Land-Mobile Services (TR8)

Radio Technical Commission for Aeronautics

Radio Technical Commission for Marine

Radio Technical Commission for Land-Mobile Service

American Radio Relay League

FCC Bureau of Engineering

Inter. Assoc. of Chiefs of Police

Assoc. of Police Communication Officers

International Municipal Signal Association

Assoc. of American Railroads

Other organizations concerned with safety services

Miscellaneous

IRE Technical Committees:

Antennas & Wave Guides
Wave Propagation
Standards
Sound Recording & Reproducing
Measurements & Instrumentation
Industrial Electronics
Circuits
Electroacoustics
Electron Devices
Electronic Computers
Symbols
Servo-Systems

RTMA Eng. Dept. Committees.

General Standards (GS)
Transmitter Executive (TREX)
Receiver Executive (REX)
Joint Electron Tube Eng. Council (JETEC)

Research and Development Board.

Committee on Electronics
Panels of above

International Scientific Radio Union (URSI)

International Radio Consultative Committee (CCIR)

National Bureau of Standards

FCC Bureau of Engineering

Other organizations

CHARTER OF THE JOINT TECHNICAL ADVISORY COMMITTEE

Function and Procedure of the Joint Technical Advisory Committee

1. *Preamble* For the purpose of rendering additional public services in their fields of activity, the Institute of Radio Engineers (IRE) and the Radio Manufacturers Association (RMA) * jointly created a committee named the Joint Technical Advisory Committee (JTAC) responsible to their respective Boards of Directors, and establish this charter under which the Committee shall operate.

2. *Objective* The JTAC shall obtain and evaluate information of a technical or engineering nature relating to the radio art for the purpose of advising Government bodies and other professional and industrial groups. In obtaining and evaluating such information, the JTAC shall maintain an objective point of view. It is recognized that the advice given may involve integrated professional judgments on many interrelated factors, including economic forces and public policy.

3. *Duties* The duties of the JTAC shall be as follows:

a. To consult with Government bodies and with other professional and industrial groups to determine what technical information is required to insure the wise use and regulation of radio facilities.

b. To establish a program of activity and determine priority among the problems selected by it or presented to it in view of the needs of the profession and the public.

* Now the Radio-Television Manufacturers Association (RTMA).

c. To establish outlines of the information required in detailed form. These outlines will be submitted to qualified groups as hereinafter defined, who shall study the requirements and supply the required information.

d. To sift and evaluate information thus obtained so as to resolve conflicts of fact, to separate matters of fact from matters of opinion, and to relate the detailed findings to the broad problems presented to it.

e. To present its findings in a clear and understandable manner to the agencies originally requesting the assistance of the Committee.

f. To make its findings available to the profession and the public.

g. To appear as necessary before Government or other parties to interpret the findings of the Committee in the light of other information presented.

4. *Membership* The JTAC shall consist of eight (8) members.

The members shall be chosen on the basis of professional standing, integrity, and competence to deal with the problems to be considered by the Committee. The members shall be chosen from among all qualified engineers irrespective of the organizations to which they belong or the companies by whom they are employed and shall operate without instruction. Half of the members shall be nominated by IRE and half by RMA, and the appointment of all members shall be confirmed by both bodies. None of the members shall receive any regular compensation for services from the National or any State Government.

There shall be no alternate members.

Members shall serve for a term of two (2) years, commencing July 1 and terminating June 30. To assist in maintaining the continuity of action of the Committee, half the initial roster of members of the Committee shall be appointed to serve two consecutive terms.

5. *Officers* The officers of the Committee shall be a Chairman, a Vice Chairman, and a Secretary. The Chairman and Vice Chairman shall be appointed from among the eight members of the JTAC by the Boards of Directors of the IRE and of the RMA on alternate years and will serve for a term of one year, except as may be otherwise determined by the Boards. The Secretary shall be a qualified individual appointed by the members of the JTAC and shall serve for a term of one year. The Secretary shall not be a member of the Committee.

6. *Committees and Consultants* The JTAC shall make use of existing committees in the IRE and RMA organizations wherever possible. Where a qualified group does not exist, the JTAC shall appoint ad hoc committees to study and report on particular subjects. Such ad hoc committees shall be disbanded upon completion of their assignments. The Committee shall also make use of qualified sources of information outside the IRE and RMA organizations, including the engineering staffs of Government bodies as well as professional, educational, and industrial groups qualified to assist in its program. Technical consultants may be invited to assist upon occasion, by the Committee as a whole.

7. *Procedure* The proceedings of the JTAC shall be conducted in accordance with parliamentary procedure as outlined in Roberts' "Rules of Order." Five (5) members shall constitute a quorum. In view of the nature of the activity of the Committee, it is expected that the majority of actions taken will be by unanimous vote. In any event, no affirmative

action shall be taken by the Committee based on less than five (5) affirmative votes. Minutes of all proceedings shall be recorded by the Secretary, and shall be distributed to the members of JTAC and to the members of the Boards of Directors of the IRE and RMA. The business affiliations of the members shall be omitted from the Committee records. The JTAC may authorize the distribution of minutes to qualified representatives of the agency requesting its advice and assistance. Meetings shall be called by the Chairman as necessary, or by a majority of the members upon ten days' notice, except that meetings may be held on less than ten days' notice if waivers of notice are obtained from the entire membership. To insure that the JTAC findings are based upon all available information, the Committee will accept and endeavor to secure information on particular topics from all organizations and individuals having such information, and a complete record of this fact-finding procedure shall be kept by the Secretary. The JTAC may invite observers from those agencies seeking its advice, such observers to attend meetings at which their problems are considered. The expenses of the Secretariat shall be borne equally by the IRE and RMA to the Boards of Directors of which statements thereof are to be provided quarterly. In event of question, the amount of allowable expense shall be determined by the two Boards of Directors.

Adopted by the Boards of Directors of the Institute of Radio Engineers and the Radio Manufacturers Association.

B. E. SHACKELFORD
For the Institute of Radio Engineers
June 17, 1948

W. R. G. BAKER
For the Radio Manufacturers Association
June 21, 1948

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Philadelphia, Pennsylvania

Mr. L. G. Cumming, Non-Member Secretary
New York, New York

INDEX

THE STRUCTURE AND POLICY OF ELECTRONIC COMMUNICATION

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CONTENTS

PREFACE

This brief treatment of a large subject grew out of a concern over the lack of knowledge outside of industry and government circles about the structure and policy of electronic communications. Even within those circles the knowledge tends to be colored and circumscribed by the interests and activities of the particular institution — be it corporation, trade association, or government agency. A number of years of experience as the economist responsible for social and economic research on the staff of the Federal Communications Commission provided me a limited background of understanding of the topic. And nine years of university research and teaching in the field of communications made the paucity of public information painfully evident. A number of studies of broadcasting activities have illuminated many aspects of that portion of electronic communications. Yet an adequate understanding of even broadcasting would seem to rest on a broader base: the policy and structure of electronic communications. For inevitably all of the diverse activities which utilize the radio spectrum have this much in common, that they must all be accommodated to an over-all pattern of policy and structure for the use of this natural resource.

The immediate occasion for embarking on the writing of this bulletin was a jointly authored article which Robert A. Brady and I at one time considered writing. That article unfortunately was never written. However, to him I owe acknowledgment for his share in the discussions which started me on the writing of the present work. I also express appreciation to Marion H. Woodward, Chief, International Division, Federal Communications Commission, and to Joseph D. Phillips, University of Illinois, who read the manuscript in draft and raised numerous helpful questions concerning my interpretations.

DALLAS W. SMYTHE

May, 1957

I. THE PROBLEM AND ITS CONTEXT

Ruskin is reported to have asked, when pressed for comment on the opening of cable service between England and India, "What have you to say to India?" This is merely one of innumerable reflections on the social consequences of the introduction of electronic means of person-to-person communications. It is a commonplace that because of the virtual elimination of space as a barrier to communications of this type, nations, individually and collectively, are compelled to live within a business, political, and social structure which is closely articulated and integrated. It is even more a commonplace, because it is so dramatically evident to all manner of social critics, that the application of electronic means to mass communication (radio, television, and so on) generates as yet ill-understood effects on individuals and on all social institutions. The present purpose is not to explore these familiar issues, but something else again. It is to consider the degree of integration of communications agencies in organization and practice which the technology of electronic communications has forced both within and between nations.

Specifically, the purpose of the present monograph is to demonstrate that

(1) The technological imperative in telegraphy and telephony resulted in an articulated structure of organization and operation, both within nations and internationally;

(2) The addition of radio communications to the wire telegraph and wire telephone (the three together being hereafter called "telecommunications") intensified this technological imperative and added an inevitable element of centralization of control both within and between nations; and

(3) The economics of the radio spectrum compels unified international and intranational planning to function passably well, considering the near-infinite range of conflicting demands for the use of the spectrum, the technical limitations on its use, and the high policy considerations which are its politico-economic context.

In the foreground of the context for the analysis of these propositions stands the postal service. Unlike telecommunications, postal service is not inseparably tied to a given method of transportation of the message. It may work with horses, railroads, automobiles, airplanes, or sail, steam, diesel, or atom-powered ships. Unlike telecommunications, postal service is not the usual primary or exclusive purpose of a given transport technique. Nevertheless, the significance of postal service in providing precedents for the organization and operating features of telecommunications requires recognition.

It can be taken as axiomatic that the facilities employed and the kind and quality of postal service rendered are generally consistent with the needs of the interest groups which control a government and with the resources at their command. The rise of the national state in Western Europe from the seventeenth to the nineteenth century required the creation of a national military establishment, a national government bureaucracy, and a national postal service. The national postal service of such states was governed by policies shaped by the military, political, and economic interests of the heads of states and their supporting interest groups. The Industrial Revolution (with the application of large-scale technology to manufacturing, commerce, and extractive industries) generally followed the bourgeois political revolutions which took place in those national states. And as the industrial and middle-class groups in their populations began to enjoy substantially the economic, political, and social fruits of the bourgeois revolution and the Industrial Revolution, the objectives of postal policy reflected the pressures of the complicated interest groups which came to focus on it. To be sure, in a newer order, postal policy continued to be used as an instrument for diplomatic and military ends (as in subsidies extended to railroads, steamship lines, and airlines). It also took on the function (in the United States) of subsidizing political parties, the press, and the rural population (through parcel post, rural free delivery, and so on). In the process, postal policy shifted its concern from being a source of revenue for the national government to providing universal service with flat rates, even at the cost of deficit operations. In short, during the nineteenth century postal policy effectively came to offer a wide variety of services to most parts of the population. Withal, it remained a monopolistic, integrated structure of facilities and employees, answerable to the national state.

But this is by no means the full extent of the postal precedent. As the network of postal service broadened and deepened in and between nations through the agency of improved means of transportation, the growing corps of professional postal civil servants began to plan internationally. As early as 1863, the International Postal Union was organized, and by

1874 such planning provided for the interchange of mail between most countries of the world on operating standards (fixed international units of weight, elimination of accounting for and division of postage, and so forth) which facilitated the movement of mail world-wide. Detailed examination of national and international planning of postal service may be omitted here because the unique quality of postal service lies in a concern for handling record communications. If, as was the case, telecommunications activities were grafted onto the postal organization in most countries, it is still evident that postal experience provided a monopolistic model at the national level, linked through international organization and procedure to provide postal service throughout the world.

This, in brief, was the context in which telecommunications came to the Western world. But before proceeding to the main business of the present study, it may be useful to summarize some of the contextual implications of the arts of telecommunications.

The first of these art forms to appear on the scene was wire telegraphy. Telegraphy was a *record* communication. As such it served as an extension of writing and other methods of record communication which, as Innis has remarked, tended historically to confer monopolies of space on cultures which employed them.[1] Telegraphy, like other forms of record communications, was eminently suited to the administration of *decentralized* organizations widely spread over space. Indeed its use has been primarily for military, political, and business purposes; private individual uses have never dominated its traffic.

For person-to-person communication telegraphy is accomplished by transporting the *message* over space, and the time factor is flexible, although significant in comparison with slower means of communication.[2] Telephony, however, performs a quite different service: it links together the calling and the called parties in voice communication with each other for a *period of time.* Having supplied facilities with capacity to handle the message, telephony is unconcerned with messages; those who pay for its facilities may leave the channel silent if they please.

If wire communications effectively eliminated the importance of space as a limiting factor on the operation of a communication facility (and because electricity travels at the speed of light, the length of time required for transmission of messages is insignificant), radio completed the emancipation of communications from the limitations imposed by space

[1] Harold A. Innis, *The Bias of Communication* (Toronto: University of Toronto Press, 1951), Chap. 2.

[2] The vagaries of telegraph speed of service have long since been embodied in American folklore by means of the familiar gags and jokes concerning the telegram that was delivered after the sender reached the destination personally.

by also eliminating the necessity to *build* anything between the transmitter and the receiver.

It is obvious that the development of telecommunications has broadened the scope of the behavior symbols which may be communicated. Printing in all its forms is limited to written (i.e. impersonal) symbols. Telegraph has a narrower scope; it is effectively limited to alphabetical symbols. Pictorial or diagrammatic messages can only be transmitted by resort to the little-used facsimile version of telegraphy. The use of telephony (wire or radio) for voice transmission obviously shifted the nature of communications to include all symbols expressible in *sound*. The scope of communications became personal in a new sense. The use of telephony for video transmission (now only in television broadcasting but ultimately for person-to-person communication too) adds *visual* symbols of all kinds to the scope of communications. When to this is added the *recording* of *sound* and *visual* symbols (which is now possible with the use of video-tape recording), something like a synthesis of communications except those by touch and taste (or smell) has been accomplished.

By thus linking separated people for communication with each other, telephony tends to create monopolies of time as well as of space. The addition of sight and sound to record communications, moreover, begins to confer on telephony the possibility of monopolies of sensory attention. Person-to-person use of telephony has already achieved a little noticed dependence on synchronized use of time. It is a rare person in the Western world who is capable of ignoring a ringing telephone; and it is remarked that the ringing telephone tends to interrupt and supersede other activities. This time factor becomes even more evidently central to telephony when its use for what is commonly known as broadcasting is considered. For broadcasting is like person-to-person telephony in that the transmitting and receiving equipment when tuned together provide a channel of communications *for a period of time*. Broadcasting differs from person-to-person telephony in technical essentials only in two respects: it is multiple-address telephony (i.e., instead of a single transmitter and a single receiver coupled together, the single transmitter is coupled with a mass of receivers); and broadcasting lacks the capacity of two-way communications (i.e., there is no possibility of electronic "feedback" from the addressed receivers).[3]

Because of its cheapness and flexibility of operation in relation to

[3] Having built a broadcast system on this basis, electronic "feedback" is effectively foreclosed at the present time. It would have been possible in the beginning, and it would be possible in the future, however, for engineers to design broadcast equipment so that the capacity for electronic feedback would be built into the equipment, with social and psychological effects now beginning to be appreciated.

space served, radio communication facilitated the administration of far-flung organizations. And by virtue of its relation to the use of time, *radiotelephony* offers administrators the alternative of *centralized authority* over and above the possibility of using *radiotelegraphy* with its potential for *decentralized authority.* Radiotelephony, whether used for person-to-person or broadcast communications, therefore implies the possibility of centralized or integrated administration of organizations spread over the whole face of the earth. It invites downward-flowing authority to integrate control through monolithic units. The full implications in this connection of the potential for monopolizing sensory attention which the addition of video and video-tape to aural communication permits have hardly begun to be appreciated outside of fiction.[4]

These implications are inferable from the technology of telecommunications. They also appear to be validated by empirical observations. The uses made of person-to-person telephony by military, political, and business institutions as well as by individuals have accustomed the Western world to synchronized use of time by persons widely separated in space. Radio broadcasting, whether of aural or television programs, has been treated as something which must emanate from centralized locations and to which no electronic "talking-back" is possible. Through well-known examples, such as those of Roosevelt, Hitler, and Eisenhower, it is possible to show that the political process can be closely integrated with the personality of the political leader. In the area of the arts, it is evident that the entertainment industry centralizes popular attention on its "stars," whether in the fields of drama, variety, comedy, or sports events. And the inference that monopolies of time are created by radiotelephony is supported by the observation that in fact the broadcast industry exists on the basis of the *sale of time.* The "sale of time" is an accurate and illuminating trade expression which means that the station sells the use of its transmitter for clock-hours of time at prices which reflect the probability (derived from audience surveys) that stated numbers of persons in the population will devote *the same clock hours* to listening or listening and viewing what comes through their broadcast receivers. The authoritative connotation is inescapable.[5]

The foregoing implications are explored here to point up the significance of what follows. As will be noted later, telecommunications devices have permitted greater efficiency in the use of time and property by

[4] See Aldous Huxley, *Brave New World* (London: Chatto and Windus, 1932), and George Orwell, *1984* (New York: Harcourt Brace, 1949).

[5] In a sense slavery means the sale of 100 percent of the time of the slave. And George Orwell's *1984* fantasies use of television which approximates 100 percent control of individuals by a centralized authority.

organizations of all kinds, regardless of purpose. They permit more effective education in the appreciation of cultural values; they also permit debasement of such values. Our purpose in what follows is not to explore such ultimate effects further. Rather, it is to demonstrate how, in order to use such devices, unified and centralized planning was mandatory both within and between nations. Telecommunications demonstrates that integrated national and international organization is already present (and it is idle to speculate on the assumption that it is not). It also provides the basis for the conclusion that such being the case, the relevant issues for social consideration stem not from the question, Should there be such organization? but rather, What policies should such organization follow?

II. UNIFICATION OF WIRE-TELEGRAPHY

The technological imperative of wire-telegraphy in the social, political, and economic context of Europe and the United States yielded an integrated structure of organization and operation both within and between nations. This is demonstrable as to individual nations in such diverse circumstances as are provided on the one hand by Continental states which from the beginning treated wire-telegraphy as a national government monopoly and on the other hand by England and the United States where the technique was left to the innovation of private business. The present chapter summarizes the development of the national wire-telegraph systems, and proceeds to describe the origins of international planning for their integration across national boundaries.

National Unification of Wire-Telegraphy

The immediate antecedent to the innovation of wire-telegraphy was the short-lived innovation of optical telegraphy. In the last decade of the eighteenth century under Napoleon in France, the optical telegraph, using semaphore signal stations on towers six to twelve miles apart, was introduced. By 1842, when the last new line was built, the French War Department operated more than 3,000 miles of such telegraphs.[6] Operated solely for military intelligence purposes, the optical telegraph was never opened to the use of the French public. The British also experimented with optical telegraphs, beginning in 1796 with lines to Dover and Portsmouth. After the Napoleonic Wars, however, England abandoned all except one line which was used for commercial shipping information. In the 1830's, the Prussians built similar lines to connect Berlin and Coblenz, and the Russians constructed a line between St. Petersburg and Kronstadt. Following the War of 1812, the United States War Department explored the possibilities of an optical telegraph line to connect

[6] A. N. Holcombe, *Public Ownership of Telephones on the Continent of Europe* (Boston: Houghton Mifflin Company, 1911), pp. 4-5.

New Orleans with Washington and through a survey of scientists stimulated Samuel F. B. Morse in his development of the electromagnetic telegraph.

For our purposes, the optical telegraph is significant as a transitional link between older techniques of communicating intelligence and those of telecommunications. It illustrates the strong national interests attached to communications policy and the fact that as the possibilities of improved technology were tested, communications came to be regarded as a monopolistic function of the state rather than a preserve for private business.

Electronic telegraphy was given working demonstrations first in England (1837) by Wheatstone and Cooke, using private resources, and in the United States by S. F. B. Morse (1844), with Post Office financing. Its innovation in the large nations took place within the decade beginning in 1846. On the Continent unification was planned from the beginning by the state agencies.

> Private enterprise never showed any disposition to engage in the telegraph business on a scale that would have made the service of much use to the general public. . . . The needs in response to which the electrical telegraphs were first called into existence, on any considerable scale, were purely military and political, and they were anticipated and satisfied by public authorities themselves.[7]

The German states planned wire-telegraphy to serve either politico-military interests or those of state-owned railroads. France embarked on wire-telegraphy construction initially for military and political reasons, but only after delays attributed to reluctance to accept the obsolescence of the considerable investment just made in the optical telegraph system.

England, like the United States, permitted the innovation of wire-telegraphy at the hands of private business, but shortly thereafter nationalized its telegraph lines (by the 1870's). English private ownership of wire-telegraph systems was distinguished by voluntary avoidance of duplicate construction. Less than 10 percent of the wire mileage and only 17 percent of the telegraph offices were competitive in 1865. Unification was achieved with relative ease and without "wasteful" use of resources.

By contrast, the "planning" of a national wire-telegraph system in the United States involved no central planning authority. That a unified telegraph system emerged was the result of monopolistic tendencies inherent in industries of high fixed cost and of the exigencies of the telegraph technology in its politico-social setting. A brief account of the innovation phase of telegraphy in the United States suggests both the lavish use of resources and the nature of the process of *de facto* "planning" for an articulation of facilities in ever more unified organizations.

[7] *Ibid.*, p. 15.

When Congress ignored the plea of Postmaster General Cave Johnson that ". . . the public interest, as well as the safety of the citizen requires the government should get the exclusive control of [telegraph], by purchase, or that its use should be subjected to the restraint of law,"[8] the existing telegraph lines were leased by the Post Office to promoters in the winter of 1846. At that time there were only 40 miles of telegraph line; by 1848 there were 2,000, and by 1850, 12,000. In those four years dozens of companies were organized to build telegraph lines quite independently of railroads. The Morse patents were licensed to promoters on a geographical basis and they hastened, with shoddy construction, to stake out the extensive shape of their would-be business empires.[9] By the end of 1847 there were nine companies with lines extending as far west as Chicago and projected as far south as New Orleans and as far north as Portland, Maine. Rival telegraph techniques stemming from patents sought or obtained by House and Bain were employed by still other promoters who generally paralleled the rough-hewn system erected by the Morse patentees. In the struggle for position between the different companies (and Morse patentees struggled between themselves as much as with other patentees), all the means available were employed, regardless of legality. Sharp corporate practice, bribery, the use of franchises from public bodies, court injunctions, advertising, rate cutting, and physical violence were all used freely.

In this total war in which no holds were barred, a few individuals thinly veiled by corporate structures reached in the end a measure of stability in their control over segments of the telegraph market. Only at that point were they willing to negotiate mergers, consolidations, and joint operations in order to realize the greater income potentialities. Beginning toward the end of 1851 a long series of such alliances were formed, usually between pairs of rival or connecting lines. Shortly after, telegraph lines formed *rapprochements* with railroads to their mutual advantage. By the mid-fifties, the nucleus of what became the Western Union Telegraph Company began to take form under the shrewd guidance of one of the ablest of the rough-and-tumble promoters, Hiram Sibley. The thinning numbers of rival companies invited combinations on a wider scale, and Sibley was instrumental in negotiating what significantly was known in the American industry as "The Treaty of the Six Nations" in 1857 between six of the larger of these. This agreement resembled international agreements in many ways. Careful territorial divi-

[8] Robert L. Thompson, *Wiring a Continent* (Princeton: Princeton University Press, 1947), p. 33.

[9] The following description draws heavily on Thompson, *op. cit.*, and Frank Parsons, *The Telegraph Monopoly* (Philadelphia: C. F. Taylor, c. 1899).

sions of the market were agreed to with absolute sovereignty reserved to each of the six companies in its own area. Where there was duplicate service, business was to be carefully prorated. The companies pledged themselves to exchange traffic only with each other. They agreed not to build any more competitive lines and not to sell patent rights. Elaborate provisions were made for arbitration of disputes. Annual meetings were pledged and it was agreed that unanimity of the signatory companies would be required for changes in the agreement. This agreement was used as a base for aggression against the companies which were not parties to it. And as the larger companies grew more secure in their market positions, they entered into further mergers with the new arrivals as the latter grew to threatening size. This resulted in narrowing their numbers to a handful by the end of the century. The ultimate unification, organizationally, was achieved in 1943 when merger of the last two major wire-telegraph companies was permitted, under special legislation, by the Federal Communications Commission. Exchange of traffic and similar working relations between the major companies and the few remaining small regional telegraph systems had earlier been an accomplished fact.

In retrospect, the question arises as to how the United States could afford to indulge in the waste of resources and the inefficiency of industrial jungle warfare as a means of providing domestic telegraph service during the period before ultimate unification. This question is given force by the contrasting examples of European states where unification of wire-telegraphy under national control was the rule at an early date. The answer is to be found in the isolation of the United States from danger of invasion, in the richness of her natural resources, and in the political climate of opinion. In the United States, the telegraph could be and has been used for the most part in peacetime by news agencies, stock and commodity operators, gamblers, and private businessmen. When war has come, as it did in 1861, 1898, 1914, and 1941, the military have extemporized appropriate conversions of telegraph plants to war purposes.

