FEDERAL COMMUNICATIONS COMMISSION

STANDARDS OF GOOD ENGINEERING PRACTICE CONCERNING STANDARD BROADCAST STATIONS

(550–1600 kc.)

EFFECTIVE AUGUST 1, 1939

(Revised to October 30, 1947)

UNITED STATES GOVERNMENT PRINTING OFFICE
WASHINGTON : 1947

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. - - - - - - - - - - Price [illegible]

INTRODUCTION

There are presented herein the Standards of Good Engineering Practice giving interpretations and further considerations concerning the Rules and Regulations of the Communications Commission governing standard broadcast stations. While the Rules and Regulations form the basis of good engineering practice, these standards may go beyond the Rules and Regulations and set up engineering principles for consideration of various allocation problems. These standards have been approved by the Commission and thus are considered as reflecting the opinion of the Commission in all matters involved.

The Rules and Regulations contain references to these standards; however, as further standards may be issued after the Rules and Regulations are published, the absence of such references does not relieve the responsibility of meeting the requirements specified herein. The Standards of Good Engineering Practice are collected in this publication for the convenience of all considering broadcast station operation and problems.

The Standards of Good Engineering Practice set forth herein are those deemed necessary for the construction and operation of standard broadcast stations to meet the requirements of technical regulations and for operation in public interest along technical lines not specifically enunciated in the regulations. These standards are based on the best engineering data available from evidence supplied in formal and informal hearings and extensive surveys conducted in the field by the Commission's personnel. Numerous informal conferences have been held with radio engineers, manufacturers of radio equipment and others for the guidance of the Commission in the formulation of these standards.

These standards are complete in themselves and supersede any previous announcements or policies which may have been enunciated by the Commission on engineering matters concerning standard broadcast stations.

While these standards provide for flexibility and set forth the conditions under which they are applicable, it is not expected that material deviation therefrom as to fundamental principles will be recognized unless full information is submitted as to the reasonableness of such departure and the need therefor.

These Standards of Good Engineering Practice will necessarily change as progress is made in the art, and accordingly it will be necessary to make revisions from time to time. The Commission will accumulate and analyze engineering data available as to the progress of the art so that its standards may be kept current with the developments.

STANDARDS OF GOOD ENGINEERING PRACTICE CONCERNING STANDARD BROADCAST STATIONS

(550–1600 kc.)

1. ENGINEERING STANDARDS OF ALLOCATION

Section 3.28 requires that individual broadcast station assignments shall be made in accordance with the standards of good engineering practice prescribed and published from time to time by the Commission. These standards for each class of station are set out below.

Sections 3.21 to 3.34, inclusive, govern the allocation of facilities in the standard broadcast band of 550 to 1600 kc, inclusive. Section 3.21 establishes three classes of channels in this band, namely, clear channels for the use of high-powered stations, regional channels for the use of medium-powered stations, and local channels for the use of low-powered stations. The classes and power of standard broadcast stations which will be assigned to the various channels are set forth in section 3.22. The classifications of the standard broadcast stations are as follows:

Class I stations are dominant stations operating on clear channels as follows:

(1) Class I stations operate with powers of not less than 10 or more than 50 kw. These stations are designed to render primary and secondary service over an extended area and at relatively long distances, hence have their primary service areas [1] free from objectionable interference from other stations on the same and adjacent channels and secondary service areas free from objectionable interference from stations on the same channels.[2] [3]

(2) From an engineering point of view, Class I stations may be divided into two groups:

(*a*) The Class I stations in Group 1 are those assigned to the channels allocated by section 3.25, paragraph (*a*), on which duplicate nighttime operation is not permitted, that is, no other station is permitted to operate on a channel with a Class I station of this group within the limits of the United States (the Class II stations assigned the channels operate limited time or daytime only), and during daytime the Class I station is protected to the 100 uv/m groundwave contour. Protection is given this class of station to the 500 uv/m groundwave contour from adjacent channel stations for both day and nighttime operations.[2] The power of each such Class I station shall not be less than 50 kw.

(*b*) The Class I stations in Group 2 are those assigned to the channels allocated by section 3.25, paragraph (*b*), on which duplicate operation is permitted, that is, other Class I or Class II stations operating unlimited time may be assigned to such channels. During nighttime hours of operation a Class I station of this group is protected to the 500 uv/m 50 percent skywave contour and during daytime hours of operation to the 100 uv/m groundwave contour from stations on the same channel. Protection is given to the 500 uv/m groundwave contour from stations on adjacent channels for both day and nighttime operation.[2] The operating powers of Class I stations on these frequencies shall be not less than 10 kw nor more than 50 kw.

Hereafter, for the purpose of convenience, the two groups of Class I stations will be termed Class Ia or Ib in accordance with the assignment to channels allocated by section 3.25 (*a*) or 3.25 (*b*).

Class II stations are secondary stations which operate on clear channels with powers not less than 0.25 kw or more than 50 kw. These stations are required to use a directional antenna or other means to avoid causing interference within the normally protected service areas of Class I stations or other Class II stations.

---

[1] See section 3.11 for the definitions of primary and secondary service areas.

[2] See tables IV and V.

[3] The secondary service area of a Class I station is not protected from adjacent channel interference. However, if it is desired to make a determination of the area in which adjacent channel groundwave interference (10 kc. removed) to skywave service exists, it may be considered as the area where the ratio of the desired 50 percent skywave of the Class I station to the undesired groundwave of a station 10 kc. removed is 1 to 4.