The "planning" of facilities and service by means of submarine cable, like the planning of domestic wire-telegraph systems, reflected the politico-economic context of national states in imperial rivalry for colonies during the nineteenth century. The technology of telegraphy was ready for submarine use shortly after its innovation on land. The first successful submarine cable was laid in 1851 across the Straits of Dover. Transoceanic cable system building was spread over the following sixty years. While the story of these developments is too long and complex for the present paper, it is sufficient to state that the world's cable network, like the American domestic telegraph system, was "planned" through a process of market rivalry. Business interests in the several European nations and the United

States, working through and in the cable organizations, mixed their influence with military and political interests to produce a Clausewitzian type of aggressive rivalry. The setting for this volatile process lay in the dynamics of the need for colonies and the geographic logistics of the colonial systems. English, French, German, Belgian, Spanish, Italian, and Russian telegraph administrations, either directly or through private companies identified with the dominant economic interests of the respective countries, fought for security and enlargement of position in the business of international cables.[10] With the unique exception of the United States, all national cable facilities were reduced to a single operating system per country by the end of World War I. In the United States, national policy has favored competition between companies in cable as in international radiotelegraph service.

International Unification of Wire-Telegraphy

Side by side with the *de facto* world-wide planning provided by this total warfare by generally peaceful means went the development of official, orderly international planning for wire-telegraphy both on land and under the sea. The latter sort of planning dates from 1849 when the first of a series of European bilateral and multilateral treaties was entered into between Prussia and Austria. The general purpose of these treaties was the creation of an international telegraph network, first of all in Europe. The motives, in the order of importance, were diplomatic-political needs, the need to facilitate the operation of international railroad service, and the needs of commercial interests in relation to international trade.[11] The first treaty was rudimentary in scope but the following year Austria, Bavaria, Saxony, and Prussia formed the "Austro-German Telegraph Union" and adopted the "Convention of Dresden." This convention established a broad international plan for the use of telegraph facilities which (1) called for uniform telegraph legislation in the signatory countries; (2) provided for exchange of scientific and administrative information; (3) established tariff zones and rates on a mileage basis for international traffic; and (4) provided for periodic review of the telegraph interests of the parties. At its second meeting, in 1851, this union adopted Morse apparatus as official for the international lines and re-

[10] For a brief summary of plant expansion, see James M. Herring and Gerald C. Gross, *Telecommunications* (New York: McGraw-Hill, 1936), Chap. 2. For a discussion of the political and geographic aspects, see Leslie B. Tribolet, *The International Aspects of Electrical Communications in the Pacific Area* (Baltimore: Johns Hopkins Press, 1929).

[11] George A. Codding, Jr., *The International Telecommunication Union* (Leiden: E. J. Brill, 1952), p. 9. Hereinafter this source will be referred to as "Codding."

quired for the first time the physical interconnection of lines at the border (previously the practice was to decode and re-encode messages at borders). By 1854, four additional Germanic states and the Netherlands had adhered to this convention. By 1857, the preceding four conventions were codified into two categories: those rigid provisions directly bearing on the legal relations of the contracting states (known as the "convention") and the more flexible provisions dealing with the technique of telegraphy, relations with the public, tariffs, and so on (known as the "regulations").[12]

Meanwhile a similar development was taking place in Western Europe. France began a series of bilateral telegraph treaties with Belgium (in 1851) and by 1855 was one of five states (the others being Belgium, Switzerland, Sardinia, and Spain) which organized the "West European Telegraph Union," the policy for which was borrowed from the Austro-German Union. Linkage between the German and the French spheres began in 1852 with the signing of a convention in Paris by representatives of France, Belgium, and Prussia (the latter signing on behalf of both his own state and the Austro-German Telegraph Union). Although it adopted the existing provisions of the Austro-German Union, this convention departed from it to an extraordinary degree in freeing international use of telegraph from restraints. It was agreed (1) to provide telegraph facilities exclusively for international traffic not subject to border interruptions and to provide facilities adequate to carry the traffic load; (2) to recognize the right of every individual to use the international service upon payment of the posted rates; and (3) to recognize the secrecy of messages, although customers were to be required to identify themselves and to refrain from the use of ciphers. Within three years a reaction took place and in 1855 a new convention was signed between the same parties which strengthened the prerogatives of national governments. As Codding says:

> The participants decided to accept no responsibility for service difficulties and to judge for themselves the measures needed to provide for the security of the lines. Each government reserved the right to interrupt the international service for an indefinite period of time, in which case the government concerned was obliged to notify immediately each of the other contracting governments. Each government also reserved the right to police and control all traffic, and the individual telegraph offices were given the right to stop or to refuse to accept any telegrams which were considered to be contrary to good morals or to the public security.[13]

[12] This practice set a pattern for all later telecommunications planning at the international level. The meetings giving rise to the fundamental juridical policy became known as "plenipotentiary conferences." The instrumental meetings became known as "administrative conferences."

[13] Codding, *op. cit.*, p. 18.

At the same time, Morse apparatus was adopted as standard equipment and a number of regulations were adopted concerning the classification of messages, the division of tolls, and the settlement of revenue balances. Three years later at Brussels, the same parties lowered the level of international rates and made minor changes in operating practices. In the following three years, 12 additional countries adhered to the Brussels convention.

In 1864, the French government invited all major European countries (except Great Britain where telegraph lines were still privately operated) to a Paris conference where the scope of international organization would be expanded. The purpose of this conference was to draft a single convention which would bridge the gaps between existing conventions and which would initiate a new, single, uniform rate structure for international traffic. Twenty states (ranging from Russia to Spain to Turkey) met and created the International Telegraph Union in 1865. Uniform rates were adopted for areas other than Russia and Turkey. Only four years later at the second meeting of the International Telegraph Union in Vienna, a permanent administrative bureau (the "International Bureau of Telegraph Administrations") with a director and staff was established in Switzerland. The bureau was directed to (1) publish telegraph rates; (2) collect general statistics; (3) collect all information relating to international telegraph; (4) make special studies as directed; and (5) publish a journal on telegraph matters. The expenses of this first international agency were to be supported by all union members through a class-unit system. The Swiss government was asked to create the new bureau, direct its activities, and provide it administrative and budget services. Parallel to this creation of a non-policy-making international agency to function continuously, the Vienna conference also took the first step toward creation of a continuous policy-making agency. A committee of union members was authorized to interpret the convention and to make decisions which would be binding on all members in the period between conferences.

The bureau staff arranged and conducted the next conference, held in Rome in 1871. This conference was distinguished by the fact that Great Britain (which had by then nationalized some of its telegraph facilities) participated and forced the conference to admit representatives of private commercial companies operating in member states. The opposition, led by France and Russia, tried to restrict the admission of these companies to committees, but Britain, supported by the Netherlands, was successful in obtaining their admission even to plenary sessions with the right of discussion but without the right to vote. Ten such companies were immediately admitted.[14]

At the third conference, held in St. Petersburg in 1875, the definitive codification of provisions as between the permanent convention and the flexible regulations was adopted. Technical committees were authorized to revise the latter without resort to the cumbersome processes of treaty making. The new convention was given indeterminate life and a provision was inserted permitting a member to denounce the convention without affecting the relation of other members — a provision which has never been used. From then until 1932 no changes were made in the convention although the regulations and tariffs were revised by administrative conferences on six occasions. Meanwhile this international unification of facilities was extended by adherence of additional members. By 1879, members included 24 countries and 16 private companies; by 1908, 52 countries and 25 private companies.

Because of its almost unique position of having no nationalized communications facilities, the United States was officially not a member of the International Telegraph Union. Unofficial observers were sent to the St. Petersburg (1875), London (1903), Lisbon (1908), Paris (1925), and Brussels (1928) conferences, but they neither participated nor signed the regulations. American companies, beginning with the conference of Berlin (1885); were directly represented and participated increasingly. Having interconnections with union administration facilities, the American companies in effect accepted the International Telegraph Regulations, but both the companies and the United States maintain a quasi-independent position.

By way of summary, it is evident that by the time they were mature and stable, the structure of wire-telegraph systems, whether domestic or ocean-cable, was unified within each of the nations of the Western world with the conspicuous exception of the United States. Parallel with this development of telegraph systems went the growth of international organization. A clear and lasting pattern of international organization and policy was established as early as 1875. Its significant features included

[14] The scope of the unification of telegraph facilities thus added may be judged from the names of these companies: Falmouth, Gibraltar and Malta Telegraph Company; Marseilles, Algiers and Malta Telegraph Company; Anglo-Mediterranean Telegraph Company; British Indian Submarine Telegraph Company; British Indian Extension Telegraph Company; British Australian Telegraph Company; China Submarine Telegraph Company; Telegraph Construction and Maintenance Company; Indo-European Telegraph Company; Great Northern Telegraph Company; Great Northern China and Japan Extension Telegraph Company; Anglo-American Telegraph Company; and the Société du Câble Transatlantique Français. Codding, *op. cit.*, p. 26, n. 117.

the creation of an international institution (the International Telegraph Union, with buildings, personnel, and budget), international operating standards, international rate-making procedures, and other incidental functions such as the collection of statistical and other information, the making of studies, and so on. As compared with later technological developments, wire-telegraphy was simple; yet its relatively undemanding technological imperative, in the context of national states, produced the essential core of international organization which was to be required by later telecommunications technologies as a foundation for a still tighter integration of organization and policy.

III. UNIFICATION AND ASSIMILATION OF WIRE-TELEPHONY

The advent of wire-telephony presented an alternative mode of person-to-person communication which tests on several counts our hypothesis that there was a technological imperative in telecommunications which produced integration and unification, nationally and internationally. Would wire-telephony be unified, per se, or would it fall into a pattern of duplicate facilities, unrelated to each other? If it were unified as a telephone system, nationally and internationally, would it be assimilated organizationally to the agencies which operated wire-telegraphy? Would its facilities duplicate those of wire-telegraphy or would they supplement and extend them? Would wire-telephony be treated, as a matter of international planning, through the same agency created for wire-telegraphy or through a separate agency? This chapter analyzes the development of wire-telephony in relation to such questions.

Unification and Assimilation of Wire-Telephony Nationally

Wire-telephony arrived inauspiciously at a time when wire-telegraphy had been innovated and securely ensconced in the economic and political structure of both Europe and the United States. In all European countries, telegraphy had become a unified service of the state, usually associated administratively with the postal service. In the United States the privately owned telegraph empires were in the capable hands of operators who enjoyed their positions by virtue of their success in ruthlessly crushing weaker rivals. The plans by which telephone developed were derived from these assorted circumstances.

Telephone was experimentally introduced in 10 of the 13 principal European countries and in the United States within the four-year period 1877-81. In England, France, Italy, Belgium, Holland, Austria-Hungary, Norway, Sweden, Denmark, and Spain, the commercial introduction of telephony was delegated to private companies, operating under franchises from the states. This initial policy was probably the uniform result of two factors. In the first place, the state post-telegraph administrations had only recently committed themselves to substantial capital investment in wire-telegraphy and found it unfeasible politically to enlarge and reshape their capital investment budgets to accommodate the heavier costs of building telephone plants when the telephone was still largely uncertain of public acceptance. In the second place, private business capital was interested in the commercial development of the telephone, as it had not been with telegraphy.

In the countries named, the service first developed was local exchange service in the largest cities, where monopoly profits were potentially largest. In some of them (Italy and Belgium) competition between duplicating companies was encouraged, whereas in others (England and Sweden) competition in local service was between private and state-owned exchanges. In all of these countries where private capital was encouraged to undertake the risks of telephone development, long-distance facilities tended to lag in development. For this there are several reasons. State policies designed to protect the revenues and investments in telegraph facilities did not favor intercity telephony. Private companies were less eager to provide the larger plant investment required for long-distance service than for local service. And the apparent demand for long-distance was less than for local service, quantitatively. By World War I, however, competition had vanished from telephones; the state had entered directly into the operation of long-distance and local service and private ownership was extinct or dwindling in all European countries except Spain and Denmark.[15]

Unification, in the sense of elimination of duplicate facilities and the articulation of wire telephone systems within a nation, was thus complete in Europe by World War I. Organizationally, telephone was added to the administrative responsibilities of the state administrations of posts and telegraphs in all but the two countries named.

Unification, however, has a second technological meaning. It can be thought of as the articulation of wire-telephony *with* wire-telegraphy in a nationwide network of facilities and service. In this sense, the European countries differed in the rate and extent of such articulation. The most complete and rapid development of rounded telephone facilities took place in Germany and Switzerland, both of which also had state telegraph systems. Simultaneously with exchange installations in the United States in 1877-78, the German telegraph authorities installed telephones in some 300 villages *where they served as extensions of telegraph facilities.*

[15] Holcombe, *op. cit.*, p. 15.

In addition to continuing this policy, the German state authorities added local exchange service in cities (beginning in 1881), and long-distance service (beginning in 1884). A parallel development of telephony took place in Switzerland. In these two countries alone in all Europe was the telephone quickly and unstintingly accorded a place in the structure of person-to-person communications facilities.

As had been true also of telegraphy, the United States experience in the development of wire-telephony took place under conditions which favored duplication and competition between rivals. Again, if something like a nationwide system lacking in facility duplication arose, the argument of the present paper would be validated.

In the United States, the potential resistance to the innovation of the telephone was no less than in most European countries. When Bell and his associates offered service to the public in 1877 (the year after he received his patents), their resources were meager. Powerful, well-established, and well-versed in the means for subjugating puny rivals, Western Union Telegraph Company promptly moved to establish control over telephone service. It bought telephone patents from Thomas Edison and Elisha Gray in 1877 and began to build exchanges to compete with Bell. In some cities it bought controlling interests in the companies which were organizing to operate under licenses from Bell. Bell retaliated by bringing suit for patent infringement in late 1878. The relative strength of the two parties was so unbalanced that Western Union might well have expected an easy victory. Indeed, the story goes undenied that in 1878 the Bell group was so hard pressed that they offered to sell their patents to Western Union for $100,000 and the offer was rejected.

It was at this point that a fortuitous array of rival forces in the laissez-faire climate of late nineteenth-century America erected a protective shelter for the innovation of the telephone. Western Union's very strength turned out, paradoxically, to be its greatest weakness. At the time, the Vanderbilts, William H. and Cornelius, owned stock control of Western Union. The generous profits enjoyed by that company's near-nationwide telegraph monopoly had attracted the aggressive attentions of Jay Gould. He had for a few years been developing a rival telegraph system. By 1877 Western Union, respecting the growing strength of this competitor, the Atlantic and Pacific Telegraph Company, purchased it. No sooner, however, did Western Union, having apparently quieted the Gould threat, turn its attentions to the Bell group than Gould returned to the attack. On May 15, 1879, 8 months after Bell brought suit against Western Union, Gould launched another attack upon Western Union in the telegraph field by the organization of the American Union Telegraph Company. With the aid of able stock-market manipulators, and through the columns of his "New York

World," Gould attacked the credit of the Western Union and drove its stock quotations down. Apparently, he availed himself of every conceivable weakness of the telegraph company's position, one of which was its pending suit with the Bell Telephone Company. Gould also began buying telephone exchanges, operating under Bell licenses, with an implied threat to throw his financial support behind the telephone's competitive threat to Western Union's telegraph monopoly.[16]

Within 15 days after the formation of the American Union Telegraph Company, Western Union approached the Bell group with an offer which created the necessary conditions for the innovation of telephone. Western Union admitted the validity of the Bell patents and agreed to withdraw from the telephone field.[17]

Although harassed by more than 600 patent suits from other rivals in the telephone field, Bell was substantially assured the opportunity to develop a unified telephone system through this nonaggression pact with Western Union. In this period it concentrated on local exchange service in the largest and most lucrative cities and pursued a classical monopoly pricing policy. Consequently, there was a total of only 228,000 telephones in the United States in 1890 — or 4 per 1,000 population. Interurban service was relatively slow to develop: Boston and New York were not connected by long-distance service until 1884, New York and Philadelphia until 1895, and New York and Chicago until 1892. After its basic patent protection expired in 1893, Bell service was supplemented by that of "independent" commercial companies and by farmer and mutual lines which, by 1900, served 37 percent of the nation's telephones. In the process, industrial warfare by all means short of outright violence determined where Bell should advance and where independent companies should hold their markets.[18]

Intervention by the United States government in the planning of telephone and telegraph service nominally began in 1910 when the Interstate Commerce Act was amended to bring both under its general terms as common carriers. Apart from collecting uniform accounting information, this law was not enforced at all vigorously and not until 1934 when

[16] Federal Communications Commission, *Report of the Investigation of the Telephone Industry in the United States* (Washington: Government Printing Office, 1939), p. 125. The offer to sell the Bell patents for $100,000 is related in N. R. Daniellian, *The A T T* (New York: Vanguard Press, 1939), p. 10.

[17] In return, Bell promised to stay out of the telegraph field, to buy Western Union's telephone facilities, and to pay Western Union 20 percent of the rentals received for the use by its licensees of telephone instruments for a period of 17 years. During this period, Bell was to have the use of all telephone patents owned by Western Union and the latter company was to pay Bell 20 percent of the cost of any new telephone patents developed by Bell.

[18] Federal Communications Commission, *Investigation of the Telephone Industry in the United States,* pp. 133-39.

the responsibility of regulating these "public utilities" was transferred to the Federal Communications Commission was even the semblance of effective control exercised. Even then the Commission's control ran to rates rather than to the kind and amount of service supplied. Perhaps more effective in the long run has been the existence of the Sherman Antitrust Law which was brought to bear in 1912 to force the Bell system (1) to separate from its control the Western Union Telegraph Company, which it had acquired in 1909; and (2) to stop its policy of absorbing independent telephone companies. Congressional action was also responsible for stimulating the increase in rural telephone service through the enactment of an amendment to the Rural Electrification Act in 1949 authorizing loans at low rates for the construction or improvement of rural telephone facilities. The proportion of American farms with telephones had fallen from 39 percent in 1920 to 25 percent in 1940; a postwar effort by the telephone industry, stimulated by congressional consideration of predecessor bills to the one which passed in 1949, raised this proportion to 38 percent by 1950.

The technological integration of telephone service in the United States is betokened currently by the fact that virtually every one of the more than 56 million telephone instruments in the country is interconnected through the Bell System, although its own telephones are about 83 percent of the total.[19] Dial telephones constitute 87 percent of Bell telephones and 65 percent of independent telephones. Long-distance toll dialing has been inaugurated and has developed to the point where telephone users in 65 communities now dial directly their long-distance calls to 16 million telephones in 17 large metropolitan areas. Despite the formal separation which exists between the Bell System and Western Union Telegraph Company, the business practices and facilities of telephone and telegraph are substantially integrated. On the one hand, Western Union has progressively abandoned its obsolete open wire lines and with them its contractual ties with railroads. In lieu of these facilities it has leased substantial quantities of circuit mileage from the Bell System. On the other hand, the Bell System's volume of telegraphic traffic (from

[19] The Bell System operating facilities consist of the American Telephone and Telegraph Company's Long Lines Department and 20 operating subsidiaries. Tied to it through operating relationships are more than 5,000 independent operating telephone companies of which 77 reported annual gross income in excess of $1 million in 1953. Beyond the scope of Bell and independent telephone facilities there is a fringe of tens of thousands of "cooperative" and "farmer" "lines" which provide neighborly telephone service and are seldom linked with the commercial telephone system. American Telephone and Telegraph Company, *The World's Telephones,* January 1, 1956; United States Independent Telephone Association, *An American Story: The Story of the Independent Telephone Industry,* May, 1954.

TWX, leased wire service, and so on) has mounted to the point where its annual revenue from telegraph was $74 million in 1954 — or one-third as large as the total domestic telegraph company operating revenues, which in the same year were $209 million. Telephone company revenues currently exceed those of the telegraph industry in a ratio of more than 24 to 1, for Bell System revenues alone in 1954 were more than $4,901 million. According to the FCC, the Bell System now does about five-sixths of the telephone business.[20]

National Systems for Person-to-Person Communications

Before concluding the discussion of the development of telegraph and telephone facilities and operations, some sort of survey of the several national systems seems to be in order. Yet measures of the scope and character of such systems and of their use which would be directly relevant to the thesis of this study are extraordinarily hard to develop. How, other than by a case-by-case description, can one measure the degree of integration of the systems? The conclusion is that such a task is hopeless. However, indirectly, some light may be thrown on the nature of the development of person-to-person communications service as between nations through an examination of measures of their use. Information of this kind is presented in Table 1 for the 10 nations with the greatest use of facilities per capita at two points in time. The first time period was just prior to World War I, and the latter, in 1953.

Between 1910 and 1953, as shown in Table 1, there was a marked rise in the use of telephones for both local and long-distance service. General increases of a smaller order took place in postal usage between 1912 and 1952. Telegraph use generally declined.

The six nations which appeared in the lists for local telephone calls for both years all increased their use. The largest proportionate increases were registered by Japan (over 800 percent) and Switzerland (over 500 percent). Even the two countries in the 1910 list which did not appear in the 1953 list and whose boundaries remained comparable (Netherlands and Luxemburg) experienced increases which multiplied their local phone use at least several times.[21] The lowest rates of increase among these leaders in local telephone use were found in the United States and Norway where the increases were less than 200 percent.

Similarly the seven nations which appeared in both years in the lists

[20] Federal Communications Commission, *22nd Annual Report for the Fiscal Year, 1956*, p. 2; Federal Communications Commission, *Statistics of the Communications Industry in the United States*, year ended December 31, 1954.

[21] In 1953, local telephone calls per capita in the Netherlands were 82, and in Luxemburg, 63.

TABLE 1. PER CAPITA USE OF POSTAL, TELEGRAPH, AND TELEPHONE SERVICE, FIRST 10 NATIONS, 1910 AND 1953

Number of letters and postcards			
1912		*1952*[a]	
United States	101	United States	176
New Zealand	93	Switzerland	106
Great Britain	87	Canada	104
Switzerland	70	Australia	131
Germany	64	United Kingdom	107
Denmark	49	New Zealand	77
Austria-Hungary	45	Denmark	75
Luxemburg	39	Saar	71
Netherlands	38	Ireland	63
Belgium	37	West Germany	60
Telegrams			
1910[b]		*1953*	
New Zealand	8.1	Monaco	8.1
Great Britain	2.2	New Zealand	4.0
Switzerland	1.8	Iceland	3.1
France	1.7	Australia[c]	2.7
Norway	1.4	Norway	2.0
Denmark	1.3	Canada	1.6
Belgium	1.3	United Kingdom	1.2
Netherlands	1.2	Japan	1.2
United States[d]	1.1	Luxemburg	1.2
Germany	0.9	Ireland	1.2
Local telephone calls			
1910		*1953*[e]	
United States	130	Canada	483
Norway	61	United States	368
Sweden	60	Iceland	366
Denmark	59	Sweden	287
Germany	24	Denmark	223
Netherlands	22	Norway	142
Switzerland	14	Finland	122
Japan	11	Australia	110
Austria-Hungary	9	Japan	105
Luxemburg	9	Switzerland	89

of long-distance telephone use increased their long-distance calls substantially. The most rapid growth was in Sweden (176 times) and in the United Kingdom (55 times). The lowest rates of increase among these leaders in long-distance telephone use were the United States and Denmark where the increases were less than 400 percent. The two countries with constant boundaries which appeared in the 1910 but not in the 1953 list Belgium and Japan) increased their long-distance use manyfold.[22]

The intensity with which postal facilities were used generally increased

[22] In 1953, long distance calls per capita in Belgium were 8, and in Japan, 6.

TABLE 1. CONTINUED

Long-distance telephone calls			
1910		*1953*	
Denmark	13	Switzerland	69
Germany	5	United Kingdom	56
Norway	3	Denmark	39
Switzerland	3	Sweden	71
United States	3	Netherlands	20
France	1	Finland	19
Great Britain	1	Norway	16
Sweden	0.4	New Zealand	15
Belgium	0.3	United States	14
Japan	0.2	Iceland	9
Austria-Hungary	0.2	France	9
		West Germany	9
		Canada	9
		Australia	9

[a] Postal data for 1953 not yet available.
[b] Most frequent reference date for this information.
[c] Domestic telegrams only; others not reported.
[d] Data for 1907 traffic, 1910 population.
[e] New Zealand data not reported.

Sources: 1910 and 1912 — Postmaster General, *Government Ownership of Electrical Means of Communication*, Senate Document No. 399, 63rd Congress, 2nd Session (Washington: Government Printing Office, 1914), pp. 54-56 and 60. 1952 — Union Postale Universelle, *Statistique Complète des Services Postau, 1952* (Berne: 1954). 1953 — International Telecommunication Union, *General Telegraph Statistics, Year 1953*, and *General Telephone Statistics, Year 1953* (Geneva: 1954).

over the forty-year period. Four of the five nations appearing in the list for both years displayed increases averaging more than 50 percent, with the United States showing the greatest increase (74 percent). Of the other three nations appearing in the 1912 list which retained the same boundaries in 1953, two experienced appreciable increases (Netherlands, 53 percent; Belgium, 38 percent) while one had no change (Luxemburg).

Telegraph use, unlike other person-to-person communications, generally declined. The sole exception to this trend for the ten nations standing first in telegraph use in 1910 was Norway, where an increase of 43 percent took place by 1953. Even the other two countries appearing in both years (New Zealand and the United Kingdom) showed declines of about 50 percent by 1953. The United States, alone among the other six countries with unchanged boundaries, failed to show a decline; telegraph use for that country appears to have been at the same level in both years. The other five of those countries experienced declines ranging from 71 percent for France to 23 percent for Denmark. Some of the nations which appeared in the top 10 in telegraph use in 1953 but not in 1910 experienced increases in telegraph use. For Japan the increase was 100 percent, and for Luxemburg, 50 percent. For others of this group information was lacking in 1910 or the nation had come into existence since that time.[23]

A majority of the nations which were the heaviest users of all four means of person-to-person communications in both 1910 (or 1912) and 1953 were in Europe, but there were more non-European nations in the first 10 in the latter than in the former year. Four-fifths of the top 10 nations in the earlier year were European for all four kinds of service. By 1953 only three-fifths of them were European for postal, telegraph, and local telephone use. The decline in European predominance was less for long-distance telephone (from eight-tenths to seven-tenths).

The use of all person-to-person communications facilities has not become more evenly distributed among the first 10 nations. The spread between the first and tenth nation in the number of letters and postcards per capita and the number of long-distance telephone calls per capita became larger between 1910 and 1953, whereas it decreased for telegrams and local telephone calls.

The correlation between the use of the three types of service in the same nations was not well marked. No nation appeared among the top 10 in both years in the use of all four types of service. The number of nations appearing in all four lists in one year declined between 1910 and 1953. In the former year the United States, Denmark, and Switzerland appeared in all four lists. In the latter year only Canada and Australia appeared in them all. Five nations were among the 10 leaders in per capita use of both local and long-distance telephone in both years (Sweden, United States, Norway, Switzerland, and Denmark). When one adds wire-telegraph, only one nation (Norway) appears in all three lists in both years. Japan, which in 1910 was poorly equipped for telecommunications and used them little, had risen to the first 10 in use of local telephone service and wire-telegraphy in 1953.

International Unification of Telephony

Formal international planning of telephone service was undertaken by the International Telegraph Union in Europe in the 1880's. At the conference of 1885 in Berlin, Germany proposed that special rules be adopted for telephone service. At the Budapest conference in 1896 the rules adopted for telegraph service were made applicable to the telephone. In 1903, specialized telephone regulations were adopted dealing with international operating practices, types of service offered to the public, administrative rules, rates, and international accounting. These

[23] For 1953 the figures were Switzerland, 1.0; France, 0.5; Denmark, 1.0; Belgium, 0.9; and the Netherlands, 0.7. In 1912, Japan was 0.6, and Luxemburg, 0.8.

regulations remained effective without change until long after World War I.

During World War I, international telegraph and telephone services were disrupted and the International Telegraph Union was inactive until 1925. Restoration of international service in Europe was facilitated by two *ad hoc* conferences held in 1920 and 1921, which established priority lists of telegraph and telephone routes for reconstruction and reinstatement of international service. In 1925, a consultative telephone committee, which had been created the year previous, was established by the International Telegraph Union in order to study standards applicable to technical and operating problems and at the same time a parallel telegraph consultative committee was established. In 1932 both the telegraph and telephone activities of the 78-member International Telegraph Union were merged with radio organizations in a new International Telecommunication Union at the Madrid conference.

The subsequent history of the telegraph and telephone work of the ITU centers on (1) efforts to unify, rationalize, and lower rates; (2) efforts to arrange clearing procedures which would keep pace with fluctuations in the foreign exchange practices of the several nations; (3) measures to be taken to rationalize the communications facilities of airlines as against those of the government administrations, the volume and kind of traffic carried over such facilities and the rates charged for it; and (4) efforts to achieve world-wide adherence to telegraph and telephone regulations and rules. Even after the drastic impact of World War II on telephone systems, one meeting of the Telephone Consultative Committee in October, 1945, supplemented by the Atlantic City Telecommunications Conference in 1947 took care of the essential international planning. After the Paris Telegraph and Telephone Conference in 1949, it was evident that future meetings at approximately five-year intervals were all that were necessary.

The apparently settled state of telegraph and telephone regulation exists in a framework of politically diversified systems. Thus, only a tenuous acceptance of the telegraph and telephone regulations has ever been given by the United States companies. After World War II the European administrations led by France proposed that extra-European telephone networks should be governed by a set of service, tariff, and accounting regulations analogous to those in effect in Europe. This was in recognition that transoceanic telephone service (via radiotelephone) had been in existence since 1927. A world-wide telephone network was in existence by the end of 1945. The United States has opposed the proposal for extra-European telephone regulations on the grounds that informal development between private agencies would serve the needs of the extra-European network better. In the face of this position and the fact that the United States has more than half of the world total of telephones, the ITU acquiesced in the American policy. For the most part, the proceedings of the telegraph and telephone conferences have been free of political influences. A notable exception was the controversy at the Cairo conference in 1938 between the Loyalist Spanish government and Italy over the fact that the Italian telegraph company had notified the International Bureau of resumption of service to points held by the Spanish insurgents and that the bureau had accepted these notifications despite strong contrary representations from the legal Spanish government. Supported in this protest by the USSR, the Spanish government nevertheless failed to obtain comfort from the conference.

This chapter has shown that, with due regard to the geographical, social, political, and economic needs of the nations, telephony has been developed as a system which is internally integrated with postal and telegraph systems in providing person-to-person service. Accompanying the growth of facilities and operating organization was the development of international planning for telephone. The International Telegraph Union extended its scope and regulations to telephone around the turn of the century. A fund of expertise and a systematic organization — both of an international character — were being developed. Telephone, being technically more complex than telegraph, strengthened the international organization. The basis was established for the close-knit international regulation which was to be required for the use of radio.

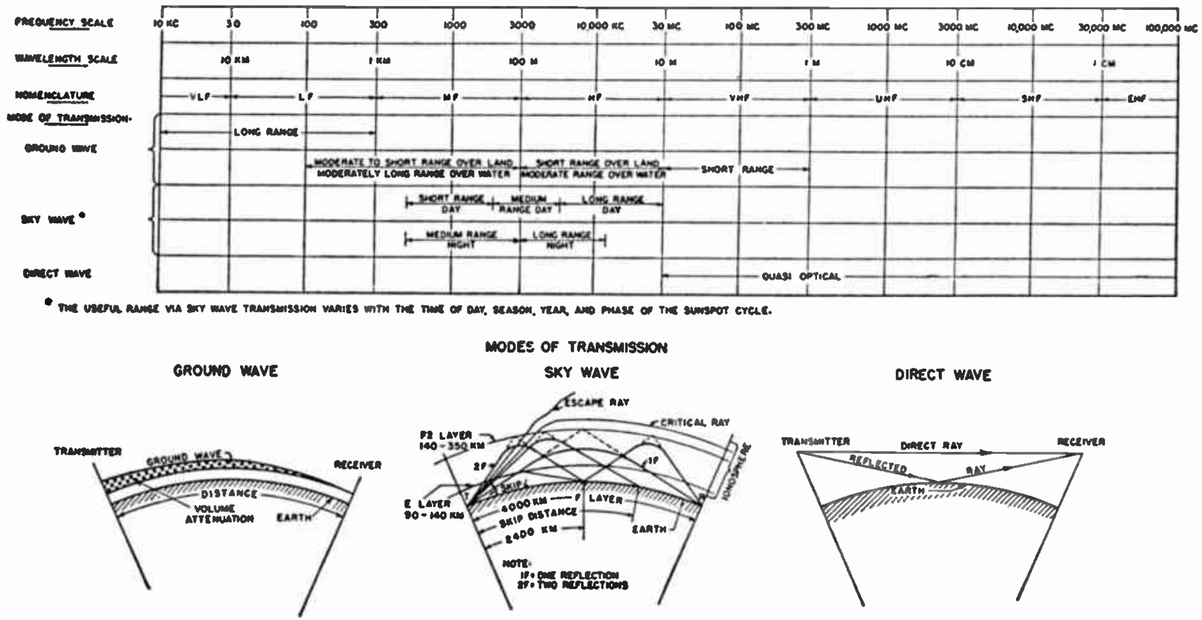
IV. THE NATURE AND SCOPE OF RADIO SERVICES

The inescapable centralization of control required by radio was manifest as soon as the first crude beginnings of the art appeared. The strength of this planning imperative is suggested by the fact that scarcely a decade elapsed between the date of Marconi's patents and the signing of the first international radio convention by all major world powers (including the United States). Symptomatic of the world-wide scope of the planning required for radio was the further fact that this international "legislation" *preceded* by four years the first United States law on radio. By contrast, international planning for wire-telegraphy had developed nationally *before* internationally, and half a century elapsed between its discovery and the development of integrated international controls.

Planning for the use of the radio spectrum is referred to as "allocation." This is the process by which the determination is made that certain radio frequencies may be used for one rather than for other mutually exclusive uses. For example, it is the determination that a particular type of radio service (e.g. "marine coast") shall be conducted in a certain "band" of radio frequencies. While the term "allocation" is sometimes limited to this particular step, it is also used broadly to include two subsequent processes. One of these is the process of defining the engineering standards for the particular use of the band of frequencies, the number of channels it is to contain and the width of each, and the geographic location of radio station "assignments" on the channels. The other is the process of assigning the use of the channels at particular geographic locations to particular persons who are authorized to operate radio stations.

In order to understand the implications of radio it is necessary to grasp the essential characteristics of this natural resource. The dimensions and operating characteristics of the radio spectrum are summarized graphically in Chart 1. Its limits are closer to finite than infinite, being bounded at the low end by 10 kilocycles and at the upper end by 300,000

CHART 1. RADIO FREQUENCY SPECTRUM[a] SHOWING SOME OF THE BROADER FREQUENCY CHARACTERISTICS



[a] Frequency subdivisions and ranges: VLF (very low frequency), below 30 kc; LF (low frequency), 30 to 300 kc; MF (medium frequency), 300 to 3,000 kc; HF (high frequency), 3,000 to 30,000 kc (30 mc); VHF (very high frequency), 30 to 300 mc; UHF (ultra high frequency), 300 to 3,000 mc; SHF (super high frequency), 3,000 to 30,000 mc; EHF (extremely high frequency), 30,000 to 300,000 mc.

Source: President's Communications Policy Board, *Telecommunications: A Program for Progress*, p. 22.

megacycles, at which point the infrared portion of the spectrum begins.[24] The upper section of Chart 1 shows the capabilities of the different portions of the radio spectrum for transmitting messages of any kind. The earliest portion of the spectrum to be developed was in the low and very low frequencies (from 10 kc to 300 kc) where signals are carried for thousands of miles during both day and night, over both land and water. About the time of World War I, the art extended to the use of the medium frequencies (from 300 to 3,000 kc) where propagation was moderately long range over water and only moderate to short range over land during both day and night. Between World War I and World War II, the possibilities were realized of using the frequencies between 500 kc and 30,000 kc (the latter also being known as 30 mc) for different coverage during the day and night hours — medium- to long-range propagation being possible at night but only shorter distance transmissions in the daytime. During and after World War II, the frequencies above 30 mc were developed for short-range communication. The frontier for development of the art now lies above 300 mc where the propagation of radio waves is quasi-optical in character, i.e. approximates line-of-sight. The lower portion of Chart 1 illustrates the physical behavior of each of the kinds of waves which will work in those portions of the spectrum. Such, at least, is the current standard explanation. In the past few years, however, new evidence suggests that both in the very high frequencies and in the ultra high frequencies, long-range propagation (referred to as "scatter" propagation) is practicable. This principle is now in use by United States armed forces. To the extent that "scatter" propagation proves useful it will modify the general assumption that these frequencies are useful only for quasi-optical coverage.

Even as modified, however, the foregoing summary of radio behavior is deceptively simplified. In addition to the propagation characteristics of the spectrum which are explained in Chart 1, the extent of radio service depends physically on a number of other variables: the power used by and design and condition of the transmitter, ground (or water) conductivity characteristics, and the circuit design and condition of the receiver. Moreover, all of the propagation characteristics are subject to fluctuation

[24] These are only approximate limits which are described by the engineers in these terms:

"Even these are not strict limits. They are dictated in part by the fact that at frequencies below 10 kc it is difficult to radiate enough power to do useful radio work and, above 300,000 mc, it is difficult to produce radiated fields of relatively constant and coherent phase with sufficient power to overcome the severe attenuation caused by rain, oxygen and water vapor."

Joint Technical Advisory Committee, *Radio Spectrum Conservation* (New York: McGraw-Hill, 1952), p. 21.

with meteorological conditions, which force all plans for radio spectrum use onto a basis of statistical probabilities.

The earliest systematic use of radio was simple. It was employed on ships for safety at sea and as such was an adjunct to the techniques which over centuries had been gradually systematized in international law governing the obligations of shipmasters to provide emergency assistance to each other. Marconi's demonstrations of radiotelegraphy between 1896 and 1903 were shortly followed by installations on trans-Atlantic vessels. Even this simple use of radio, however, quickly led to international agreement for its regulation. The near-monopoly of the ship radio market achieved by the Marconi company and its competitive practices (e.g. refusing to correspond with non-Marconi-equipped ships) resulted in a conference called by Germany in Berlin in 1903. The nine powers represented there[25] were sharply challenged by the Germans with these words:

> . . . only the elimination of a monopoly in radio and the adoption of provisions aimed at the elimination of interference between stations could prevent "une guerre de tous contre tous."[26]

The Berlin conference adopted policies to cope both with monopolistic practices and interference but only over the objection of the British and Italian delegates. These policies were spelled out in detail in the first International Radiotelegraph Convention, at a second conference in Berlin in 1906. In that convention, the obligations to communicate, to avoid interference, and to give priority to distress calls were made absolute, even to radio stations operated by military or naval forces. Furthermore, at that time the first international allocation of radio frequencies was agreed to: the frequency 500 kc was established as the international distress frequency and all nations agreed to respect its use for that purpose alone.

From this beginning, radio proliferated in many directions and the subsequent analysis of facility unification requires for manageable exposition the consideration of its several principal aspects separately. The remainder of this chapter will survey the growth in the number of services and their extent in physical terms. Chapters V and VI will consider the organizational structure which developed for its administration and regulation, both national and international. And chapters VII, VIII, and IX will discuss the development of allocation policy — the planning function for radio.[27]

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[25] Austria, France, Germany, Great Britain, Hungary, Italy, Russia, Spain, and the United States.

[26] Codding, *op. cit.*, p. 85.

[27] Some unavoidable duplication will follow from this procedure but much less than if the discussion attempted to trace the development of these aspects through the scores of conferences and acts from which they actually grew.

Development of Radio Services

In 1912 the world total of radiotelegraph stations was 3,231, of which more than four-fifths were ship stations and the remainder were mostly shore stations established to communicate with ships. Their use was primarily for communicating operating information (safety and other) to and from ships; yet almost three-fourths of them handled person-to-person communications as common carriers. Apart from them the only other classes of stations were operated by amateurs (whose undisciplined enthusiasm provided the interference which forced Congress to pass the Radio Act of 1912) and by governments. As a consequence of the assignments made by the nations pursuant to the London convention of 1912, the amateurs were forced out of the then desirable frequencies below 1600 kc and moved to higher frequencies including those between 3 and 30 mc. During World War I the amateurs were silenced, but after the war, with the new three-element tube and improved circuits, they rapidly proved the long-distance transmission values of the high frequencies. Within the previously established service categories, there were almost 14,000 radio stations reported by all nations to the Berne Bureau in 1920 — more than four times the number in 1912.

The two decades between World Wars I and II witnessed a differentiation and adoption of radio on a scale beyond the capacities of a brief paper to trace in detail. To new uses of radiotelegraphy were added many uses of radiotelephony, including transoceanic voice transmissions. Of them all, the one with the most obvious immediate economic and cultural importance was broadcasting, which early was differentiated as between intra- and inter-national services. Apart from broadcasting, the uses of radio fall into two very general classes. The first is common carriage of messages, either in code or voice, between fixed points. The second is the so-called safety and special services. All told, in the United States alone, there were 348,000 authorized radio stations in the nongovernment services on June 30, 1956 — an increase to 24 times the number in the world in 1920. Largely for political reasons, information on the number of government radio stations is currently withheld from the ITU by the United States and the Soviet Union so that no world total of radio stations is available. The United States probably has developed radio uses more than any other country and for this reason we may usefully examine the scope and purposes for which radio is applied in this country.

The composition of the 348,000 radio stations in the United States in 1956 is shown in Table 2. Those exclusively devoted to common carrier communication service totaled 2,308 — the smallest component. In this group are found the international radio common carriers — fixed public

TABLE 2. AUTHORIZED RADIO STATIONS (NONGOVERNMENT SERVICES) IN THE UNITED STATES, JUNE 30, 1956

Class of station	Number of stations	
Common carrier (exclusively)		
Domestic public land mobile	800	
Fixed public telegraph	31	
Fixed public telephone	18	
Experimental	1,459	
Total		2,308
Broadcast		
Commercial AM	3,020	
Commercial TV	609	
Educational TV	41	
Auxiliary TV	682	
Experimental TV	17	
Commercial FM	546	
Educational FM	136	
International	3	
Remote pickup	1,936	
Studio-transmitter link	50	
Developmental	2	
Total		7,042
Safety and special services		
Aviation services		
Aeronautical and fixed group	2,445	
Aircraft	33,689	
Aviation auxiliary group	188	
Aviation radionavigation land	316	
Civil Air Patrol	12,107	
Total		48,745
Marine services		
Alaskan group	919	
Coastal group	301	
Marine auxiliary group	91	
Marine radiolocation land	19	
Ship group	55,585	
Total		56,915

telegraph stations providing service over direct circuits to 87 countries, and fixed public telephone stations providing radio telephone service directly to 63 foreign countries and through connections abroad, to 48 other foreign countries and overseas points.

Broadcasting, which tends to be identified in the layman's view with all uses of radio, involved some 7,000 stations in the domestic services of AM, TV, and FM, of which all except about 200 stations authorized to educational institutions were commercial stations.

By far the largest use of radio — judged by numbers of stations and transmitters — in the civilian economy of the United States is for the broad group of uses called "safety and special services." Our interest

TABLE 2. CONTINUED

Class of station	Number of stations	
Safety and special services (continued)		
Public safety services		
Fire	3,062	
Forestry conservation	2,704	
Highway maintenance	1,699	
Police	10,819	
Public safety (combined)	70	
Special emergency	2,344	
State guard	20	
Total		20,718
Land transportation services		
Automobile emergency	571	
Citizens	18,602	
Highway truck	842	
Interurban passenger	68	
Interurban property	680	
Railroad	1,731	
Taxicab	4,830	
Urban passenger	111	
Urban property	157	
Total		27,592
Industrial services		
Forest products	1,316	
Industrial radiolocation	168	
Low-power industrial	1,269	
Motion picture	50	
Petroleum	6,754	
Power	9,874	
Relay press	95	
Special industrial	11,071	
Total		30,597
Amateur and disaster services		
Amateur	150,549	
Disaster	327	
RACES[a]	3,461	
Total		154,337
Grand total		348,254

[a] Radio amateur civil emergency service.
Source: Federal Communications Commission.

here is to review the ways in which these uses of radio are ramified through the American social organization. In doing so we will attempt to distinguish between the use of radio for reasons of safety as distinct from its function in facilitating operations of the agencies and industries which employ it.

Historically, the first of the safety and special services was the marine use of radio, which still is the largest class with almost 57,000 stations. Early in its use, ship operators realized that radio could expedite ship operations at the same time that it increased the safety of life and property. Through an obvious extension, radio was applied for direction-finding (by triangulation, using two or more signals) and radio beacons by the end of World War I. Developed before and during World War II, radar and Loran (long range) systems freed ships from dependence on sight in navigation. By 1956, 2,980 United States merchant ships were authorized to use radar equipment. Because Loran and other classified developments in radio control devices are mostly within the province of the armed forces, their development is not reflected in Table 2.

Aviation has developed an extremely complex pattern of organization for the use of radio in a variety of ways. The Post Office pioneered in providing navigational information to its aircraft used in flying airmail. As early as 1920 it operated a network of seven radio stations through which administrative and weather information was communicated between airports, and was developing plane-to-ground and radio direction-finding devices.[28] The unsystematic use of radio for aviation which followed the turning-over of airmail to private commercial operation was re-structured when in 1929 the Federal Radio Commission ruled that commercial airlines must cooperatively build and operate ground stations at airports for radio communication. As a result, Aeronautical Radio, Inc., a nonprofit organization, was organized in 1930 to supply and coordinate the radio requirements of the scheduled airlines. The 2,445 stations shown in Table 2 as "aeronautical and fixed" are the core of the system which developed under this organization. They ". . . furnish a non-Governmental radio communication service necessary for the safe, expeditious and economical operation of aircraft."[29] Communicating with these ground stations and with each other in 1956 were some 3,000 authorized common carrier aircraft and about 30,000 private aircraft radio stations. In addition, a number of classes of radio stations are authorized for airdromes, flying schools, the Civil Air Patrol, and flight-testing. Apart from these general purpose radio stations, aviation employs a variety of navigational aid radio stations including radio beacons, radio direction finders, radio ranges, localizers, glide paths, marker beacons, and ground-control-approach stations. Although most of this service is operated by the Federal government, 316 of these stations are licensed by the FCC and appear in Table 2.

"Safety" as a justification for the use of radio by marine and aviation activities obviously relates to safe transportation in otherwise hazardous circumstances. When we turn to the "public safety" category of radio

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[28] Postmaster General, *Annual Report to Congress,* 1921, pp. 47-48.

[29] Federal Communications Commission, *Annual Report to Congress,* fiscal year ended June 30, 1954, p. 74.

services, however, the meaning of safety relates to curtailing losses of life and property because of law-breakers, fire, accidents, and public disasters such as floods and earthquakes. Police radio stations, numbering almost 11,000 in 1956, were pioneers in this use of radio and the justification for such use was roundly stated by the FCC in its reports on the 1944 allocation hearings in these terms:

> Facilities which will permit instantaneous and continuous communication between police headquarters and mobile units are essential to the efficient operation of both state and municipal police departments. Radio serves two extremely important functions in the police service. First, it provides communication in areas lacking other means of communication; and second, it makes possible a rapid mobilization of the protective forces at crucial points. In order to combat modern criminal methods, speed and flexibility of communication and operation of police departments are essential.[30]

Similarly, the basis for recognizing the importance of radio for the "fire" services is the speed with which fires spread. With the "forestry and conservation" service, the recognition rests on the value of the acreage of forest area, the efficiency of fire-fighting methods, and the fact that

> to effect both [fire prevention and fire suppression], speedy and reliable communication, point-to-point, as well as fixed point-to-mobile and mobile-to-mobile is essential in areas where wire lines are non-existent. Radio affords the only solution.[31]

Safety of the motoring public and efficiency in the use of highway labor and equipment are the bases for the "highway maintenance" service, which includes some 1,700 radio stations licensed to states or territories and their subdivisions. Radio stations are authorized for "special emergency" service to the Red Cross, governmental subdivisions concerned with civil defense, and to provide facilities

> . . . for the safety of life and property for diverse groups of persons such as physicians and veterinarians normally practicing in rural areas, ambulance operators and rescue organizations, beach patrols providing a life-saving service, school-bus operators, persons in isolated areas where public communication facilities are not available, communication common carriers desiring to provide standby facilities or make emergency repair . . .[32]

In addition, a "disaster communications service" and "radio amateur civil emergency service" (shown in Table 2 under "amateur and disaster") under governmental control are open for anyone qualified to hold a station or amateur license.

[30] Federal Communications Commission, *In the Matter of Allocation of Frequencies to the Various Classes of Non-Governmental Services in the Radio Spectrum . . . Docket No. 6651, Report of Proposed Allocations from 25,000 kilocycles to 30,000,000 kilocycles,* January 15, 1945, p. 100. Hereinafter this report will be cited as *1945 Allocation Hearing Report.*

[31] *Ibid.,* p. 113.

[32] Federal Communications Commission, *Annual Report to Congress,* fiscal year ended June 30, 1954, p. 79.

Under the heading of "land transportation" a family of radio services developed after World War II is to be found, all except one of which is necessarily connected with transportation. In each case, these transportation activities (railroad, urban transit, intercity bus, taxicab) rest their need for radio on safety. Urban transit illustrates the general tendency for "safety" to broaden to include operating uses as radio proves its value to industries. Prior to its establishment as a separate class of service, urban transit had used radio as a "special emergency service" where the rules permitted the use of radio only for safety purposes. In its 1945 allocation report, the Commission said:

It was stated, for example, that transit utilities have refrained from using radio for trouble calls involving faulty equipment or the transmission of instructions relating to general dispatching operations. It is urged that permission to use radio in connection with such matters would serve the public interest and convenience.[33]

The use taxicabs make of their 4,830 radio stations is also primarily for efficiency in operation rather than safety. The "citizens' radio service" was originally justified as a matter of the personal convenience of anyone who desired to employ radio for short-distance, two-way communications, but the users, totaling well over 18,000 stations, have for the most part been business organizations which use radio for dispatching purposes within urban areas. Although classified among the safety services, safety is at most a minor object of this class of stations.

"Safety," though present as a consideration, is relatively subordinated to the value of radio as an intra-business means of communicating operating information for the group of classes of stations termed "industrial." Thus, in the petroleum industry, the principal uses advanced as the justification for using radio were these: (1) for communications between bases and "drilling parties" which may be offshore, in marshes, or in other inaccessible locations; (2) for patrolling pipelines; and (3) for geophysical explorations for oil. In testimony to the value of the third of these uses, the FCC found in 1945 that

. . . billions of barrels of oil have been found by seismic prospecting since its inception in 1924 and this method has been used in finding more than one-half of the new oil discovered in recent years.[34]

Motion picture companies are licensed to use radio stations for "location" work where wire communications facilities often are inadequate or altogether absent. These illustrations suffice to explain the general group of services which altogether account for some 31,000 stations.

Finally, in explanation of Table 2, the rationale for assigning spectrum space to the "amateurs" (totaling 150,549 stations in 1956, or al-

[33] *1945 Allocation Hearing Report,* p. 129.

[34] *Ibid.,* p. 137.

most half the total of civilian radio stations in the United States) should be summarized. The clearest exposition of this rationale is to be found in the FCC's report on frequency allocations in 1945. There we are informed that the amateur radio service "is a vast training school and constitutes a huge reservoir of skilled radio operators" who are extremely skilled and experienced. A second justification is that the frequencies allocated to amateurs are a military reserve immediately available in time of war.[35] And a third justification is that amateurs render invaluable public service during natural disasters: "Thousands of lives, an untold amount of human misery and millions of dollars in property have been saved by their efforts."[36]

This extended survey of the uses of radio, running from common carrier to broadcast and to the safety and special services, provides a rough introduction to the scope and complexity of radio communication in the country which has probably exploited radio more widely than any other. While the economic, political, and psychological aspects of broadcasting and common carrier communications are commonly acknowledged, it is the safety and special services in which the largest and most active development of radio is currently taking place. In the two years between mid-1954 and mid-1956 the number of these stations increased by 29 percent while the rapidly growing broadcast field increased its stations by 23 percent. Radio, if not social security, now covers one from cradle to grave in the United States. At least that is what the FCC, with unwonted expressiveness, says:

> This [safety and special services] usage now extends from the cradle to the grave. There are radio facilities for calling doctors and ambulances to the homes of expectant mothers as well as other persons requiring emergency medical assistance, and for speeding milk and other essentials to the newborn — even diaper pickup-and-delivery services. During life's span, radio protects public and personal safety and property, and is used for a myriad of business and individual purposes. At the omega of life, radio is utilized to dispatch vehicles in connection with death and burial, to the inclusion of directing the movement of funeral processions at large cemeteries.[37]

The process of development of these radio services, despite their extreme differentiation in end-uses, follows a typical pattern. The life

[35] "History has shown that frequencies retained by the military during the time of peace are insufficient for their needs in time of war. When amateur stations are closed in time of war, blocks of frequencies immediately become available for military operation. If there were no amateur assignments, these bands would be filled with the signals of every nation, and their recapture for military use would be difficult or impossible in blocks of any appreciable width." *Ibid.*, p. 54.

[36] *Ibid.*, p. 54.

[37] Federal Communications Commission, *Annual Report to Congress*, fiscal year ended June 30, 1954, p. 5.

cycle of a new radio service usually begins with experimentation, when it will be classified by the FCC as "developmental," "provisional," "miscellaneous," or simply "special." Historically and until transportation agencies were each given their unique radio classifications, "safety" was the objective and the rationalization for innovating new classes of service in their own right. As experience is gained with the economies permitted through integrating radio with the operating functions of the organizations using radio, "efficiency" supplements safety as the objective of a radio class. Radio classification therefore is essentially a device for fitting the uses of the spectrum to some sort of homogeneous categories of like users. It permits such users to be subjected to operating regulations appropriate to the characteristics of the radio frequencies assigned to them and to the end-uses to which radio will be put by them. It also permits the FCC to determine the kind of organization which will operate the stations authorized to a class of users. Thus, as noted earlier, in aeronautical services, the Federal agency required that a nonprofit cooperative organization for the administration of the fixed stations be created by the aggressive rivals making up the scheduled commercial airlines. Thus, too, the FCC reserved the decision in 1945 as to whether the mobile land station service should be operated in part as a common carrier as the telephone industry had requested, or through individual licensees, or through a cooperative organization, until further experience and evidence should point to an appropriate policy.[38] The role of planning in the development of the services, therefore, is seen to be an unfolding process in which radio classification regulates growth and adapts itself to that growth.[39]

This chapter has noted that immediately upon its innovation, radio communication precipitated international agreement on measures for its control. The chapter demonstrated that in the United States, where a maximum of laissez faire was early permitted to direct the development of radio services, radio uses have penetrated the civilian portion of the social structure progressively and at ever increasing speed. Paradoxically, while this diffusion of radio uses was taking place, unification in its control was being strengthened. This unification is an inescapable attribute of the function of allocating radio frequencies to users and determining engineering standards for their use. Apart from the grosser aspects of this unification, it was also noted that the regulatory agency has on significant occasions required the creation of unified social organizations to operate

[38] *1945 Allocation Hearing Report,* p. 183.

[39] It is thus clear that comparisons between the numbers of stations at two or more different time periods are meaningless for the classes of stations where the evolutionary process is most active.

radio services for certain kinds of radio users. Nevertheless, this chapter has focused attention on the *uses* to which radio has been put. In the next two chapters the focus shifts to the *organization* of radio uses, both nationally and internationally. In them will be gauged the extent of integration in social structure which is implied by radio communications.

V. THE ORGANIZATION OF RADIO SERVICES

In the preceding chapter the articulated structure of *uses* of the art of radio was described, and the elaborate extension of the different applications of the art through the economic, political, and social order was indicated. The present chapter deals with the nature of the organization which has developed for the administration and use of radio in the United States. In this country, radio organization found the least restrictive conditions of government control to be found in any major nation. In selecting the United States for analysis of intranational organization of radio, the thesis that the technological imperative of radio results in an integrated structure with a high degree of centralization is put to a severe test.

It was observed earlier that radio, promptly upon its discovery, was recognized by the national states as a device of great strategic value, and as one with a peculiarly international character. It was only to be expected, therefore, that the several nations have jealously reserved to their national governments control over radio stations located in their jurisdictions rather than permitting dispersion of control within the nations. Usually the common carrier uses of radio are provided by the state through the administrative agency which handles posts, telegraphs, and telephones. Although broadcast radio is in a few countries programmed in part by business corporations, even there the technical operations are usually conducted by the state administration for posts, telegraphs, and telephones. The majority of the world's population receives its intranational broadcast service wholly from a state administration or from a public corporation. The safety and special services are likewise commonly state operated. Marine radio service is usually provided by the post, telegraph, and telephone administration or by a national company in which the government is represented. The aviation radio service is operated either by the government communications authority, the ministry for aviation, or a company in which the government is represented. And so on.

As compared with the unification manifest in most nations, American national radio policy began by accepting a high degree of laissez faire in the organization of radio. The first congressional regulation of radio in 1910 followed by some years the extensive application of radio on ships and at coastal stations for naval and maritime purposes. It prescribed in vague terms the use of radio by large passenger vessels and gave the Secretary of Commerce and Labor authority to regulate its use. This law[40] was cast in the mold of earlier laws concerning the regulation of lifesaving appliances on shipboard and implicitly regarded radio as private property.[41] The legislative history of the second piece of radio legislation — the Radio Act of 1912 — reveals that it was this concern for private property which prompted Congress belatedly to attempt to write the regulations of the Berlin Radiotelegraph Convention of 1906 into substantive law in the 1912 act, rather than to delegate effective rule-making power for its administration to the executive branch.[42] The evidence which impressed Congress with the urgent need for the legislation, however, related to the destructive interference which unregulated private operation was creating.

> Now, each of these stations considers itself independent and claims the right to send forth its electric waves through the ether at any time that it may desire, with the result that there exists in many places a state of chaos. Public business is hindered to the great embarrassment of the Navy Department. Calls of distress from vessels in peril on the sea go unheeded or are drowned out in the etheric bedlam produced by numerous stations all trying to communicate at once. . . . It is not putting the case too strongly to state that the situation is intolerable, and is continually growing worse.[43]

It was this interference potential which constituted the lowest common denominator of national as well as international regulation of radio.

Though private ownership seemed the dominant mode of organization at the time, the American political scene was fluid enough in the second decade of the century to encompass trends widely divergent from it. The Wilsonian program, victorious at the polls in 1912, included reformist elements which pointed toward government ownership of communica-

[40] Public Law 262, 61st Congress, 36 *Stat.* 629.

[41] "In the United States such legislation involves questions of federal regulation of private and corporate property, which in view of the constitutional limitations upon the powers of Congress, must be approached with greater caution along pathways less cleared [than in European countries where communications facilities were publicly owned]." Letter from the Secretary of Commerce and Labor, March 29, 1910, quoted in U. S. Senate, Committee on Commerce, Report No. 659, 61st Congress, 2nd Session, May 6, 1910, pp. 2-3.

[42] U. S. Senate, Committee on Commerce, Report No. 698 to accompany S. 6412, 62nd Congress, 2nd Session, May 2, 1912.

[43] Letter from Secretary of the Navy, March 30, 1910, quoted in U. S. Senate, Committee on Commerce, Report No. 659, 61st Congress, 2nd Session, May 6, 1910, p. 4.

tions. Thus, shortly after taking office, that administration announced its communications policy in a report, *Government Ownership of Electrical Communications Industry,* prepared by a committee appointed by the Postmaster General, pursuant to a Senate resolution.[44] That report called for government ownership and operation of radio, as well as telegraph and telephone facilities. Whereas the drive at that time for public ownership of telephone and telegraph drew its support from popular criticism of the rate and service policies of the land-line industry, that for radio stemmed from national security considerations.

The Navy Department was particularly impressed with the need for government ownership or control of radio in the service of advancing American interests as against those of other nations. In 1910 a Navy spokesman told Congress that the department favored ". . . the passage of a law placing all wireless stations under the control of the Government" while simultaneously admitting the political infeasibility of such a move.[45] At its urging, the Radio Act of 1912 included provision for Presidential seizure of radio stations in the event of war, public peril, or disaster. This provision was used when, by an Executive order in 1917, all commercial radio stations — the majority of which were British-owned — were taken over by the Navy.[46] The Navy continued to operate such commercial service as did not interfere with the war program, and in addition broadened the service to include the communication of news and propaganda for the soldiers in Europe, and a daily shipping bulletin of maritime news, subscribed to by 1,400 commercial firms in 1918. When Congress was considering a joint resolution in July, 1918, under which the President assumed control of the telegraph, telephone, and cable systems, Secretary of the Navy Josephus Daniels testified that the government "should control and own telegraph, telephone and all means of communication permanently," as did also Postmaster General A. S. Burleson.[47]

Economically, the onset of World War I found radio ripe for increased centralization of control and the economic policy issue concerned whether it should be vested in government or private hands. A stalemate of mutually blocking patents prevented private industry from developing the

[44] S. Doc. 399, 63rd Congress, 2nd Session, 1914.

[45] Letter from Secretary of the Navy, March 30, 1910, quoted in U. S. Senate, Committee on Commerce, Report No. 659, 61st Congress, 2nd Session, May 6, 1910, p. 4.

[46] Secretary of the Navy, *Annual Report to Congress, 1916-17,* p. 44.

[47] U. S. House of Representatives, Committee on Interstate and Foreign Commerce, *Hearings on H. J. Res. 309,* 65th Congress, 2nd Session, July 2, 1918, quoted in Federal Communications Commission Exhibit 2096-B, *Control of Telephone Communications, Appendix A, Data Relating to Federal Control of the Bell Telephone System, August 1, 1918-July 31, 1919,* p. 4.

equipment essential to long-distance radiotelegraphy and radiotelephony. A subsequent Federal Trade Commission investigation reported that

There were, prior to the entrance of the United States into the World War, a number of inventions covered by patents, which could have been utilized in the manufacture of a large portion of the modern radio apparatus, and also numerous inventions covering various systems which could have been employed in rendering a more efficient transoceanic radio communication service. These patents were, however, controlled by opposing interests who refused to license one another.[48]

War requirements made this situation intolerable.

During the World War the necessity for efficient radio apparatus and devices for naval and military purposes became of increasing importance. As a result of Government appeal, the manufacturers, disregarding patent rights, engaged in the manufacture of radio apparatus and devices for the Government, upon the Government's guarantee to protect them against all infringement suits.[49]

The government, in its own right, acquired a sufficient patent position to dominate the field.[50] These patents came to it through the purchase for $1.6 million from the Federal Telegraph Company and the Poulsen Wireless Corporation (whence it acquired the Poulsen arc) of 22 patents, and the purchase of some 110 German patents (including the Schloemilch and Von Bronken patent) from the Alien Property Custodian.[51]

The decision was for private ownership of communications facilities although the decision was reached without debate at the legislative level. Secretary of the Navy Daniels' bills, which would have perpetuated Navy operation of radio, quietly died in the committees to which they were sent in 1917 and 1919. Quite evidently they were looked on as a serious threat and they drew sharp opposition from industry, which characterized them in House committee hearings as "un-American," "Prussian," and "autocratic," and argued the inevitable inefficiency of government and the efficiency of private enterprise.[52] Daniels' request that Congress at

[48] Federal Trade Commission, *Report on the Radio Industry,* 1924, p. 14.

[49] *Ibid.*

[50] Col. J. I. McMullen, in charge of patent work, Judge Advocate General's Office, War Department, testified in 1929: "But, of course, you probably know as well as I do that if anybody has a monopoly of radio communications the Government has it in its ownership of at least two or three systems of radio communication. In the Telefunken patents they have two systems, the spark system and the high-frequency system; and in the Federal Telegraph patents they have the Poulsen arc." He added that the government could, if it wanted to, assert its rights under these patents to prevent the monopolistic practices of the Radio Corporation of America. U. S. Senate, Committee on Interstate Commerce, *Hearings on S. 6,* 71st Congress, 1st Session, May 24, 1929, p. 874.

[51] *Ibid.,* pp. 868, 1013-14.

[52] See U. S. House of Representatives, Committee on the Merchant Marine and Fisheries, 65th Congress, 3rd Session, testimony of Mr. Nally, president of American Marconi Company, and Mr. Davis, Tropical Radio, pp. 314, 317-18.

least authorize a comprehensive investigation before deciding the issue was ignored.[53] Instrumental in this treatment was the nationwide propaganda campaign organized by American Telephone and Telegraph Company in order to obtain the end of the government's legal control of its facilities.[54]

The form of centralized control adopted was a cartel of communications equipment manufacturing and operating companies. Ostensibly because the Navy Department's middle echelon personnel requested it not to sell the Alexanderson alternator (a device which would serve the same purpose as the Schloemilch-Von Bronken patent for long-distance radio communication) to the British-controlled American Marconi Company, General Electric caused the Radio Corporation of America to be organized. With the unofficial blessing of the Navy Department (Secretary Daniels still holding out for government ownership), General Electric caused RCA to acquire the properties of the American Marconi Company and to enter into a patent and market agreement with the British Marconi Company for the division of the world into four areas for the conduct of radio communications.[55] Concurrently, General Electric and RCA agreed to cross-license patents and General Electric agreed to limit its radio activities to manufacturing equipment while RCA would limit itself to equipment sales and use in radio communication. Seven months later the cartel was extended to include American Telephone and Telegraph Company and its manufacturing subsidiary, Western Electric, in the first of the famous "patent pool agreements" of 1920.

This agreement broke the patent jam between the parties by providing for cross-licensing and it ensured for RCA the enjoyment of the market for radiotelegraphy and for AT & T the market for person-to-person telephony. In the following year, the cartel was extended to include the radio communication activities and patents of the United Fruit Company (through which markets were divided between the Fruit Company territory in the Caribbean, and RCA territory) and the radio

[53] See *Annual Reports* of the Secretary of the Navy, 1918-19 and 1919-20.

[54] Federal Communications Commission, Exhibit 2096-B, *Data Relating to Federal Control of the Bell Telephone System, August 1, 1918-July 31, 1919.*

[55] In the RCA territory (the United States and its possessions) and the Marconi territory (the British Empire and its mandates, except for certain RCA rights to communicate with Canada and Caribbean possessions), each party was to enjoy the use of the other's patents (including the Alexanderson alternator). These were agreed to be noncompetitive areas. "No Man's Land" was defined to include Holland, Spain, France, Italy, Russia, Norway, Japan, Germany, Austria, Poland, and the Argentine. In it, neither party could use the patents of the other, but the markets were left free for development. "Neutral territory" included the remainder of the world and in it competition might occur with the use of the other's patents. Federal Trade Commission, *Report on the Radio Industry*, 1924, p. 229, where the documents are reproduced.

patents and activities of Westinghouse Electric Company. Westinghouse, the second largest manufacturer of electrical apparatus in the United States at that time, had long been a rival of General Electric and held significant radio patents. In 1920 it had further strengthened its radio position by acquiring the patents held by the International Radio Telegraph Company and the Armstrong and Pupin patents. In 1921 Westinghouse joined the patent pool on the same terms as General Electric and agreed to divide the manufacture of receiving sets and tubes with that company — both to sell through RCA.[56]

In the early years of its existence, RCA's economic position was far from secure.[57] Equipment sales, however, rose with the advent of broadcasting, and through its monopoly position in equipment selling, RCA prospered. This monopoly position rested to some degree on the tacit policy of the Navy and the Department of Justice to refrain from enforcing government-owned radio patents against RCA-owned patents when the former appeared to be infringed on by the latter. In 1929 the responsible policy and legal officers of the Navy and Army testified before a Senate committee that had the government litigated the priority of the Schloemilch and Von Bronken tuned-frequency circuit patent as against the Alexanderson patent, it would have undermined the RCA monopoly position.[58] Analogous results would have flowed from protection of the other government-owned radio patents. The theory on which this unwillingness to litigate was ostensibly based was that the government had no legal right to assert a patent monopoly as against a citizen.[59] The testi-

[56] Federal Trade Commission, *op. cit.*, reproduces all the agreements.

[57] "Circuits were not as efficient as anticipated, particularly to South America, and only pride, patriotism and hope kept the company from becoming discouraged. But two things happened to save the situation: the advent of broadcasting with great profits, and the short wave, which reduced costs and made the service reliable." U. S. Senate, Committee on Interstate Commerce, *Hearings on S. 6,* 71st Congress, 1st Session, testimony of Captain S. C. Hooper, p. 321.

[58] Colonel McMullen, Judge Advocate General's Office, testified that this issue was carried to the Canadian Supreme Court with victory for the Schloemilch and Von Bronken patent; that in his judgment a similar result would have followed from government litigation in the United States; and that this result would have given the government power to destroy RCA's patent monopoly. *Ibid.,* p. 868-71.

[59] Colonel McMullen testified that the government had not intervened in two key cases where the Schloemilch and Von Bronken patent was involved and the following colloquy ensued:

"Senator Dill: Yes; I know about that. And I wrote a letter to the Secretary of the Navy last winter calling attention to that situation, and urging that the Government intervene, but no action has been taken, as I understand the situation.

"Colonel McMullen: I think the present Attorney General has different ideas about that. But there has been a pretty well-established idea in the Department of Justice, for a number of years, at least, that the Government as such has no right to maintain a monopoly of a patent." *Ibid.,* p. 868.

mony of the officer in charge of naval communications, who had participated in the creation of RCA, makes it plain, however, that he favored a policy of assisting RCA, in respect to patents as well as in other ways, to become the "chosen instrument" of United States communications.[60]

Even though the structure of the American communications cartel was later revised in substantial respects — especially after radio broadcasting developed in ways not foreseen in 1920 — the entrenchment of the economic interests along the lines of the patent pool agreements set the basic economic organization of radio in the United States. Government ownership of all radio communication has never been seriously considered since the failure of the Navy and Post Office efforts described earlier. Indeed, in World War II, no Federal assumption of control was needed, although legal authority for it existed, for by then it was possible to create a Board of War Communications of government officials from interested agencies, and to "coordinate" the work of private companies through a series of advisory committees composed of private businessmen representative of the several classes of radio service, together with their opposite numbers in the Federal agencies. Nevertheless, government has had a significant relationship to radio organization in the United States since 1921 in two respects: as a regulatory device for private users of the radio spectrum, and as a user of radio itself.

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[60] Captain S. C. Hooper denied all knowledge and responsibility for what the government had or had not done since 1919 with respect to protecting its radio patents against infringement.

"Captain Hooper: We gave them [RCA] advice, and we urged them on. And I might say that we thought we were doing a great thing, to help get up a great American company to compete with the British monopoly in communications.

"Senator Howell: Well, now, so far as this Von Bronken patent is concerned, the Navy Department has not been insisting upon its prior rights to the tuned frequency patent, but has allowed the Radio Corporation of America to go on and sell the apparatus and compel manufacturers to pay them a royalty, amounting to millions of dollars; so that we might say that was a sort of recompense for their organizing this Radio Corporation?

"Captain Hooper: No, sir; it has nothing to do with it at all. The patent situation is something entirely separate from this communications company business. . . . I do not have a thing to do with it. . . ." *Ibid.*, p. 317.

And at another point, he explained: "The way the matter turned out, it may appear unfortunate in some ways that I advised the RCA in such manner that a monopoly in the receiver trade patent situation resulted. This made the company appear as an undesirable money-making monopoly — and many people believe it is — but the receiver trade is not of interest to me. Had this not occurred, the country would have taken great pride in the R. C. A. communication company, and Congress would probably by now have assisted them in every way possible. The company, with the American position in shipping, and in aviation, would have been considered as one of the three great advantages gained for this country due to the war." *Ibid.*, p. 321.

The literature on American radio mostly concerns the regulatory function with respect to private radio users, so we may deal with it first. It will be recalled that the Radio Act of 1912 was premised on the crippling effect of radio interference on messages involving either national security or safety of life and property. And while it gave the Secretary of Commerce and Labor nominal power to license radio users (and thus preserved in the law the concept of a license), it permitted him no effective discretion in issuing licenses. At that time there were few applicants and even though the crude apparatus used required wide channels in order to avoid interference, the supply of frequencies was relatively ample. So long as users stayed on the channels agreed to in the international convention, national regulation could use a loose rein. During World War I, government operation of radio had ensured control adequate to eliminate interference possibilities. With the return of peacetime conditions and the marketing of new equipment (three-element tubes and regenerative circuits especially), the situation changed.

By 1926, the radio interference problem in all fields except high frequency had developed into a matter of such importance and wide ramifications that various private organizations were powerless to govern themselves.[41]

Evidently "government" by cartel depended on the state to make it viable. The growth of the fixed public service, the ship services, the aeronautical services, and other safety services rendered obsolete the previously adequate tolerances in equipment specifications and the services were beset by interference problems except in the high frequencies above 3,000 kc. Rapid growth of radio broadcasting to the extent of many hundreds of stations, however, caught public and legislative attention when it strained the Radio Act of 1912 past the breaking point. In despair of coping with the regulatory problem with the meager power given him by that act, the Secretary of Commerce stopped exercising any discretion and appealed to the industry and to Congress to form a new regulatory policy. A brief period of laissez-faire chaos on the broadcast frequencies produced the Radio Act of 1927.

The Radio Act of 1927 affirmed the public ownership of the radio spectrum and reaffirmed the previous concept of licensing its use, but now for terms limited by statute to a maximum of three years. The basic theory of the law discarded the assumption of the 1912 act that an applicant was entitled to a license if he could show that no interference would be created by his operations. Instead, under the 1927 law the test was whether the applicant's quality of service (in a non-technical as well as in a technical sense) would serve "the public interest,

[41] U. S. Senate, Committee on Interstate Commerce, *Hearings on S. 6,* 71st Congress, 1st Session, testimony of Lt. Commander T. A. M. Craven, p. 272.

convenience and necessity." This concept, borrowed from the public utility regulatory jargon, of necessity had to be interpreted differently when the license was for broadcasting (though it fitted neatly the common carrier and safety and special service radio communication services). In broadcasting, where the act encouraged a maximum of competition between licensees, the public interest test applied to comparative program services promised and delivered.

With the passage of the Communications Act of 1934, this policy was reaffirmed. At the same time, Congress by this act attempted, in several respects, to exert more state power to integrate and effectively use telecommunications. It created a new, single, and larger administrative body — the Federal Communications Commission. Congress centralized in that body (1) the control previously exercised by the Federal Radio Commission; (2) the regulatory authority previously granted to (but substantially ignored by) the Interstate Commerce Commission over common carrier uses of wire-telegraph, wire-telephone, and radio; (3) the regulatory authority over ocean cable landing licenses previously vested in the Secretary of State; and (4) the power to examine and license radio operators, previously vested in the Secretary of Commerce. In addition to avoiding the ordinary inefficiencies arising from division of responsibility, it was expected that the new commission, through its wide range of jurisdiction, would be able to exercise its allocation function for radio effectively. But beyond that, Congress attempted to place the commission in a position to exert positive guidance in the development of the art of telecommunications. It gave the commission power to

> . . . study new uses for radio, provide for experimental uses of frequencies, and generally encourage the larger and more effective use of radio in the public interest,

and implemented this directive by telling the commission to

> . . . keep itself informed as to . . . technical developments and improvements in wire and radio communication and radio transmission of energy to the end that the benefits of new inventions and developments may be made available to the people of the United States.[62]

In view of the fact that the government had in the early 1930's attacked the patent pool agreements under the antitrust acts, it is significant that the Communications Act charges the commission with so conducting its licensing of radio as not to permit monopoly, directs it to deny radio licenses to convicted violators of the antitrust laws, and authorizes judges to invalidate radio licenses when antitrust law violators are punished.[63] That the commission, as a matter of fact, has

[62] Communications Act of 1934, Secs. 303(g) and 218, 48 *Stat.* 1077.
[63] *Ibid.*, Secs. 311, 313, and 314.

generally followed rather than led private industry in determining the timeliness of innovations in the art of communications, and has failed to deny radio licenses to antitrust law violators, is the result of the political climate in the United States rather than of the expressed intent of the communications policy.

The preceding references to a policy of competition in radio broadcasting and to the sanctions related to the antitrust laws require clarification if one is to understand the organization of all radio communication in the United States. The competitive policy is most conspicuous in the broadcast use of radio. The common carrier application of radio is subject to different policies depending on whether it is domestic or international. Until 1943, the competitive policy ruled the domestic land-line telegraph field and until 1921, domestic telephone common carriage. Since those dates, by congressional action, mergers in those fields have been permitted under specified conditions and the carriers are protected against competition. Among the international common carriers (cable, radiotelegraph, and radiotelephone), however, the competitive formula has prevailed ever since it was enunciated by President Grant in 1875 when he barred a French cable from landing unless France would permit an American cable to land there.[64]

It appears that until the advent of radio communication the competitive formula was generally acceptable for international common carriers. However, since the mid-twenties when the lower cost service of radiotelegraph began to seriously reduce cable revenues, there have been frequent proposals to limit competition, initially through permitting merger of international carriers. The scope and conditions of proposed mergers have varied greatly. Most of the proposals have been for permissive mergers, though in 1945 the Navy recommended a compulsory merger in a private company with a minority of government directors. At times the Navy has advocated separate mergers of cable companies and radiotelegraph companies, and at other times, one inclusive merger. It appears that all proposals have excluded the common carrier service of the Bell Telephone System from the scope of the proposed merged company. The most recent such proposal was carefully analyzed by the President's Communications Policy Board in 1951, which recommended that the competitive formula be retained. Consideration of the existence of competition is substantially irrelevant to the administration of radio in the safety and special services. In that area, radio is deemed incidental to the conduct of some other industry, such as ocean shipping, air

[64] U. S. Senate, Committee on Interstate Commerce, *Hearings on S. 535*, 67th Congress, 1st Session, 1921, p. 37.

transport, land transport, or the activities of such public functions as police and fire protection.

The structure of organization of radio activities in the United States includes more than the governmental regulatory agencies and the private corporations which operate the facilities.

Expertise is supplied the Federal Communications Commission by, and the interests of radio equipment manufacturers and radio stations of all kinds are represented through, the trade association of equipment manufacturers (Radio Television Manufacturers Association) and by the professional society of radio engineers (Institute of Radio Engineers). But even these associations have proved insufficient for the needed integration of radio in the United States. Using the pattern established for the first time by the Board of War Communications in World War II and waiving the antitrust laws, the government suggested in November, 1942, that the radio industry set up an organization to coordinate planning for frequency allocation and engineering standards in preparation for postwar policy making. Accordingly, there was established a Radio Technical Planning Board in September, 1943. It included representation from 19 trade associations and established 13 panels[65] on which representatives from interested private organizations worked up plans under the observation of and with the assistance of commission personnel. This organization was extremely active both before and during the 1944 frequency allocation hearings, and earned the commission's gratitude

> . . . for the conscientious and thorough way in which this work was done. Without their assistance the Commission's task would have been far more difficult and time consuming.[66]

A successor and permanent organization was created in 1948 by the Institute of Radio Engineers and the Radio Manufacturers Association, known as the Joint Technical Advisory Committee with the chartered purpose of

> . . . obtain[ing] and evaluat[ing] information of a technical or engineering nature relating to the radio art for the purpose of advising Government bodies and other professional and industrial groups. In obtaining and evaluating such information, the JTAC shall maintain an objective point of view. It is recognized that the advice given may involve integrated professional judgments on many interrelated factors, including economic forces and public policy.[67]

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[65] Spectrum Utilization; Frequency Allocation; High-Frequency Generation; Standard Broadcasting; FM Broadcasting; Television; Facsimile; Radio Communication; Relay Systems; Radio Range; Direction and Recognition; Aeronautical Radio; Industrial, Scientific, and Medical Equipment.

[66] Federal Communications Commission, *1945 Allocation Hearing Report, op. cit.*, p. 7.

[67] Joint Technical Advisory Committee, *Radio Spectrum Conservation* (New York: McGraw-Hill, 1952), p. 211.

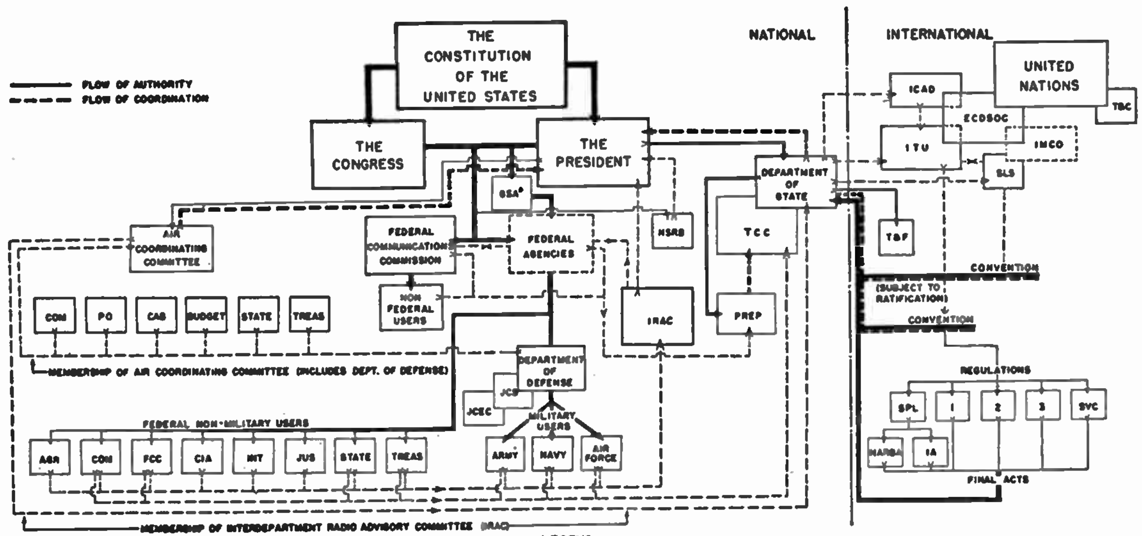
In spelling out its detailed duties, the charter makes plain that the primary purpose is to consult with government bodies "to determine what technical information is required to insure the wise use and regulation of radio facilities and to prepare and present such information." The organization chart of JTAC shows a tightly knit yet wide-spread web.[68]

Among the organizations represented through JTAC committees are a number of specialized organizations among classes of users of radio for safety and special purposes. When the FCC was holding its general allocations hearings in 1944-45, dozens of industry groups appeared, each prepared to argue its need for spectrum allocation. Following World War II some of these organizations were given semiofficial status through the addition of government representatives. Some of them were designated to discharge government policy under the constitutional powers of the State Department and legislation on marine, aviation, and communications matters. Thus there now is a Radio Technical Commission for Marine, a Radio Technical Commission for Aeronautics, and a Radio Technical Commission for Land-Mobile Service. Such organizations participate in international allocations negotiations and activities. They also provide liaison between the principal trade associations, the principal companies in the respective industries, and the government agencies (principally the FCC, the State Department, and the armed forces) in planning for radio engineering standards, frequency allocations, and operating procedures and rules.

In the eyes of the law, the Federal Communications Commission deals with the individuals (mostly corporations) who are licensees or applicants for licenses. Where individual applications are involved, the commission hears directly from them and usually only from them. When

[68] *Ibid.* The JTAC under the heading of "broadcasting" draws on eight IRE committees, 24 RTMA engineering department committees, the NARTB Engineering Department, the FM Association, the FCC Bureau of Engineering; under "common carriers" on four IRE technical committees, three RTMA Engineering Department committees, the FCC Bureau of Engineering; under "safety services" on two IRE technical committees, three RTMA Engineering Department committees, the Radio Technical Commission for Aeronautics, the Radio Technical Commission for Marine, the Radio Technical Commission for Land-Mobile Service, the American Radio Relay League, the FCC Bureau of Engineering, the International Association of Chiefs of Police, the Association of Police Communication Officers, the International Municipal Signal Association, the Association of American Railroads; under "miscellaneous" it draws on twelve IRE technical committees, three RTMA Engineering Department committees, the Joint Electron Tube Engineering Council, the Research and Development Board of the United States government, the Committee on Electronics Panels of the Research and Development Board, the International Scientific Radio Union, the International Radio Consultative Committee, the National Bureau of Standards, the FCC Bureau of Engineering, and other organizations.

Chart 2. Flow Chart of National and International Telecommunication Authority and Coordination



—LEGEND—

AGR — Department of Agriculture
BUDGET — Bureau of the Budget
CAB — Civil Aeronautics Board
CIA — Central Intelligence Agency
COM — Department of Commerce
ECOSOC — Economic and Social Council (UN Organ)
FCC — Federal Communications Commission
GSA — General Services Administration
IA — Inter-American Convention and Agreement
ICAO — International Civil Aviation Organization
IMCO — Inter-Governmental Maritime Consultative Organization
INT — Department of the Interior
IRAC — Interdepartment Radio Advisory Committee
ITU — International Telecommunications Union
JCEC — Joint Communications — Electronics Committee
JCS — Joint Chiefs of Staff
JUS — Department of Justice
NARBA — North American Regional Broadcasting Agreement
PO — Post Office Department
PREP — Conference and Position Preparatory Committees
SLS — International Convention for the Safety of Life at Sea
SPL — Special Arrangements Between ITU Member Countries
STATE — Department of State
SVC — Radio Service Conferences
T & C — Transport and Communications Commission (UN Organ)
T & F — Territorial and Foreign Relations
TCC — Telecommunications Coordinating Committee
TREAS — Department of the Treasury (Includes Coast Guard)
1 — Region 1 of ITU, Embracing Europe and Africa
2 — Region 2 of ITU, Embracing North and South America and Hawaii
3 — Region 3 of ITU, Embracing Australasia

* Authority under Public Law 152 over public utility communication services of executive agencies except for certain of their activities.

Source: President's Communications Policy Board, *Telecommunications: A Program for Progress*, p. 190.

applications "go to hearing" where competition for a license exists, members of the general public are sometimes heard. At rule-making hearings — such as those on allocations or engineering standards — the parties appearing also commonly include trade associations representing the classes of radio stations whose interests are involved in the issues. Testimony from members of the general public or from employees or unions is comparatively rare. Unlike the practice in railroad regulation, individual users or associations of users seldom appear in matters affecting the facilities, service, or rates of communications common carriers, and for the most part participation by unions of communications employees has been limited to that of the American Communications Association in the domestic telegraph and international common carrier fields.

To understand the radio administrative structure in the United States it is not enough to apprehend the scope and complexity of the private business organization of radio. One also has to examine the organization for the government use of radio. This alone is not a small affair. In 1951 a special investigation revealed that the United States government occupied almost half of the frequency space assigned to this country between 4 and 20 mc and 28 percent of the probable number of channels available in this country between 30 and 300 mc. Elaborate radio networks using both radiotelephone and radiotelegraph span the world and are operated by or for the Army, the Navy, the Air Force, the Voice of America, and the Civil Aeronautics Administration.[69] The organizational structure which administers use of radio by the military, six government departments, and two independent agencies is shown in Chart 2.[70]

In legal theory, the power to assign frequencies upon showing of adequate need and to regulate their use by all nongovernmental users rests with the FCC and for governmental users with the President. To perform the latter function, an interdepartmental committee composed of representatives of the interested agencies (known as IRAC) has operated since 1921 with no legislation authorizing it.

On the performance level, serious criticism has been directed at the policies followed by the IRAC. It has been charged with assigning frequencies through a process of mutual accommodation rather than through requiring rigorous showings of need. While each of the user agencies knows its own uses of radio, there was in 1951 no single complete record of all frequency assignments to all users in the United States. The structure is not suited for planning for future needs. These

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[69] President's Communications Policy Board, *Telecommunications: A Program for Progress* (Washington: Government Printing Office, 1951), pp. 41-43.

[70] *Ibid.*, p. 190.

criticisms by the President's Communications Policy Board suggest that the planning imperative in telecommunications presses uncomfortably on the loose organization for radio prescribed by the traditional decentralization of the administration of America's Federal government.

A summary view of the structure of organization for the use of radio would show that in most countries it is tightly knit and confined in composition to government or to combinations of government and nongovernment interests (the latter being private business organizations in capitalist countries and Communist party organizations in noncapitalist areas). In the United States, our survey of radio organization reveals an immensely complex network of private corporate organization which blends with the government organization. Taking account of the prevailing institutional and policy climate in the United States, the total effect of the existing radio organization is of a cumbersome but integrated structure. The most pervasive criticism addressed to both the private and government components in radio organization is that too little integration is achieved. The waiver of the antitrust laws to permit over-all industry organization, now exemplified in the JTAC, signifies the unique technological imperative which even in the United States requires the creation of integrated organization.

VI. INTERNATIONAL UNIFICATION OF ORGANIZATION FOR RADIO SERVICES

The intranational organization for the use of radio which was described in the preceding chapter has developed in intimate relation to the international organization with which this chapter is concerned. Here we will analyze its development and examine briefly some of the nontechnical policy issues on which the maneuvers of the national powers have shaped the structure and policy of the international organization.[71]

In a span of some forty years, concern for radio moved the nations from a loose organization, similar to the original telegraph union, to a tightly knit world organization with planning powers and a continuing policy-making executive. The original Berlin convention of 1906 was concerned primarily with obligatory communications — with procedures and equipment for radio to the end that its use should be feasible for all nations. Progress in the radio art rapidly outdated this convention and its accompanying regulations, so that by 1912 the London Radio-Telegraph Conference revised them to take account of problems raised by the several distinct use-patterns which were emerging. The rapid differentiation and development of radio associated with World War I provided plenty of cause for further revisions by the end of that war. The five Allied Powers in 1920 considered plans for an international congress aimed at establishing a "Universal Electric-Communications Union" and at planning the allocation of the spectrum up to 150 kc, but were unable to proceed to the point of calling the congress. It was not until 1927 that the Radio-Telegraph Union had another meeting, this time in Washington.

[71] From this point to the end of the paper, the author has drawn freely upon G. A. Codding, Jr., *The International Telecommunication Union*, as well as on reports from that organization and the Federal Communications Commission and speeches by members of that commission.

Here, for the first time, the emphasis shifted from a concern over procedures and equipment to a concern for comprehensive frequency allocation in order to eliminate radio interference. The scope of authority was extended from merely maritime use of radio for correspondence to include all radio communication stations open to the international service of public correspondence. In practical terms, this meant that new regulations were written for aeronautical radio (both for its use for operating aircraft safely and for public correspondence), for meteorological services, time signals, and aids to navigators such as radio-compass and radio-beacon services. Organizationally, too, this conference marked the end of an era. The Berlin conference of 1906 and the conference of 1912 had been independent of the International Telegraph Union but had asked it to administer such limited housekeeping functions as the resultant conventions required. The 1927 meeting recommended unification with the International Telegraph Union at the following meeting, and created a permanent International Radio Consultative Committee (parallel to the telegraph and telephone consultative committees). At the Madrid conference in 1932, this recommendation was adopted and a new organization created, for which the name "International Telecommunication Union" was found. Organizationally, radio was raised to a parity with wire-telegraphy and wire-telephony. Substantively, the work on radio continued at both this and the succeeding International Telecommunications Conference (Cairo, in 1938) on the level of *ad hoc* decisions on particular allocation problems and particular procedure and equipment problems. Between conferences there was little for the ITU to do about radio, except conduct studies through the Radio Consultative Committee.

In the interim between the two World Wars, significant organizations in international regulation of radio developed on a Continental basis alongside the world-wide structural changes traced earlier. Thus, what began at the instance of the British Broadcasting Corporation as a radio conference on European radio problems in 1925 produced a regional radio union for the voluntary redistribution of frequencies for European broadcasting. This work was taken up in 1933 by the Brussels Technical Commission and the Lucerne Broadcasting Conference. It was carried to fruition in the Montreux convention of 1939, which established the International Broadcasting Union as the technical authority on European broadcasting, performing the standard-setting and station-assigning functions for that area that the Federal Communications Commission performs in the United States. A somewhat looser organization developed in the Western Hemisphere. Even before 1927 there was a "gentleman's agreement" between the United States and Canada as to the use of broadcast channels. An Inter-American Radio Office was created to administer the terms of the Inter-American Agreement and the North American Regional Broadcast Agreement, both of which were the outcome of a conference in Cuba in 1937. It must be remembered that such regional radio administrations as these are both feasible and necessary because of the regional propagation characteristics of the portions of the spectrum used for AM radio broadcasting.

Immediately after the close of World War II, organizational policy decisions of major significance were taken even before the formal opening of the first postwar telecommunications conference. Thus, at Moscow in the fall of 1946 there was held, at the suggestion of the United States, a "preparatory conference" at which the participants were China, France, the United Kingdom, the United States, and the USSR. All were in agreement that the existing state of frequency allocations needed reorganization. All were agreed that there should be created a world-wide frequency allocation board which would screen for possible interference future requests from particular countries. In the past there had been no organ capable of making policy decisions for the ITU between its plenipotentiary and administrative conferences. The nations at Moscow were in agreement that there should be created an administrative council of elected members who should control the ITU and make policy between conferences. The whole, it was also agreed, should be detached from dependence on even a neutral state such as Switzerland, and tied closely to the United Nations. In evaluating later developments it is important to note that a strong tide of feeling for international cooperation was manifested before and during the Atlantic City meetings of 1947. The United States had proposed holding the preparatory conference in the USSR. At that conference, as Codding says:

> With regard to the proposals, as well as in the discussions that followed, we find the United States and the U.S.S.R. acting as the progressive elements of the Conference, the United Kingdom and France as the conservative elements, and China as an interested spectator.[12]

When dissension arose concerning the place for the 1947 meetings, with a majority of the states polled by the ITU desiring it to be held in Europe, the USSR supported the United States in forcing the holding of the meetings at Atlantic City.

The Atlantic City conferences in 1947 tightened the previously sprawling organizations concerned with telecommunications. The 78 countries admitted to participation in the conferences revised the previous conventions (at Cairo and Madrid) and worked out the following organizational innovations.

[12] Codding, *op. cit.*, p. 198.

(1) They established an Administrative Council with discretionary powers to act between world-wide conferences. The council was to consist of 18 members, each of whom would be qualified in telecommunications and would serve for five years.

(2) A schedule of regular meetings every five years was established.

(3) The Consultative Committees for Telegraph, Telephone, and Radio were incorporated into the union and provided with some uniformity in organization and procedure.

(4) A permanent secretariat was created to replace the existing bureau and its scope was broadened to include the personnel serving the consultative committees. The secretariat of the ITU was detached from its administrative dependence on the Swiss government and placed under the new Administrative Council. Physically it was moved from Berne to Geneva. Personnel for the bureau and for the staffs of the consultative committees were given an international status and were to be recruited internationally, and their salary schedule was moved in the direction of parity with those of UN agencies.

(5) An International Frequency Registration Board was established. The board itself was to consist of nine men, selected for their technical knowledge. In an effort to insulate these men from national or regional pressures, members of the board were prohibited from receiving instructions from any source. In creating the board the nations hewed to a narrow line in defining its functions. They were anxious to avoid conferring discretionary powers on this board, yet they desired to centralize more power to police radio interference than had previously existed. Consequently, they gave it considerable power to review and either approve or disapprove frequency requests, though spelling this power out in terms of detailed procedural steps which covered all possible alternative situations. By its terms of reference, the board was limited to on-going functions of registering changes in radio frequency assignments. In order to get it started, another procedure was required which was met by plans for a new international frequency list, and a Provisional Frequency Board.

(6) A Provisional Frequency Board was created with instructions for preparing a new international frequency list. As will be more fully explained when we consider the development of international frequency allocation policy, this was the nub of the problem of international organization for radio. Despite the indications of US-USSR cooperation which were so evident at Atlantic City, the conditions for the intrusion of the "cold war" into international radio organization lay in the terms of reference for the Provisional Frequency Board which was created to build the new international frequency list. As will be shown in the discussion of

radio allocation policy, delays in the construction of this list defeated, at least temporarily, the original hopes for the International Frequency Board.

(7) Formal relationships were established between the International Telecommunication Union and the United Nations. Careful consideration was given by the Atlantic City delegates to this matter. The old ITU had avoided any affiliation with the League of Nations and there was a strong feeling that the ITU, like the Universal Postal Union, should avoid political issues. The dominant feeling expressed was that the ITU should remain "technical," "administrative," and "universal,"[73] and remain aloof from political alignments which could cause schisms. Consequently, the ITU entered into a relationship with the UN similar to that of the Universal Postal Union. The relationship established was characterized by:

(a) Absolute technical independence; (b) general coordination with the United Nations; (c) coercive political coordination, as provided in chapter VII of the Charter of the United Nations, binding only on those members with a double, ITU-UNO membership.[74]

The union also resolutely expressed the intention to protect the sovereignty of ITU members who were not members of the UN. A related issue arose over the extent of the application of the convention and regulations. An effort was made by some countries to force the obligation to conform on all members of the ITU. After protests were heard from the United States and China, the decision was made to permit reservations to specific regulations in the light of "the 'sovereign right' of each country to regulate its own telecommunications."[75] Even though integration was being achieved, it was neither rigid nor monolithic.

(8) Continuing rules on membership and voting were established. National powers had maneuvered for position on these issues at previous international conferences. The principle of "colonial voting" (multiple

[73] According to the delegate from France, speaking in a committee, "The ITU was 'technical and universal,' dealing specifically with promoting methods for the facilitation and development of telecommunications, while the U.N.O. was more 'political and restricted,' and dealt with general political topics." In the fifth plenary meeting of the Telecommunication Conference, the delegate from Belgium expressed the attitude of the assembly when he said, "'. . . our Union is an essentially technical and administrative body and that as a result international politics must continue to be excluded from its discussions. Belgium is favorable to our Union being connected with the United Nations, but under the formal stipulation that the complete independence of the Union shall be maintained. The I.T.U. is an organization which has existed for eighty years and has given brilliant proof of its ability; it is of primary interest to all countries and must be preserved from any schisms.'" Codding, *op. cit.*, pp. 316-17.

[74] *Ibid.*, p. 320.

[75] *Ibid.*, p. 325.

votes for colonial empires) was tacitly accepted as early as 1868 as the price of gaining participation by Great Britain and India in the Vienna telegraph conference of that year. At the Berlin Radio-Telegraph Conference in 1906 the discussion turned, realistically, not on the issue of holding an imperial power to one vote, but rather on the issue of setting a limit to the total number of imperial votes obtained through colonial representation. The limit set was six.

But the dynamics of empire being what they were, this did not represent a permanent policy. Again in the London conference in 1912, the first debates were on voting rights. The major colonial powers retained a voting advantage in that conference (with France and Great Britain having five votes, Germany three, and the Netherlands, Portugal, Belgium, and Japan each two). Apparently as the price of retaining this temporary advantage, the conference made concessions to the United States, Italy, Russia, and Turkey for future conferences while denying these countries additional votes in 1912. For future conferences, France, Germany, Great Britain, Russia, and the United States were to have a maximum of six votes each, while Italy, the Netherlands, and Portugal were to have three votes, and Belgium, Japan, and Spain, two.

A concern for the issue of representation and voting was in the foreground of the Washington conference in 1927, for the United States refused to invite the USSR delegation to attend, despite the USSR's adherence to the 1912 convention. At the Washington conference itself colonial voting, as determined at the London conference, was permitted, even to Germany.[76] Again, in 1932, at Madrid, the custom of colonial voting proved too deeply imbedded to be overturned, although two months were spent in attempting to work out an acceptable alternative to it. In the last pre-World War II conference — that at Cairo in 1938 — the voting procedure adopted at Madrid was again employed, with minor and noncontroversial amendments.

As might be expected, the political upheavals incident to World War II presented the Atlantic City conference with thorny membership problems. The United States, as host, had invited 77 countries, including (a) those which had adhered fully to the Madrid convention (these, numbering 44, were members by any standard advanced in the debates); (b) those who were members of the United Nations but not of the ITU;

[76] "Although Germany was no longer an Empire, and had lost her 'possessions,' at the suggestion of Secretary [Herbert] Hoover the conference 'unanimously' agreed to accord six votes to Germany, 'only for the duration of the conference . . . and not to form a precedent.'" While protesting its exclusion, the ". . . U.S.S.R. sent a group of proposals to the conference, which were considered along with the rest." Codding, *op. cit.*, pp. 117 and 119.

and (c) those who were not members of the UN or the ITU. Sharp objections were made by Belgium and Switzerland to the admittance of 10 nonmember Latin American countries in view of the fact that selection of a new site for the ITU was on the agenda. Nevertheless, all those invited were given voting rights. Protracted debate took place over the desire of the USSR, Byelorussia, Yugoslavia, and Albania that Mongolia, Latvia, Lithuania, and Estonia be admitted to vote, but none of them was granted this privilege. Byelorussia and the Ukraine, as UN members, had been invited. Further controversy took place over the exclusion of Spain, to which the United States had first extended and then withdrawn an invitation following insistence by the USSR on compliance with the resolution of the General Assembly of the UN denying Spain membership in agencies related to the UN so long as Franco's government ruled it. Spain, having been one of the original members of the ITU and host at the Madrid conference, drew support from Argentina, the Vatican, Eire, and Portugal. With some assistance from the American chairman who posed the question appropriately to the answer desired, Spain failed to get a two-thirds vote for admittance.

The innovation on membership at Atlantic City consisted in the adoption of rules for membership. This relieved subsequent conferences of developing their own *ad hoc* rules. At the same time the ITU determined a precise voting procedure providing for effective quorums and secret balloting.[77] This greater subordination to discipline even extended to the point where, at the suggestion of the United States delegation, a rule was adopted prohibiting private companies from submitting proposals to the conference unless such proposals were supported by the head of the delegation from the appropriate country. As a result of the operation of the voting procedure, by February 1, 1952, there were 81 fully qualified members of the International Telecommunication Union. By that date, Japan and Spain had been admitted and the People's Republic of China excluded, although admittedly it alone could implement the union's rules and regulations in continental China.

(9) A minor but interesting organizational problem was faced and settled in the determination of official languages for use in ITU records. In the early conferences French had become established as the official language but with English also being used. Lengthy disputes took place at Atlantic City over the desire of other countries for their languages to be used as well. Ultimately it was determined that five languages

[77] At least half the delegations must be present for a valid vote to be taken; decision must be postponed if abstentions exceed half of the delegations present; a secret ballot will be taken on request of five or more delegations; a two-thirds majority is necessary in voting on a new member.

would be termed "official" and used for all final documents of ITU conferences. These were French, English, Spanish, Russian, and Chinese. Designated as "working" languages for use in conference proceedings were French, English, and Spanish. And as a reference point in the event of ambiguities in translations between the "official" languages, French was chosen as the "authentic" language.

(10) Union finances, arbitration of disputes, and regional agreements were provided for. A number of minor organizational features of the International Telecommunication Union were dealt with at Atlantic City. Revenues were provided through an eightfold classification of member countries, with a range from 1 to 30 units. The never-used arbitration procedure contained in the Cairo convention was carried over intact into the new convention, together with provision for settlement of disputes through diplomatic channels. Similarly there was carried over to the Atlantic City convention provision for members to make special arrangements on telecommunication matters which do not concern the union in general. This provision permits the obviously necessary agreements for operating wire line or radio common carrier service across national borders. The new convention, however, added a provision giving members the right to hold regional conferences, to make regional agreements, and to form regional organizations in order to deal with telecommunications matters susceptible of treatment on a regional basis. Such regional activities were required to avoid conflict with the convention.[78]

The reorganization of the union in 1947, its reconstitution with a permanent executive body, and the aspirations toward international allocation of radio for the greatest efficiency in its use — all these were undertaken with great enthusiasm. So enthusiastic were the delegates that while the effective date of the convention and regulations was January 1, 1949, the final action of the union on October 2, 1947, was to direct the new Administrative Council and the International Frequency Registration Board to come into existence and to function immediately.

There followed an extremely active period. Between 1948 and 1952 there were 12 different international conferences (11 on frequency allocation, 1 on telegraph and telephone), numerous meetings of consultative committees, and six sessions of the Administrative Council. As indicated

[78] There are four significant regional organizations. One, the League of Arab States, located in Cairo, concerns all telecommunications problems. Three others deal only with broadcasting: the European Broadcasting Union, Geneva; the International Broadcasting Organization, Prague; the Inter-American Radio Office, Havana, Cuba. The two European broadcasting organizations each has a membership divided between countries in western and eastern Europe.

in the discussion of frequency allocation, what the Atlantic City delegates feared came to pass, namely the formation of a deep schism between the United States and the USSR. Although it was outvoted in the allocations conferences, the USSR nevertheless maintained its active membership in the union. Though these policy disputes did frustrate the intentions of the Atlantic City delegates in respect to frequency allocations, the Administrative Council was less affected by them. To be sure, reverberations of the allocations dispute disturbed the Administrative Council, which was called on by the USSR to direct the allocations conferences along policy lines which the USSR maintained were intended in the 1947 meetings. With its majority controlled by the Western powers, the Administrative Council generally took the position that since it, like the Provisional Frequency Board and the radio conferences, was a creature of the Atlantic City plenipotentiary conference, it could not effectively supervise or control the work of the radio conferences. While the substance of its actions was effectively a compromise, the council adopted the procedure of trying to affect the actions of such specialized conferences through a graded series of "invitations" to reconsider their actions. The council held that if these failed to achieve the desired results, it would reserve the right to initiate new conferences to redo the work of the errant ones. Otherwise, the Administrative Council appears to have lived up to the hopes of its founders. It has managed the secretariat of the union. Because of personnel "legacies" from the old secretariat, it has been slow to internationalize the personnel and to raise the salary scales as planned. It has maintained close relations with the UN.

In this chapter the development of radio organization on the international level has been traced. The structure of that organization has been integrated and unified to the degree required for the solution of radio problems — and no further. It stands, along with the Universal Postal Union, as a world-wide organization with a continuing executive body capable of dealing with the pervasive implications of radio allocation and radio standard-setting. Thus far, and in order to facilitate analysis, no systematic attention has been paid to the central policy issues which radio persistently presents. Explication of these issues is the burden of the final three chapters.

VII. THEORY OF RADIO SPECTRUM ALLOCATION

At the root of all use of radio is frequency allocation policy — the logic and practice of assigning the particular parts of the radio spectrum to various uses. The mere fact that a conscious social process is required to accomplish radio allocation eliminates the use of such devices as the market to effect tolerable results.[79] It is therefore in allocation policy that what we have referred to as the technological imperative has its clearest consequences in requiring centralized planning. In chapters IV, V, and VI the scope of the differentiated uses of radio and the nature of the administrative organization by which they are articulated both within and between nations have been displayed in summary fashion. The present chapter deals with the theory of frequency allocation as it is exemplified in the United States. This will provide a basis for understanding how international radio allocation policy demonstrates the integration and centralization which is implicit in radio communication.

So long as the only systematic use of radio was for marine and coastal fixed stations (in the few years from about 1903 to 1908), the demand for frequencies did not press on the supply. Allocation policy was then only in embryo. With the tremendous growth of radio during World War I and the 1920's, however, demand began to press heavily on the supply of frequencies, and as we have observed, forced the development of a technology capable of utilizing the "very high frequencies." While this increase in supply eased current problems, it created new ones. Within national states where a centralized authority could readily assert it, allocation policy became imperative as a means of rationalizing the treatment accorded the rapidly differentiating users. Thus Commander Craven testified in 1929 that prior to World War I

> There were a limited number of organizations who desired to use these frequencies. . . . While the type of apparatus used required a wide channel, in

[79] See Dallas W. Smythe, "Facing the Facts About the Broadcast Business," *University of Chicago Law Review,* Autumn, 1952, pp. 96-106.

order to avoid interference, the demand for the use of channels was not so great as to force the imposition of technical restrictions.[80]

At that time, according to Commander Craven, the assignment of bands of frequencies to services was "built upon former practice."

Conscious frequency allocation policy starts with the assumption that generally the demand for radio frequencies will exceed the supply — that, as a former chairman of the FCC put it, the problem is to accommodate six bushels of ripe tomatoes in a single bushel basket. This state of affairs is likely to prevail in the foreseeable future. The basis of this prediction is the rapid proliferation of demands for spectrum assignments, plus the resistances encountered before allocated bands will be surrendered by existing services or the investments in equipment to operate them will be recognized as obsolescent. Innovations designed to increase the economy of frequency utilization must perennially face such resistances, which will become tougher as radio's uses multiply. In this respect, the economics of allocation policy resembles somewhat the economics of urban land use in a city like New York.

The ideal objective of frequency allocation is to so govern the spectrum that the best use is made continuously of all frequencies by radio stations with adjacent but not overlapping service areas. More specifically, it consists of making the rules for fitting justified uses of radio to the varying capabilities of the different frequencies with due regard to geography, under regulations which prescribe appropriately small tolerances and which hold man-made "noise" (interference) to tolerable levels consistent with the assigned uses of the frequencies. The four variables in frequency allocation are radio frequencies, uses, time, and space.

Our analysis of radio frequency allocation theory may be restricted to the United States, inasmuch as this country provides wide experience under ideological conditions which put our technological imperative hypothesis to a severe test. It may also be restricted to current allocation policy rather than to an exploration of the evolution of the policy. The factors which constitute elements in frequency allocation policy are as follows:

(1) Use (or demand) factors:

(a) A primary principle for screening requests for radio frequencies is that they must show why wire lines will not serve instead of radio. Unless, as in the instance of the international fixed public common carriers, contravening considerations of public policy dictate the

[80] U. S. Senate, Committee on Interstate Commerce, *Hearings on S. 6*, 71st Congress, 1st Session, May 18, 1929, p. 265.

use of radio where wires would be a technically adequate substitute, the service for which the request is made will be rejected. Thus, a domestic United States fixed public service radiotelegraph or radiotelephone service between urban areas would, if it had been proposed after World War II, fail to meet this test.

(b) The fundamental factor underlying any approvable radio service is the public need for it. As we have observed in reviewing the grounds on which the FCC has approved many of the recently developed services, safety of life and property are weighed more heavily than is mere convenience. The commission has also established two further tests of need:

Where other factors were equal, the Commission attempted to meet the requests of those services which proposed to render benefits to large groups of the population rather than of those services which aid relatively small groups.

. . . . .

With the shortage of frequencies available, the Commission did not believe that it would be in the public interest to assign frequencies to a new service unless it could be shown that there would be public acceptability and use of the service.[81]

(2) Technical (or supply) factors:

(a) Propagation characteristics. Propagation characteristics of the frequencies in relation to the needs of the user provide a factor of key importance in determining frequency allocation policy. Reference to Chart 1 will show that for carrying signals over land for a distance of several thousand miles, day *and* night, frequencies between roughly 3 and 25 mc and below 300 kc are most reliable, while short-range transmission is obtainable between 1.5 and 3.0 mc and in the very high frequencies between 30 and 300 mc. While all of the VHF frequencies are "quasi-optical" in propagation — that is, they retain adequate signal intensity only within roughly line-of-sight — this characteristic becomes more pronounced as one moves to frequencies above 200 mc. Because users of frequencies above that point can be located relatively close to each other (on the same frequency) in terms of geography, it is apparent that more radio transmissions may be authorized for a given frequency the higher in the spectrum you go. Yet, paradoxically, the effective service area of each transmitter diminishes as resort is had to those higher frequencies. The FCC states the allocation principle, which rests on these facts, as follows:

Certain frequencies could be more effectively used by those services where long range communication was necessary. Other frequencies were better suited for short range communication. In the case of some frequencies, the principal source of interference to a station on these frequencies would be from stations

[81] *1945 Allocation Hearing Report, op. cit.,* pp. 18-19.

located nearby, while in the case of other frequencies the principal source of interference would be caused by distant stations. All these factors had to be evaluated so that the service could be assigned to that portion of the spectrum where it could render its best service.[83]

Several kinds of consequences flow from this propagation factor:

1. Because most radio uses involve both longer- and shorter-range communications, the assignments of frequencies to a given service commonly will be distributed in widely separated parts of the spectrum. The allocation policy adopted for aviation illustrates this point. Allocations were made in the very high frequency area for all communication with aircraft flying over land, and frequencies below 25 mc were used only for communication with aircraft flying international overseas routes. The result of such an allocation policy is that services with widely different uses and justifications for spectrum space are found close together in many portions of the spectrum. Any subsequent attempt to vacate such a portion of the spectrum in order to make space for a new service, therefore, is confronted with a variety of vested interests. This situation does not arise where the end-use service needs are homogeneous — as in AM radio broadcast. In such cases the regulatory authority is apt to find that massive investments have been made both by business and by the public, which present obstacles to innovating a new service in the block of frequencies thus occupied.

2. The allocation problems presented by propagation characteristics in relation to the needs for the service would be complex enough even if the users of the service were evenly distributed in geographic space. Unfortunately for the allocaters, however, the human geography of both the United States and Europe displays high degrees of concentration of population and of demand for radio spectrum space in relatively small areas of their land space. The pinch in allocating radio frequencies arises precisely at these points of greatest demand. To illustrate — the amount of spectrum space necessary to provide all the TV channel assignments ever likely to be required in the United States outside of the Middle Atlantic and New England states is much less than the amount of spectrum space necessary to accommodate the TV service in those areas. Frequency allocation policy is thus forced to establish the minimum amount of service required by the "crowded" areas (e.g. a total of 12 VHF channels which permits only seven in New York, four in Boston, three in Philadelphia, three in Baltimore, and four in Washington, D. C.). Even so, wastefully large chunks of the spectrum are sure to lie idle. To a limited extent, this Procrustean-bed characteristic of radio allocation can be offset by making frequency-sharing allocations

[83] *Ibid.*, p. 19.

to a second service — let us say general mobile radiotelephone — to use TV channels in the less crowded areas. But even there the relief is slight. That this problem is not unique to television is indicated by the following:

> The ship-shore radio telephone message load is greater at New York than at any other port now served by coastal harbor stations and it is estimated that it will increase several hundred percent in the next five or ten years. The geographical separation between ports, except Great Lakes ports, where coastal harbor stations are now located appears adequate to permit the re-use at practically all of these stations of any group of frequencies that might be allocated to the Maritime Mobile service in the Very High Frequency range. From these two circumstances it appears that if the frequency needs of the New York area in the Very High Frequency range are met, provision will have been made in this range for the other important ports. . . . These frequencies would also be made available for the Geophysical service in areas where destructive interference would not be caused the ship and coastal services. Since it may be desirable to furnish ship-shore telephone service on a joint basis with the highway mobile services in some areas, the Commission further proposes to make [frequencies] available on this basis. . . .[83]

Similar arrangements abound in frequency allocation.

Because of the pressures built up through propagation characteristics of a band occupied by a service, the growing demand for more stations within that band, and the eccentricities of geography, allocation policy sometimes resorts to directional antennas. This expedient efficiently permits greater use of frequencies assigned to long-distance services such as the fixed public international common carriers. It is a less satisfactory palliative for such problems as are posed by the post-World War II expansion in numbers of AM broadcast stations in the United States. The investment in stations rises rapidly as directional elements are added to antennas, and engineers wryly regard such antennas as all too convenient excuses for introducing more stations, which in the aggregate reduce the *de facto* engineering standards of AM broadcasting to unsatisfactorily low levels.

Propagation characteristics also present a factor of quite another kind in allocation policy. It was remarked earlier that radio service areas are computed on a probability basis. Depending on the phase of the sunspot cycle and a number of other physical phenomena, radio signals, especially in the portions of the spectrum used for medium- and long-distance communication, have a tendency to skip occasionally over very long distances. With the spreading use of radio-frequency energy in diathermy machines, industrial heating processes, and electric arc-welding devices, the FCC has been confronted with the fact that unless such machines are properly shielded and filtered, signals emanating from them

[83] *Ibid.*, pp. 38-39.

create intolerable interference over wide areas. Thus, an improperly shielded diathermy machine in a doctor's office in Miami, Florida, has created disruptive interference in radiocommunications in Washington, Oregon, and California. The commission in the 1944 allocation hearings was forced to cope with this menace by assigning some spectrum space to which the signals emanating from such equipment should be tuned and by establishing rules which require adequate shielding as an alternative. In effect, allocation policy must provide such "disposal" frequencies in order to protect the spectrum against interference from noncommunications users of it.

(b) Technical efficiency. Frequency allocation policy must contemplate a number of facets of the technical efficiency with which the spectrum is used. The state of technical efficiency at any time is affected by the direction of the equipment, the operating techniques, and what has been called "circuit discipline." Whereas, broadly speaking, propagation problems involve knowing the physical behavior of radio waves under various physical conditions (such as phases of the sunspot cycle) and coping with the pressure of human geography on the available supply of frequencies, the technical efficiency problems involve radio theory, the state of the industrial arts, and the policies of the economic and political organizations which are related in one way or another to the use of radio.

Implicit in any design of radio transmitting and receiving equipment is a capability for operating in a certain band *width* (the number of kilocycles of frequency space required for a single signal). This is possibly the most important factor affecting frequency economy. Variable use of the carrier waves is necessary for the transmission of information and the lost occupancy of the band inherent in this variation is largely, but not wholly, unavoidable. The "density" of sideband use which accounts for some of that variability is apparently a function of the state of the art. At the margins of the band, carrier tolerances are a variable factor, some provision for which is necessary to accommodate inescapable variations in carrier frequencies.

> The amount so required varies from a thousandth of a percent of the carrier frequency to about 1 percent, depending on the frequency and the state of equipment development. Space so reserved serves only to avoid interference; it does not otherwise contribute to the transmission of intelligence. . . . the loss of occupancy thus incurred is not great. But the loss is one which can be reduced by purely technical means, provided only that sufficient incentive is offered to justify the cost.[84]

[84] Joint Technical Advisory Committee, *Radio Spectrum Conservation* (New York: McGraw-Hill, 1952), p. 182. This section draws heavily on the content of this report.

Related to carrier tolerances and to equipment design is the fact that historically "guard bands" of frequencies have had to be allocated as buffers between channels in order to protect against excessive carrier tolerances, inefficient transmitter modulation, and inadequate receiver selectivity. Given sufficient incentive, the art can reduce or eliminate this drain on available frequencies. Also inherent in the equipment design is the possibility of reducing harmonic and other spurious emissions — serious causes of use-destroying man-made noise.

Attention focuses most easily on transmitter characteristics and it is less generally recognized that receiver design is equally important. So important is it that the FCC repeatedly speaks to the receiver manufacturers (over whom it has no direct jurisdiction) in terms like these:

The limited available spectrum space makes it mandatory that many services prepare to employ much stricter engineering standards in future operations, such as improved frequency tolerances, reduced harmonic and other spurious emissions, better receiving equipment, etc. . . . Improvement in receiver performance is particularly important. For example, if the advantages of frequency modulation are to be obtained such as to warrant the required spectrum space, it is essential that well-designed frequency modulation receivers be provided. Such receivers must have proper selectivity, limiter and discriminator characteristics. *Further, it is urged that no receivers for any service be manufactured which radiate an appreciable signal. A radiating receiver is in effect a low power transmitter often capable of causing serious interference to other receivers in the same or other services.* The slight difference in cost between a well-designed receiver and one of poor design is more than offset by the gain to all services. It is expected that post-war receivers will be designed and manufactured so as to minimize the effects of image frequency response, radiation from beat frequency oscillators and other effects that may be directly attributed to equipments of inferior design and performance.[85]

Anticipating the near future when the number of radio transmitters licensed in the United States will reach the million mark, a well-informed member of the Federal Communications Commission recently intimated that unless "self-regulation" corrects prevalent defects in receiver manufacture, Federal action to enforce engineering standards for receivers will be taken.[86]

Apart from equipment characteristics, operating procedures are a second technical efficiency factor. Here, we may distinguish between the

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[85] *1945 Allocation Hearing Report*, pp. 19-20. Emphasis added.

[86] Commissioner E. M. Webster, "Implementation, Cooperation and Self-Regulation," an address before the Armed Forces Communications Association, New York, January 19, 1955 (Washington: Federal Communications Commission, mimeo). Commissioner Webster, himself a leading figure in the development of allocation policy, calls for self-regulation by receiver manufacturers, dealers, and radio licensees in view of the fact that the FCC's budget is hopelessly inadequate to police the ether (by monitoring) even today with some 800,000 licensed transmitters.

possibilities of either restricting the geographical scope of the signal or restricting its band-width requirements. As to the former, the interference-creating area of a transmitter far exceeds its useful service area. Obviously, if the users will content themselves with less in the way of intelligibility of signal, lower power may be employed. Similarly, directional antennas economize spectrum space, as does synchronization of carrier signals. Less spectrum space will be required for a given signal by accepting the minimum range of voice modulating frequencies in radiotelephone equipment consistent with minimum acceptable intelligibility.

Obviously the application of this technical efficiency factor runs to the operating techniques of many disparate kinds of agencies which find that radio communication is valuable to them. Thus, such expedients as time-sharing in the use of stations (the simultaneous operation of which would cause intolerable interference) present the frequency allocater with endless possibilities of articulating the uses of different classes of radio licensees so as to reduce their total spectrum requirements. It should be noted that these expedients are applicable to stations located sufficiently far apart that adjacent channel assignments as well as co-channel assignments may be fitted together like a multi-level jigsaw puzzle.

What we have termed circuit discipline is a feature of the technical side of frequency allocation which is closely related to operating techniques and to public policy. For example, the designation of common "calling" frequencies for a service requires all users to use the same frequency for initiating coordinated action of transmitter and receiver, but the actual message is communicated on the designated "working" frequency. Circuit discipline of this order vastly increases the efficiency of frequency use, and frequency allocaters have required it in numerous services. Any thoroughgoing effort to extend circuit discipline to its logical limits, however, runs into conflict with policy objectives of a political and economic nature. Thus, the traditional policy of permitting "competitive" service in the international fixed public services licensed by the United States requires that more than one set of frequencies be allocated for service between the United States and most foreign points. As a matter of frequency allocation policy, this is a wasteful situation because the combined traffic of the competing carriers could almost always be accommodated on less frequency space than is allocated to them, if the operations were integrated.

(c) Obsolescence-innovation. The third distinguishable factor on the supply side of frequency allocation is Janus-faced and bears on both the demand for and the supply of frequencies. It is the economic process of permitting or requiring innovation (responding to a demand for frequencies for a new service) and simultaneously accepting the costs of obsolescence (freeing part of the supply of frequencies by outlawing old uses of it). Paradoxically enough, innovation-obsolescence in radio is both supremely essential (for only through innovation can ever greater use be made of the radio spectrum) and supremely difficult. Its difficulty lies not alone in the resistances to acceptance of obsolescence once it becomes clear to the frequency allocater that a particular innovation must be made, though this resistance may be near-immovable. Fundamentally, the difficulty in applying innovation-obsolescence to radio lies in the fact that all on-going uses of radio must be so completely standardized that *partial* innovation is hard to accomplish. A decision to innovate and accept obsolescence, once made, must apply to *all* of a certain class of use of a certain band of frequencies.

The FCC has stated its policy in general terms as follows:

> In determining the competing requests of two or more services for the same portion of the spectrum, when one or more of the services was already operating in that portion of the spectrum, the Commission gave careful consideration to the number of transmitters and receivers already in use, the investment of the industry and the public in equipment, and the cost and feasibility of converting the equipment for operation on different frequencies, as well as to *the time required for an orderly change to the new frequencies.*[87]

As applied in the United States, the policy on innovation-obsolescence has resorted to the transitional period (emphasized in the preceding quotation) as a device for escaping from the dilemma. This policy has coincided with the views of the electronics industry:

> Services occupying regions of the spectrum not particularly adapted to their needs and capabilities should be transferred to other regions, in accordance with the dictates of full spectrum occupancy, and outmoded services deleted. Economic resistance to such shifts can be overcome by announcement of the impending change with a statement of the technical and economic advantages to be obtained, sufficiently in advance to permit old equipment to be amortized and to allow new equipment to be procured and installed. As knowledge of propagation and equipment improves and becomes stabilized, it should be possible to establish in advance the basis for such transfers over periods as long as 25 years although shorter periods should suffice in most cases.[88]

The consequence of undue reliance on time as the shoehorn for innovation-obsolescence, of course, is the fact that the resulting innovation policy tends to be backward-looking because an accomplished innovation will always be substantially obsolescent (inferior to later and non-innovated systems and equipment) by the time it is accomplished. Even

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[87] *1945 Allocation Hearing Report, op. cit.*, p. 19. Emphasis added.

[88] Joint Technical Advisory Committee, *Radio Spectrum Conservation*, p. 189.

though it may be true, as the industry contends, that a plateau of innovation is being approached, the fact remains that discovery of possible technological innovations in radio has been and remains essentially unpredictable. This is to say no more than that the frontier in radio planning probably lies precisely at this point: the absence of a national planning authority equipped to make forward-looking innovation policy and to implement it. It does not appear possible to anticipate if and when such an innovation policy might be developed in the United States. For this there are two reasons. The first is that it is a fairly safe rule to follow in radio allocation policy that if sufficient economic and technical resources and sufficient time are devoted to research aimed at effecting *any* given type of radio development, it *can* be developed. The second is that under the policy and structure developed for radio administration in the United States, the direction of such research efforts is vested in the private business organizations which share the radio equipment market, while the responsibility for determining national allocation policy remains in the final analysis the responsibility of the national state. Regardless of the degree of "cooperation" between the industry and the government, the dynamics of their respective institutional processes restrict the possibilities of forward-looking allocation policy to those rare instances where disagreement between significant sections of the industry provide "leverage" which the public agencies may exploit to encourage innovation.[89]

In any event, whether United States policy on innovation-obsolescence is sluggish or not in comparison with that of other national states, the fact remains that radio allocation policy controls the pace of innovation. For better or for worse, the applied art of radio communications must move as an integrated whole. The experience with radio allocation policy in the United States demonstrates that it requires, even in the institutional and ideological climate of this country, conscious planning for the intricately woven pattern of radio use.

As this goes to press, the latest example of the point appears. The FCC in April, 1957, announced a "legislative fact-finding type" of inquiry into the allocation of frequencies to the nongovernment services operating between 25 and 890 mc. This, the first over-all review of allocations in

[89] An illustration is the controversy between RCA and CBS over the standards and the timing for the development of color television. Had the Senate Interstate Commerce Committee and the FCC not had the leverage provided by the CBS proposal with its astute public relations handling, color TV standards would undoubtedly have been finally accepted from 10 to 20 years later than they were. This conclusion is independent of any view of the merits of the CBS or the first two RCA color TV systems, per se.

that portion of the spectrum since the 1944 allocation hearings, was prompted by the recent growth of radio use by both government and nongovernment users, the demands by both existing and potential users for more spectrum space, and the recent developments in electronics. The scope of the inquiry is summarized in the following terms by the commission:

> The inquiry contemplates a review of the present allocation of frequencies in this important part of the spectrum, in the light of the technological progress which has been made since the last review, to determine whether a more efficient utilization can be made; to evaluate the long-range requirements of existing and potential users; to obtain data as to the feasibility of applying known and potential techniques and methods relating to efficient utilization of spectrum space; to evaluate what system or systems of frequency allocation for the future would best serve the public interest; to obtain knowledge of the possible conflicts between the requirements of non-government radio services and the space allocated to Government users; to consider long-range plans for the future use of the radio spectrum and, in particular, to determine the impact, economic and otherwise, upon users of the spectrum and the general public of implementing desirable future changes.

The force of the world-wide imperative for such frequency allocation planning is evident when we find the commission saying:

> In addition, the forthcoming International Radio Conference, scheduled to convene in Geneva, Switzerland in 1959, makes it imperative that the Commission commence the formulation of its position with regard to the proposals which will be advanced by the United States Delegation in the matter of allocation of spectrum space to the various services. This can be accomplished only by an overall review of the present allocations and the requirements for future adjustment and growth.[90]

[90] Federal Communications Commission, *In the Matter of Statutory Inquiry into the Allocation of Frequencies to the Various Non-Governmental Services in the Radio Spectrum between 25 mcs and 890 mcs.* Docket No. 11997. Order of Inquiry and Public Notice, Report No. 245.

VIII. EMERGENCE OF INTERNATIONAL RADIO ALLOCATION POLICY

The counterpart of national allocation policy is international allocation policy. The essential elements in each are alike. The only significant difference is that in the international area, allocation policy must cope with the additional variable of national policy with all of its political, military, and emotional content. Nevertheless, it is precisely because radio is so clearly recognized as an instrument of national policy that international allocation policy has become so vital an area of international negotiation and agreement. The present chapter traces the development of policy in this area to the end of World War II.

The seeds of later allocation policy were contained in the Berlin convention of 1906, although the relative freedom from frequency scarcity enjoyed until the 1920's delayed the emergence of full-blown allocation policy problems until the Washington conference of 1927. The fundamental record-keeping basis of allocation policy, however, was established by the requirement of the Berlin convention of 1906 that signatory nations file for publication with the International Bureau in Berne data on each of their radio stations (including wave length, range, call letters, and so on). The primitive standards adopted, requiring "synchronized" systems and establishing working procedures for the obligatory communication between ships, were the crude beginnings of the "technical efficiency" element in frequency allocation. The London Radio-Telegraph Conference of 1912 elaborated the procedural rules for the use of radio on ships and established a frequency for and rules governing messages between ships and remote shore stations in order to reduce interference with nearby shore stations. At the same time, frequencies were designated for time, weather, and marine beacon signals. The earlier radio conventions had not attempted to establish compulsory international rules requiring ships to carry radio equipment, but this step was taken by the convention adopted at the International Conference on Safety of Life at Sea in 1914. In addition to carrying radio equipment with a certain minimum range, this convention required ships carrying 50 or more passengers to maintain a continuous radio watch and to be equipped with standby radio equipment. In similar fashion, a Convention for Regulation of Air Navigation, signed in Paris in 1919, required every aircraft used in public transport and capable of carrying 10 or more persons to be equipped with both radio transmitters and receivers.

Allocation policy, in any full sense of the term, implies, as noted in Chapter VII, the duty of the allocating agency to assign *and reassign* frequencies in accord with the merits of the demand and supply factors. In the international area since World War I a dualistic policy has prevailed. Radio frequency registrations with the International Bureau, like oil reserves and other measures of national power, have been treated as one of the important "counters" in international rivalries for power positions. Generally speaking, the nations which emerged victorious from World War I found it possible with their superior resources to become the "haves" in radio allocation, while the nations less endowed with power resources regarded themselves as the "have-nots." The United States regarded radio (and international communications in general) as an area in which it was consciously seeking to equal or improve upon the strategic position of the British Empire.[91] Upon discovery of the long-distance communications possibilities of the frequencies 3 mc to 25 mc, a race took place to stake out maximum claims to those frequencies. Thus, speaking of the mid-twenties, the Director of Naval Communications in the United States said, ". . . the most important thing was to get the channels allocated, so as to get them registered in the International Bureau before foreign nations did."[92] The extent of the success of this effort becomes pertinent at a later point in our analysis; for the present, the point is that the frequency registration provision stemming from the Berlin convention was employed in the 1920's to stake out radio "empires" bulwarked by what came to be known as the "right of priority."

The Washington convention of 1927 gave practical force to this right by determining, as proposed by the United States, that when a new frequency was assigned, it

. . . must be chosen so as to avoid so far as possible interference with inter-

[91] See U. S. Senate, Committee on Interstate Commerce, *Hearings on S. 6,* 71st Congress, 1st Session, testimony of Captain S. C. Hooper and Owen D. Young, pp. 319 and 1089. Mr. Young rated international shipping, communications, and petroleum as most important for national "protection and prestige," and posed Great Britain as the rival to surpass.

[92] *Hearings on S. 6, op. cit.,* May 29, 1929, p. 319.

national services carried on by existing stations the frequencies of which have already been notified to the International Bureau.[93]

Following the Washington conference, the International Bureau began publishing a current list of frequencies notified to it, with the dates of notification as an aid to the determination of priority "in case of dispute or interference." At the Madrid conference in 1931, the list was made official and registration provisions were strengthened to require adequate notice before a notified frequency might actually be used. At the same conference, the position adopted was that if a question of priority was taken to arbitration, the date of notification, along with other factors, should be taken into account. In practice, but not in explicit policy, priority was recognized at each of the three major radio conferences between the World Wars. A dramatic illustration of the force of the technological imperative which supports telecommunications planning is afforded by the fact that during World War II, notifications of new radio stations continued to be published by the bureau and within limits even the warring powers continued to abide by the allocations made during peacetime.

We have noted that the international allocation policy appeared *in practice* to be based largely on the right of priority. Yet the other side of the dualistic concept was also evident. In 1927, the United States delegation stated that the United States would not subscribe to any rules which would give any country or company an absolute control of the use of a particular frequency. And at the Madrid conference in 1932, upon insistence from such "have-not" nations as Italy and Japan, a statement was adopted which emphasized that "there was no relation between notification and the right of priority,"[94] although to be sure the date when *use* of a frequency began might be substantiation of priority.

In essence, the international regulatory institution for radio has treated the issue of priority practically. It has respected it in practice, but to a small degree it has also ignored it in practice.[95] Moreover, the major powers were careful never to press for recognition of priority as a legally binding matter. Intentionally or not, this course gained them

[93] Codding, *op. cit.*, p. 126.

[94] Codding, *op. cit.*, pp. 189-90.

[95] Codding speaks of ". . . the known, but unpublished, fact that administrations, even before the publishing of the Frequency List, assumed that they had a claim to any frequency registered with the Bureau. Even more important was the fact that administrations recognized the right of other administrations to operate radio stations on previously registered frequencies, without being bothered by 'harmful interference.' In cases where interference was experienced, the date of registration was the determining factor in deciding which station could continue to operate." *Op. cit.*, p. 191.

good will which would help win the votes of small powers when, at a later time, in the course of major reallocation of frequencies, they would stand to lose important requests for frequencies.

The first attempt at a comprehensive allocation plan which would assign all of the usable frequencies to bands for the various services was made at the Washington conference in 1927. This allocation plan, which covered the frequencies 10 kc to 22,300 kc — i.e., all the frequencies capable of long-range service — did not receive sufficient support to permit its being made mandatory. Rather the nations agreed only to use it "as a guide" and reserved the right to make any frequency assignments they pleased, provided no interference was thereby created for any radio service in another country. Five years later, at Madrid, the conference eliminated the "guide" aspect of the allocation plan and made it mandatory; the plan was also extended upward to include frequencies between 22,300 kc and 28,000 kc. In order to achieve an enforceable plan, the Madrid conference had to resolve the issues which had divided the Washington conference. These issues centered on the fact that the older radio services — especially the maritime — had staked out shares of the long-range service regions in the spectrum which newer services contended were excessive. Among the newer services, the broadcast (especially in Europe) and aeronautical were most aggressive in demanding spectrum space. It is notable that the lines were here drawn between the "have" and the "have-not" *services* rather than solely along *national* lines. Thus the demands for more frequencies were expressed through the International Commission on Air Navigation, the International Air Transport Association, the Conference of Aeronautical Radio Experts, and the International Broadcasting Union (the European broadcasting organization), as well as by the smaller nonmaritime countries which were interested in aeronautical and broadcast services, such as Hungary, Czechoslovakia, Poland, Rumania, Switzerland, Lithuania, Morocco, and Greece. The pressures in this instance typify the complex of conflicting interests which confront the allocaters. The mixture of national and class-of-service interests is evident from a statement of the British delegate:

All of those who have taken the floor, up to now, have spoken in favor of a single service (aeronautic, maritime or broadcasting). I would like to speak as the delegate of Great Britain which is equally interested in all three categories. We have almost five million licensed broadcast listeners, and the B.B.C. supported by public opinion, is asking for an enlargement of its frequency band; in the same manner, the maritime navigation service is asking for the enlargement of the band allocated to radio-beacon stations; the aircraft navigation interests, in their turn, are asking for new wave lengths because of the rapid expansion of the aircraft services. The British amateurs are asking for an extension of their frequency band; the commercial communications services complain of frequent interference; the police are asking for a wave length. We understand very well the reasons for all of these requests but it is impossible to satisfy them.[56]

The situation was further complicated by the fact that the USSR, which had been pointedly excluded from the Washington conference and therefore had no legal or moral obligations to the 1927 allocation plan, had six broadcast stations operating outside the band assigned for this service. The solution found was one where all parties compromised their demands; it involved three steps. The allocation plan for the low and medium frequencies (below 3,000 kc) was divided as between the European region and "other regions," with both regions provided with their own allocation plans. Secondly, and in order to accommodate more intensive use of the spectrum, tables of tolerances and of acceptable band width (i.e., technical standards) for all types of service were adopted. Thirdly, prior to the effective date of the Madrid convention, a European broadcasting conference was to be held in order to determine allocations on a station-by-station basis and operating rules.

The European broadcast conference was held at Lucerne in 1933. An example of the factors entering into frequency allocation at the international level is provided by the "general considerations" underlying its plan:

(1) The number of existing stations and those under construction or alteration.
(2) The requirements of countries in which broadcasting is either non-existent, just beginning its development or in the course of expansion.
(3) Technical and physical considerations: e.g., laws of propagation, topographical situations, geographical situations, longitude, latitude and climate.
(4) Political and national considerations: e.g., importance of broadcasting as an instrument of government, customs, languages, political subdivisions and existence of minorities.
(5) Conditions already established which it would be difficult not to take into account.
(6) The General Radio Regulations and the Additional Protocol of Madrid.[57]

The resulting station-by-station allocation plan was acceptable to 27 of the 35 countries involved (19 of which signed with reservations), but unacceptable to 8.

Broadcasting allocations for the Western Hemisphere were worked out at the Havana conference in 1937, which divided the region into three zones. Precise station-by-station allocations and operating procedures were incorporated into the North American Regional Broadcast Agreement covering medium-wave assignments in the United States, Cuba, the Dominican Republic, Haiti, Mexico, and Canada. Out of this

[56] Codding, *op. cit.*, pp. 147-48.
[57] Codding, *op. cit.*, p. 158.

conference also came recommendations that the world-wide allocation table be extended upwards to 300,000 kc, and that higher standards for tolerances be required of all nations.

At the next world-wide radio conference, in Cairo, 1938, allocation policy was concerned with finding space for the expanding mobile, fixed, and broadcasting services, and with raising engineering standards to permit more intensive use of the spectrum. As in Madrid, a piecemeal, practical solution was found. A conspicuous advance in allocation policy was made in a forward-looking allocation plan, adopted world-wide, for intercontinental air routes in the band below 24,000 kc. Channels were reserved for specific air routes, some of which were not yet in operation. Broadcasting was denied further long-wave assignments, but three short-wave bands previously assigned to fixed and mobile services were also assigned on a shared basis to broadcasting in tropical areas, with specific allocations to stations to be worked out at regional conferences. Sharing of a band between 6,000 kc and 25,000 kc by amateurs in the United States and broadcasting in Europe accompanied assignment of more high frequencies to broadcasting. The allocation plan was extended from 25,000 to 200,000 kc and divided between the European region (where specific bands were assigned to radio-sounding, TV, broadcasting, aeronautical, amateur, fixed, and mobile services) and the rest of the world (where specific assignments were left to regional conferences).

Two measures were taken to improve the technical efficiency of spectrum utilization. Higher standards for tolerance and band width were adopted and made applicable with a 1944 deadline to both old and new equipment. A sharp dispute took place over the proposal to outlaw the primitive spark transmitters which illustrates the role of innovation-obsolescence in frequency allocation matters. Some 8,000 of 15,000 ships were still equipped with the early Marconi-type spark apparatus and this obsolete equipment was defended by Great Britain, Italy, France, Belgium, Greece, and the shipping interests. Opposed to it were the United States, Spain, the USSR, and the European broadcasting union. In the end, a compromise confined the use of the obsolete equipment to three frequencies. The Cairo conference also tightened the operating procedures for using radio for safety of life at sea.

The last significant pre-World War II radio allocation took place at the Montreux radio conference in 1939. There station-by-station allocations were made for all European broadcast stations between 150 and 1,560 kc. Ten stated principles similar to those employed at Lucerne were applied in working out a plan which received somewhat more general assent than was accorded the previous effort (though 5 of 36 nations refused to sign it).

In approaching the frequency allocation problems which confronted the world at the end of World War II, the nations faced the fact that the United States was the most advanced national state in terms of the development of radio. It had largely supplied its allies with radio equipment of all kinds during the war. It had devoted a lot of the time of able people to a study of the problem beginning as early as 1943. Its political and economic position, coupled with its adroit handling of frequency allocation problems affecting small nations, gave it tremendous power to win votes for its policies in radio matters. While evidence of relative spectrum occupancy by different nations is difficult to obtain, it appears that the United States had a major share of the total. Most meaningful, of course, is information of this kind with respect to the long-range portions of the spectrum where little, if any, duplication of simultaneous use is possible.

The Director of Naval Communications in the United States testified in 1945 that in the range 4,000 to 20,000 kc the United States had already registered for its own use about one-third of the total world *requirements*. The United States frequency registrations, which the Navy referred to as "permanently assigned to U.S. stations," totaled 1,699 "yardstick channels" or slightly more than half of the channels *available* to the world.[98] United States government agencies had exclusive use of 665 of these channels, 948 were exclusively nongovernment, and 86 were shared between government and nongovernment services. The same authority stated that some 73 percent of all world radio frequency assignments lay between 4,000 and 10,000 kc — the lower portion of the band previously discussed. He further testified that the United States held 911 yardstick channels ("permanently assigned" to United States stations) in the 4,000-10,000 kc band, out of a world supply of 1,200. By way of explaining how the United States had acquired so large a share of the world total (75 percent in the 4,000-10,000 kc band), he stated:

Chairman [Senator Burton K. Wheeler]. How do we get this big percentage to which you refer?

Admiral Redman. We get that primarily by anticipating our needs and getting in the registration in the Berne registration book on the basis of priority. . . . You get your priority by being a little ahead of the other fellow, being a little

[98] Admiral Joseph R. Redman presented analyses of world and United States requirements on a peacetime basis (not including temporary wartime assignments). The world requirements were estimated at 5,337 "yardstick channels" and the world supply, 3,200. U. S. Senate, Subcommittee of the Committee on Interstate Commerce, *Hearings Pursuant to S. Res. 187* (78th Congress, Extended by S. Res. 24 of the 79th Congress), 79th Congress, 1st Session, Part 1, pp. 110-14 and Navy Exhibits 3 and 5.

more active, and registering; and by means of this agreement [international conventions], you are first when it comes to priority.[99]

It appears that the most rapid growth in the share of the world total of the most valuable frequencies for long-distance communication (4,000 to 10,000 kc) held by the United States took place during and after World War II and that it was United States government radio use which accounted for the increase. The marked increase in congestion in the long-range portions of the spectrum invited international planning for over-all frequency allocation in the light of the advances in technology available at the conclusion of World War II. At the same time, the international problem was made extremely difficult because of

. . . inflated demands for radio frequencies. The apparent shortage of frequencies thus engendered has been aggravated as each nation attempts to provide for future as well as present needs.[100]

The international radio allocation policy situation at the end of World War II might be briefly summarized in these terms. For a third of a century the international custom had been followed of "notifying" frequency registrations to an international bureau. And an unresolved duality existed in the policy aspects of such registrations. In practice registration seemed to confer prior rights of occupancy and the largest national states consciously pursued policies of empire-building in staking out for themselves control of the bulk of long-range frequency assignments. At the same time at least lip service was given even by the same national states to the contrary principle: that registration and occupancy were subordinate to the overriding international right to reassign frequency uses. The frequency allocation situation in 1947 was critical. Radio uses had proliferated rapidly during World War II and had burst the limits set by prewar conventions for certain classes of stations, especially those concerned with aviation, radiolocation, and international broadcasting. The asserted national needs for frequency assignments were inflated. And the firm requirements demanded by the smaller and newer national states had to be met somehow, even if only partially, out of the frequency assignments claimed by the major powers. All in all, the challenge offered to the Atlantic City conference by this problem was well-nigh insurmountable. What happened there and subsequently is the subject matter of the next chapter.

[99] *Hearings on S. Res. 187, op. cit.*, March 19, 1945, pp. 110-11.

[100] President's Communications Policy Board, *Telecommunications: A Program for Progress*, p. 34.

IX. UNIFICATION OF INTERNATIONAL RADIO ALLOCATION POLICY FOLLOWING WORLD WAR II

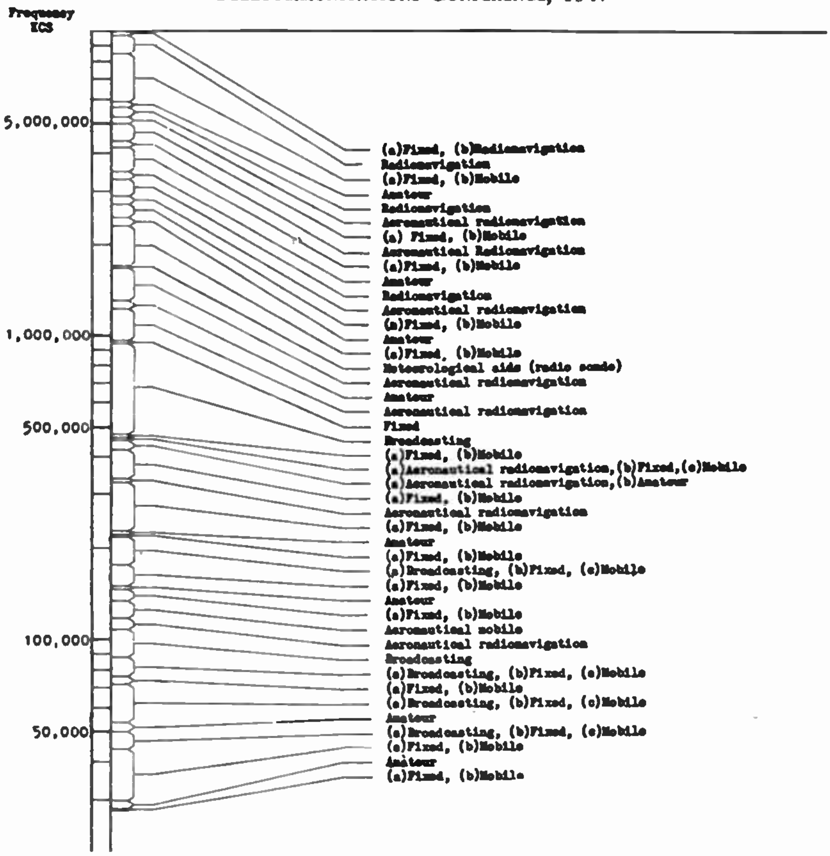
It was evident when the delegates convened for the Atlantic City telecommunications conference that frequency allocation problems rivaled in importance the revision of the organization for international control of radio. And in the first flush of postwar friendship between the allied powers, it was generally agreed that the existing frequency allocations should be revised. Our concern here is to analyze policy developments in radio allocation policy in the first 10 years after the war.

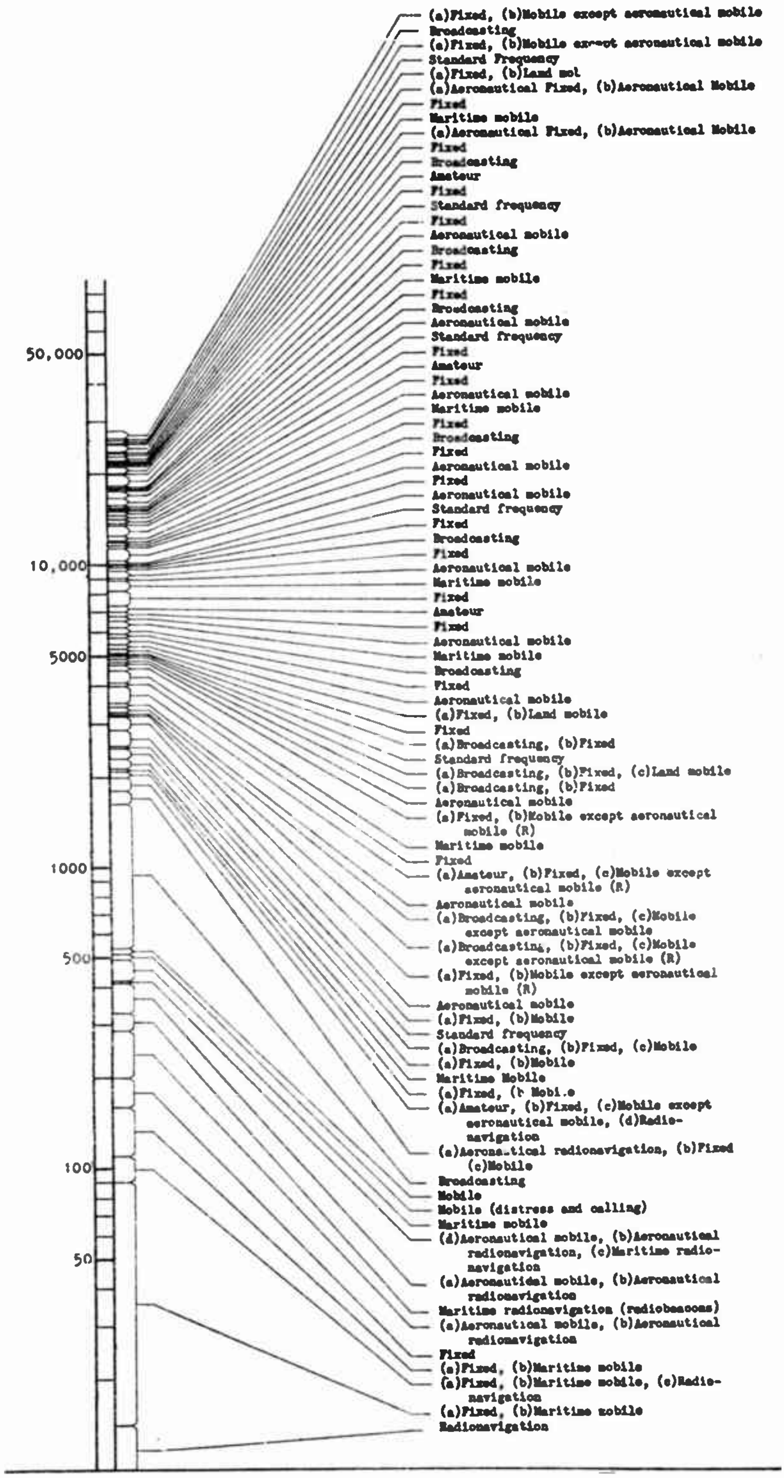
Serious differences between the views of the United States and the USSR concerning the scope and procedure for this revision appeared at the Moscow preparatory conference even before the Atlantic City meetings. This difference hardened during the latter meetings, and under the influence of cold-war strategies, ultimately resulted in a bifurcation of frequency allocations into two allocation structures related to each other by tacit, rather than explicit, agreement. In broadest terms, the difference between the two opposing states was as follows. The USSR, which had apparently lost ground relative to the United States in its share of essential frequencies during World War II, proposed to compile a new frequency list based on ITU registrations at the outbreak of the war, with all subsequent requests to be screened for conformity to the technical standards adopted at Atlantic City. The United States proposed to overhaul completely all frequency assignments regardless of when notified to the ITU, and to reallocate them all. To do this, it proposed that the international organization collect from each nation a list of all radio circuits and stations they would require, and work out a new frequency allocation plan without regard to previous registrations, but consistent with the postwar engineering standards.

The schism in frequency allocations which resulted from the Atlantic City conference must not be allowed to obscure the real achievements during this period. At Atlantic City, three objectives were sought in the realm of frequency allocation policy. In the first place, a new allocation table of frequencies was to be prepared, giving effect to the major changes in needs for frequencies and technological advances in spectrum use. Linked with this were new and higher standards for frequency utilization. In the second place, it was desired to establish a continuing organization equipped with policies which could carry on the periodic assignment, standards, and allocation work on a future, current basis. In the third place, it was desired to review and revise the assignments to use the frequencies in the allocation table (as between both locations and nations) in order to maximize the usefulness of radio within the limits of the standards adopted.

The Atlantic City meetings achieved the first of these objectives without very much difficulty. Chart 3 displays the allocation plan there developed. Some 129 different bands of frequencies were allocated, either

CHART 3. WORLD FREQUENCY ALLOCATIONS, ATLANTIC CITY TELECOMMUNICATIONS CONFERENCE, 1947





Source: Federal Communications Commission.

on a sole- or joint-use basis; this represents more than double the number of bands allocated 20 years earlier at the Washington conference. The frequencies 30,000 kc to 10,000,000 kc were allocated with no disagreement, largely to radio-navigation aids such as radar, to TV, and to FM, while the amateurs received numerous narrow bands in that area. In the long-range portion of the spectrum, 2,850 kc to 30,000 kc, the most significant changes were the doubling of the allocation to aeronautical services (divided four-sevenths to civilian carrier aircraft and ground stations and three-sevenths to military and private aircraft) and an increase of 35 percent in the frequency space allocated to high-frequency broadcasting. Such increases could only be at the expense of previously existing services and the losers were the fixed and amateur services; the maritime services retained their previously allocated space in this range. In the low frequencies (below 2,850 kc), the United States insisted on the allocation of frequencies for long-range navigational aids for both aircraft and ships, and provisions were made both for LORAN and for experimental operations of this type. The principal problem created by these allocations was interference with North Sea fishing fleets' radiotelephone safety service, which the United States undertook to remedy by providing for the fishing fleets, free of cost, new equipment which would reject the noise from the radio-navigation aids.

Apart from these allocation changes, the Atlantic City meetings yielded marked advances in the technical regulations. The obsolete spark-type transmitters were prohibited except as standby ship and lifeboat equipment. Important innovations were made in operating procedures. Aeronautical stations were permitted to use some of the maritime frequencies for air-to-ship communications for safety and operating messages. And the maritime frequencies were reorganized into three groups: "calling"; passenger-ship working; and cargo-ship working. Circuit discipline was established for all users of these frequencies, which increased efficiency of frequency utilization. In the end, because of difficulties in working out the new frequency list, the effective date of all the 1947 radio regulations was set for 1949, except for the allocations below 27.5 mc and the provisions depending on the development of the new international frequency list. Meanwhile, the Cairo regulations and allocation table remained effective below 27.5 mc.

The second prime allocation policy objective at Atlantic City was also accomplished. A continuing organizational structure was established and equipped with rules for handling frequency assignments, standards, and allocation matters between plenipotentiary conferences. As noted earlier, an Administrative Council was created and given inter-conference authority to administer the regulations. And an International Frequency Registration Board was set up to administer the frequency allocation policy in detail. On the assumption that the 1947 allocations would be approved and that a new frequency list would be established consistent with them, this board was to follow a prescribed procedure,[101] the general effect of which would be to protect prior listings, provided the prior listing was for a frequency assignment within the approved allocations and that it met the agreed-upon standards. It was understood that the fact that a notified frequency was given the tentative status of being stamped "notification" rather than "registered" would not prevent the notifying country from using it; the effect would arise later when arbitrators might take the fact into consideration. With respect to the screening of notifications, the board was to base its decisions solely on technical considerations and to act as a "witness and nothing more." It was also given the duty of making studies, upon request, in situations where (1) there were alleged violations or harmful interference; (2) a possible alternative assignment might avoid probable interference; or (3) a need should arise for additional channels within a certain portion

[101] Previously, the board had acted as a kind of post office for international negotiations on interference. Now it was to proceed as follows. Upon receipt of a notice of a frequency assignment, the IFRB would (1) circulate by airmail copies of such notice to all countries; (2) examine each notice with respect to (a) conformity with the table and rules of allocation, (b) conformity with other provisions of the convention and radio regulations, and (c) the probability of harmful interference either to any service of a prior-recorded frequency which had been entered in the "registration" column, or to a service prior-recorded only in the "notification" column which had not in fact caused harmful interference; (3) if the notice passed the test of (2), it would be recorded in the registration column and would have "the 'right of international protection from harmful interference' "; (4) if the notice failed to pass (2)(a), it would be registered as notified, but if its use created harmful interference to existing services, the new station must immediately suspend operations; (5) if the notice failed to pass (2)(b), it was to be returned to the notifying country with reasons; (6) if the notice failed to pass (2)(c), it was to be returned to the notifying country with reasons and any suggestions the board had for solving the problem; (7) if the notifying country resubmitted the notice with modifications which permitted it to meet the tests of (2), it should be entered as "registered"; if it still failed the tests, it should be entered as "notification." At any time, the board could be asked to reconsider a finding by a notifying country, or if harmful interference was either anticipated or actual, by other countries. On such request, the board would circulate copies of it to all members for objections or comments. If the notifying country asked for review and the board's opinion was then favorable, the notification was to be "registered." If the reconsidered opinion was that harmful interference would "probably" result, the date was to be left in the notification column. If a finding of "actual" interference was made, this was prima facie evidence of violation of the regulations. If after not more than six years of operation, the board had not found actual harmful interference, the notice was to be moved from "notification" to "registration." See Codding, *op. cit.*, pp. 242-47.

of the spectrum. If the board were to find that a change in the frequency of one or more stations would accommodate a new station, solve an interference problem, or otherwise permit more effective use of the spectrum, it was given power to effect a change (with the consent of the countries affected) in frequency registration with no change in the date. The board was given even more power in connection with frequencies found to be unused. It could cancel registrations and permit interim operations depending on propagation conditions.[102]

As with the new allocation table and standards, it was originally contemplated that the IFRB would begin work in 1949. Because of delays in the preparation of the international frequency list, the board was called into existence in 1948 to help in its preparation, although it was recognized that the "regular" duties of the board must await the adoption of a new frequency list. We therefore turn to this, the third major objective of the Atlantic City radio conference.

While the first and second frequency allocation objectives were accomplished during the meetings in 1947, the third was not; instead it became the focus of maneuvers in which cold-war motives predominated. It was acknowledged before the 1947 meetings began that the old frequency list would have to be revised if only to accommodate the stations whose frequency assignments had to be shifted in order to implement the necessary allocations of bands to the aeronautical and high-frequency broadcast services. It was also clear that an accumulation of disused frequency assignments needed to be cleared from the list. Beyond that, it was universally recognized that station assignments should be allocated not only to the extent of their current use but to meet the "real needs" of the nations.

Nevertheless, in the long-range portion of the spectrum,[103] allocation policy became one of the areas in which strategies of the United States and the USSR came into sharp conflict. Paradoxically, while what appear to have been mutually exclusive allocation policies were pursued by the two major powers, a single allocation plan exists *de facto,* if not *de*

[102] After consulting with the notifying country, the board must cancel recordings of frequency assignments if regular operation on them does not begin within two years after receipt of first notice, or after three years of disuse. If circumstances warrant, the board was empowered to grant one-year extensions. Where the reason for nonuse is the phase of the sunspot cycle, the board was given authority to grant additional three-year periods. When sunspots force a frequency into disuse, the board may permit interim operation by other stations in other services than the regular assignment of the frequency, subject to the prior rights of the nonusing registrant. Codding, *op. cit.,* pp. 246-47.

[103] Below 30 mc; above 30 mc there appear to have been no serious difficulties standing in the way of preparation of a new frequency list, which went into effect on January 1, 1949.

jure. It is to the technological imperative which yields this result that we look in reviewing the strains placed on international radio planning by nationalistic policies.

From the first at Atlantic City, the United States advocated a "one-step" procedure for assigning frequencies as between nations. Such a procedure involved (1) ascertaining the "circuit requirements" of all nations (note that the United States proposal dealt with circuits between stations rather than with stations as such, thus permitting more precise tailoring of frequency assignments); (2) determining the number and band width of frequencies needed for these circuit requirements; (3) applying sharing plans to accomplish multiple uses of frequencies where possible; and (4) reducing guard bands to a minimum and eliminating frequency assignments made solely for the purpose of guarding against interference. Where assignments could not be satisfactorily made on engineering principles alone, the priority of dates of notification to the ITU was to govern the assignment.

This plan, which was essentially similar to that employed domestically in the United States, called for a *de novo* assignment of all frequencies and assumed (1) that available propagation and equipment information was adequate to permit sound decisions on assignments and (2) that the nations of the world would be willing and able to disclose the precise geographical location of all present and proposed future radio stations, their service areas, their equipment characteristics, their hours of use throughout the sunspot cycle, and all time-sharing and operating arrangements.

Opposition to this procedure initially came from France, Belgium, Switzerland, and the French colonies, as well as from the USSR and its close associates. This opposition urged that the "one-step" policy was attempting too much at one time. These nations proposed that a "two-step" policy be adopted instead, in which (1) the necessary reassignments of frequencies to give effect to the new allocations made at Atlantic City would be superimposed on the existing assignments as registered with the ITU; and (2) at a later time, when the necessary engineering information was at hand, the more drastic step of overhauling the whole long-range portion of radio frequency assignments would be taken.

Early in the Atlantic City radio conference, the United States proposal prevailed in a division, 41 to 14. Requests were addressed to all nations calling for the information needed as to all radio circuits. When it became apparent that it was hopeless to expect that the frequency list would be completed during the Atlantic City conference, a Provisional

Frequency Board was created (consisting of one representative from each nation) to complete the task, leaving it to a subsequent administrative radio conference to adopt the new list. Before the Atlantic City meetings ended, it was evident that the "one-step" plan would require further help. The Provisional Frequency Board was relieved of the necessity of making the assignments for high-frequency broadcasting, which function was given to a scheduled high frequency broadcast conference. Additionally, special administrative conferences were authorized to treat separately with exclusive aeronautical mobile bands, exclusive maritime mobile bands, and with regional problems. The Provisional Frequency Board, nevertheless, was left with the bulk of the frequency list problem below 30 mc.

At all stages in the development of the "one-step" plan at Atlantic City, the USSR registered its objections and urged that the new list be prepared by using the 1939 Berne list and revising it to permit the introduction of frequency assignments required by the Atlantic City allocations and to redistribute unused frequency assignments to new claimants. When the Provisional Frequency Board began its work early in 1948, the USSR reasserted this position and argued that the "one-step" plan was fallacious in that it was based on unsound assumptions concerning the adequacy of existing knowledge about propagation conditions.[104]

> The USSR was certain that no "sovereign state" could agree to any such poorly planned attempt at "interfering with decisions on its internal matters, especially in view of the fact that the question of frequency allocation touches upon vital interests of each country" and since any decisions that would be taken would remain in force for a long time.[105]

In the context of the cold war then prevailing, it is not surprising that the USSR made an issue of accepting frequency requests at face value from "Franco" Spain, which requests the United States supported. Similar issues arose over the requests for frequencies for the American, English, and French zones of occupation in Germany, and those for Japan and Korea. By a margin of two to one, the USSR proposals on each of these issues were defeated. Nor is it surprising that the USSR refused to divulge the information concerning the type of service, loca-

[104] Specifically, it claimed that the engineering standards adopted at the Atlantic City meetings as a basis for establishing the frequency list were based on average conditions of propagation and did not take into account the abnormal conditions which existed for almost 40 percent of the time. It asserted that the ITU could not assume " 'the responsibility, down to the material losses, for the deterioration of radiocommunication' that would be the 'unavoidable' result if the P.F.B. continued to follow the Atlantic City directives." Codding, *op. cit.*, p. 344.

[105] *Ibid.*

tion, directivity, area served, and so on for all the radio frequencies used or to be used which all nations were requested to supply for the preparation of the new frequency list. Her policy was obviously based on concern for the military significance of such information.

The crux of the dilemma confronting the architects of the new frequency list is now apparent. How were frequency uses to be assigned when for the Soviet bloc the information necessary to make such assignments was denied the allocaters? This, however, was not the full measure of their problem. The frequency requirements reported far outstripped the available frequencies. In 10 bands located between 4 and 21 mc, the total requirements amounted to 18 times the available supply of frequencies. The expedients adopted for these twin problems well illustrate the compromises dictated by radio. The majority nations in the Provisional Frequency Board estimated the Soviet bloc's frequency requirements and assigned frequencies in the light of these estimates; thus, in effect, a world-wide frequency list was, after a fashion, constructed. The second problem was met by a variety of means. Protection ratios between frequencies were reduced and the spacing narrowed between adjacent channels. Standards were relaxed so that higher levels of interference were accepted. The standards on the number of frequencies assigned per circuit were tightened to require fewer frequencies. And lastly, after repeated appeals for voluntary reduction in requirements estimates proved ineffective, they were arbitrarily reduced.

When the Provisional Frequency Board was dissolved in 1950, it had produced assignment plans for 82 percent of the frequencies left for its disposal. The special class-of-service and regional conferences likewise failed of success. By 1950, the High Frequency Broadcasting Conference, after 24 months of work, had not succeeded in drawing up an assignment plan of any kind, primarily because of the conflicting demands for frequencies for propaganda purposes. The Administrative Aeronautical Radio Conference, after 10 months of work, did draw up an agreement and assignment plan but with the dissent of the Soviet bloc. The Region 1 Conference (including Europe) drew up an agreement and a plan, but the Soviet bloc rejected both. Even in Region 2 (the Americas), no assignment list was produced. Only in Region 3 (Far East) were both an agreement and an assignment plan prepared by 1950.

The "one-step" plan for the preparation of the frequency list had broken down after some 80 months of work by seven different conferences, attended by as many as 69 countries. Thus, when the Extraordinary Administrative Radio Conference was convened in August, 1951, its purpose was to salvage something from the wreckage of frequency lists, rather than to make effective the complete list as had been envisaged in the planning at Atlantic City.[106] In preparation for it, the United States took stock of the predicament which it, as the world's largest user of radio, faced to a greater degree than other countries. That it represented a grave breakdown of both national and international allocation policy is admitted: Commissioner Webster, then the leading allocations expert in the United States, referred to the situation as "dark," seemingly "unsurmountable," and one of "confusion."[107] The reasons for the failure to achieve the desired objective seem plain in retrospect. The assumptions, both technical and political, on which the attempt had been made to design, *de novo,* a world-wide allocation of radio frequencies with universal precise standards had proved to be impossibly optimistic. This was true quite apart from the effects of cold-war considerations, the spectacular aspects of which tend to lead to an overfacile attribution of the failure to USSR-US rivalry.

The leadership role asserted by the United States at Atlantic City was at stake, with many implications, when the Extraordinary Administrative Radio Conference convened in 1951. From a self-interest standpoint, the failure of efforts to establish the new frequency list in the international range of frequencies endangered the United States claim to use of a substantial portion of its registered frequencies. For until a new list was put into effect for those frequencies, the new allocations agreed to at Atlantic City could not be implemented, and the applicable allocation policy was that of the 1938 Cairo conference — which was long out of date and derogated by World War II departures from it. Enjoying the lion's share of the world total frequency assignments, the United States faced the probability that continuation of delay in establishing a new list would encourage squatters to encroach on its frequency assignments, with a strong likelihood that they could not later be dislodged.[108]

Obviously impressed by the effects of the charges from the "have-

[106] The United States had led 56 nations in postponing the call for the conference two months earlier because as it said: "'[In] view [of] present world conditions, [the] U. S. considers it would be impossible . . . [to] obtain substantial agreement on any of its agenda items.'" Codding, *op. cit.*, p. 366.

[107] "Implementation, Cooperation and Self-Regulation," address before the Armed Forces Communications Association, January 19, 1955.

[108] ". . . unless we are able to vigorously drive towards the implementation of the Atlantic City table in the fewest possible number of years, we will create a situation so chaotic in the assignment of international frequencies that our domestic users will suffer severe losses that we may never regain." Commissioner E. M. Webster, "Frequency Resources and National Policy," address before the Armed Forces Communications Association, February 23, 1950 (Washington: Federal Communications Commission, mimeo).

not" nations that the United States was hogging frequencies, this stock-taking period included a serious self-evaluation.[109] It was acknowledged that the multiplicity of radio organizations in the United States involved wasteful occupancy of frequencies.[110] Pressures were brought to bear on American radio users to adopt voluntarily tighter-fitting uses of frequencies. And the President's Communications Policy Board was created to study national allocation policy with a view to achieving greater efficiency and integration.

The United States recognized the legitimacy of the radio requirements of less highly developed nations to the extent of making some efforts to apply the Point Four program to radio. Training of foreign technicians and providing advice on the techniques of frequency utilization was advocated as a means of simultaneously helping less favored nations, reducing the pressures on the supply of frequencies, and improving America's diplomatic position at the council tables. It was understood that these measures were essential to a solution of the crisis, for radio allocation was admittedly conducted internationally at the highest diplomatic level after World War II[111] and to fail in the solution of the frequency-list crisis would have diplomatic consequences far beyond the immediate scope of the radio issues involved.

The Extraordinary Administrative Radio Conference, meeting in Geneva in 1951, considered three different plans for implementing through frequency lists the 1947 allocation plan in the 4 to 27 mc range.

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[109] "New empires can be built in the radio frequency field just as they can in any other field. It is perhaps significant to note here that when the Russians recently walked out of the Provisional Frequency Board meeting in Geneva, the propagandistic device they used was no different than the ones they have used at many other conferences. They accused the United States of 'expansionist tendencies.' The idea was to try to show that in the frequency field as in all other fields the United States is trying to use its influence to take all and to leave the other fellow nothing. It is indeed unfortunate that the situation among our own government and industrial users parallels this so closely: each fellow tries to get all he can and then accuses the other fellow of leaving him nothing." Commissioner E. M. Webster, "Frequency Resources and National Policy."

[110] Commissioner Webster stated that all of the traffic between San Francisco and Hawaii could be handled on less than half the 19 circuits operated by private carriers and government agencies. *Ibid.*

[111] "The extreme excess of the demand for frequencies in the post-war world over the available supply has now made virtually all countries *competitors* for frequencies. This has enormously complicated telecommunication negotiations from the time of the first post-war conference at Atlantic City in 1947. As a result of my experiences at this conference and at subsequent international conferences, I am thoroughly convinced that the day is gone when a group of technicians from different countries of the world can get together in a room and work out their telecommunication problems in quiet harmony. Today political, economic, and social problems also enter the picture." Commissioner E. M. Webster, "Frequency Resources and National Policy." Emphasis in original.

The United States, having misjudged the possibilities four years earlier, proposed a very cautious plan. In this, it was backed by the United Kingdom. It proposed to limit the conference objective to review and approval of the frequency lists prepared for the aeronautical, coastal telegraph, and coastal telephone lists, and for all frequencies below 4 mc; the remainder (broadcasting, fixed service, maritime mobile, and amateur) it proposed to leave for later attention. The Soviet group asked for a complete list, based on the 1939 Berne list, brought up to date — essentially the same plan that it had advocated since the Moscow preparatory conference in 1946. A third loose group of countries wished to achieve a complete list (which they agreed with the USSR was necessary) through piecing together the partial lists prepared by the Provisional Frequency Board and other conferences. The American plan was overwhelmingly approved. And the Extraordinary Conference adopted the revised lists which were the American objective. Only the list below 4 mc with the associated Atlantic City regulations was given a definite future effective date. The actual lists approved in the 4 to 27 mc range and future lists to be developed were left for future administrative conferences to put into effect officially. In the meantime, it was finally agreed by the majority that stations in that range should be moved into their allocated bands and given frequency assignments by the individual countries, working closely with the International Frequency Registration Board which would be continuing studies designed to assist in the allocation process. The Soviet bloc denounced as illegal the decisions reached by the majority and announced their own intention to protest them at future plenipotentiary conferences, meanwhile reserving to themselves the right to " 'take all necessary action for the protection of the interests of [their] radio services.' "[112]

In the years since the 1951 Geneva conference, the United States (and presumably other countries have moved in the same direction) has made substantial progress toward moving its radio users to assignments consistent with the lists prepared at Geneva. Air-ground communications for both civil and military aviation now for the first time have frequencies exclusively allocated for international air-ground communications. Substantially all of the coastal and marine telegraphy and telephony service by American stations is within their exclusive bands of frequencies allocated at Atlantic City. The amateur stations have been shifted to their new world-wide frequency. The fixed public service stations of the United States have been assigned circuits within the smaller number of frequencies allocated to this service at Atlantic City. The

[112] Codding, *op. cit.*, p. 377.

high-frequency broadcast stations of the United States have also been brought into conformity with the 1947 allocation plan. To that extent, the 1951 conference succeeded in its immediate objective of safeguarding the United States interests in frequencies for these services, at least so far as occupancy is concerned. The absence of internationally agreed plans of time and frequency sharing means, however, that even within the American bloc of nations there is inefficiency in frequency use. In the case of high-frequency broadcasting, intentional "jamming" of broadcasts is added to the technical difficulties of adapting international use of radio to the needs of all nations.

Any summary of this review of international radio allocation should begin with recognition of the fact that the peaceful, constructive potential of the Atlantic City conference has been substantially dissipated since then. The swollen requirements for radio frequencies for military and propaganda purposes incident to the cold war have frustrated the 1947 intentions to achieve greater world-wide use of radio in a context of tightly integrated international standards, allocation plans, and frequency lists. Those standards and plans did not contemplate the high level of military and propaganda use of radio which has developed.

From the standpoint of American national interests, Commissioner Webster affirms that "order has emerged from chaos." And the Federal Communications Commission regards the Geneva agreement as vindication of its own policies and those of the American radio industry:

> The Geneva Agreement has for its purpose "the preparation and adoption of the new International Frequency List for the various services in the bands between 14 kc/s and 27500 kc/s with a view to bringing into force the Atlantic City Table of Frequency Allocations." The Table of Frequency Allocations adopted by the International Telecommunication Union's Radio Conference at Atlantic City in 1947 does not differ in major respects from the frequency allocation proposal of the United States to that conference. This, in turn, was based upon the Commission's recommendations following its hearing in Docket 6651 (1944-45). These recommendations took into account the proposals of the communications industry, many of which were developed and presented by the Radio Technical Planning Board, which was originated by the industry for the purpose of advising the Commission in this important matter.[118]

[118] Federal Communications Commission, "Commission Progress in Carrying Out Provisions of 1951 Geneva Agreement," Public Notice 91759, June 26, 1953.

X. SUMMARY

Regarded as a whole, telecommunications activities both nationally and internationally take place in an articulated structure of organization and policy. The foundations of this structure and policy were laid in the experience with wire-telegraphy where, despite the relatively undemanding nature of the technique, the tendency toward unification was clearly marked. The international union formed for wire-telegraphy served with appropriate changes in name as the basis for developing the present all-encompassing International Telecommunication Union. The addition of telephony with its more elaborate technique required more surely the concentration of expert policy making in unified national and international organization.

The advent of radio communication affected profoundly the structure and policy of communications. It reached beyond the bounds of person-to-person communications to permit the broadcasting of entertainment, information, and propaganda. Perhaps even more striking, because it is relatively unspectacular as compared with broadcasting, is the extent to which the so-called safety and special services of radio have been adopted by industry, by public protective agencies, and by the military forces. The unification of policy and organization which is implicit in the use of radio now spreads into almost every aspect of social organization.

Apart from broadening the sweep of its influence, radio has required conscious international planning of a degree of detail which penetrates deeply even into such sensitive areas as requirements for aircraft, long-range navigation, and the like. This is the absolute requirement dictated by the economics of spectrum allocation. Thus, even with the schism between the USSR and the Western bloc concerning frequency lists, both sides are using the same international organization, but more important for our present argument, they are following international rules to a degree of precision and complexity found possibly in no other human activity. That there is only a tacit agreement between the blocs in regard to the frequency lists bespeaks the underlying technological mandate of radio, for even this tacit agreement brings them more intimately into contact with each other than most other activities. What Commissioner Webster said with reference to the forty-odd nations in the Western bloc is true to a large degree of the whole world:

> Since the radio spectrum belongs to everyone and no one, it is like the very air we breathe. When problems arise, we have become accustomed to the idea of gathering at the table and talking over these problems. Once this is done solutions not previously apparent are usually found. The fact that such solutions have inherent compromises of one sort or another as their basis is typical of the nature of the problem with which we are dealing. More importantly, it underscores the necessity for decisions in the use of a common natural resource even though such decisions are not ideal from the point of view of any one group of users. Each user and group of users has been forced by circumstances to accept a policy of "give and take," realizing that he must give in some instances in order to receive in others.[114]

The problem is how to accommodate, by international agreement, an almost infinite range of conflicting demands to the physical and technical limitations of the radio spectrum. Despite the conflicts, the nations of the world are forced by necessity to move toward *de facto* compromises which permit the telecommunications system for each nation and for all nations to operate, not perfectly or with optimum efficiency, but passably well.

[114] Commissioner E. M. Webster, "Implementation, Cooperation and Self-Regulation."

ADMINISTRATION OF AMERICAN TELECOMMUNICATIONS POLICY

Edited with an introduction by John M. Kittross

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