These stations normally render primary service only, the area of which depends on the geographical location, power, and frequency. This may be relatively large but is limited by and subject to such interference as may be received from Class I stations. However, it is recommended that Class II stations be so located that the interference received from Class I stations will not limit the service area to greater than the 2500 uv/m groundwave contour, which is the value for the mutual protection of this class of station with other stations of the same class.[2]

Class III stations operate on regional channels and normally render primary service to the metropolitan district and the rural area contained therein and contiguous thereto, and are subdivided into two classes:

(*a*) Class III–A stations which operate with powers not less than 1 kw or more than 5 kw are normally protected to the 2500 uv/m groundwave contour nighttime and the 500 uv/m groundwave contour daytime.[2]

(*b*) Class III–B stations which operate with powers not less than 0.5 kw or more than 1 kw nighttime and 5 kw daytime are normally protected to the 4000 uv/m groundwave contour nighttime and 500 uv/m groundwave contour daytime.[2]

[2] See tables IV and V.

[3a] The following approximate method may be used. It is based on the assumption of 0.25 wavelength antenna height and 88 mv/m at 1 mile effective field for 250 watts power, using the 10 percent skywave field intensity curve of Figure 1-A. Zones defined by circles of various radii specified below are drawn about the desired station and the interfering 10 percent skywave signal from each station in a given zone is considered to be the value tabulated below. The effective interfering 10 percent skywave signal is taken to be the RSS value of all signals originating within these zones. (Stations beyond 500 miles are not considered.)

Zone	Inner radius	Outer radius	10 percent skywave signal
			mv/m
A		60	0.10
B	60	80	.12
C	80	100	.14
D	100	250	.16
E	250	350	.14
F	350	450	.12
G	450	500	.10

Where the power of the interfering station is not 250 watts, the 10 percent skywave signal should be adjusted by the square root of the ratio of the power to 250 watts.

Class IV stations operate on local channels normally rendering primary service only to a city or town and the suburban and rural areas contiguous thereto with powers not less than 0.1 kw or more than 0.25 kw. These stations are normally protected to 500 uv/m groundwave contour daytime. On local channels the separation required for the daytime protection shall also determine the nighttime separation. The actual nighttime limitation will be calculated.[3a] Class IV stations may be assigned to regional channels on condition that interference will not be caused to any Class III station in accordance with the above, that the channel is used adequately and properly for Class III stations[4], and that the Class IV station will be subject to such interference as may be received from the Class III stations. That is, the Class IV station assigned to a regional channel shall protect the Class III station to the required contour, but the Class III station is under no obligation to protect the Class IV station so assigned. However, it is recommended that the Class IV stations be so located that the interference received will not be greater than to the 4000 uv/m groundwave contour nighttime and 500 uv/m daytime.

The class of any station is determined by the channel assignment, the power, and the field intensity contour to which it renders service free of interference from other stations as determined by these standards. No station will be permitted to change to a class normally protected to a contour of less intensity than the contour to which the station actually renders interference-free service. Any station of a class normally protected to a contour of less intensity than that to which the station actually renders interference-free service, will be automatically reclassified according to the class normally protected, the minimum consistent with its power and channel assignment. Likewise, any station to which the interference is

[4] The assignment of a Class IV station to a regional channel normally is not considered as making the best usage of the assignment and will be made only when it is shown among other things that—

(1) There are no other transmission facilities in the town or towns in the proposed service area.

(2) There is no local channel assignment available for that area.

(3) Adequate economic support is not available for a Class III station.

(4) It is not practical from an engineering point of view to establish a Class III station and it would not prevent the establishment of any Class III station on that channel or an adjacent channel.

reduced so that service is rendered to a contour normally protected for a higher class will be automatically changed to that class if consistent with its power and channel assignment.

When it is shown that primary service is rendered by any of the above classes of stations, beyond the normally protected contour, and when primary service to approximately 90 percent of the population (population served with adequate signal) of the area between the normally protected contour and the contour to which such station actually serves, is not supplied by any other station or stations carrying the same general program service, the contour to which protection may be afforded in such cases will be determined from the individual merits of the case under consideration.

A Class II, III–B or IV station may be assigned to a channel available for such class, when a need therefor is shown, even though objectionable interference will be received to a field intensity contour greater than that specified as the normally protected contour for its class, provided that no objectionable interference will be caused by it to existing stations, and provided further, that the population residing in the area between the normally protected contour for its class and the contour to which objectionable interference will be received, does not exceed approximately 10 percent of the population in its actual primary service area. In case the station is located in a metropolitan area, the interference-free contour shall include 90 percent of the population of the metropolitan area.

When a station is already limited by interference from other stations to a contour of higher value than that normally protected for its class, this contour shall be the established standard for such station with respect to interference from all other stations.

Tables IV and V give a complete summary of the protected service contours and permissible interference signals for broadcast stations on the same and adjacent channels, respectively.

The several classes of broadcast stations have in general three service areas;[4a] namely, primary, secondary, and intermittent service areas.

[4a] See section 3.11 for the definitions of primary, secondary, and intermittent service areas.

Class I stations render service to all three service areas. Class II stations render service to a primary area but the secondary and intermittent service areas may be materially limited or destroyed due to interference from other stations depending on the station assignments involved. Class III and IV stations usually have only primary service areas as interference from other stations generally prevents any secondary service and may limit the intermittent service area. However, complete intermittent service may be obtained in many cases depending on the station assignments involved.

The signals necessary to render the different types of service are listed below.

TABLE I.—*Primary service*

Area:	*Field intensity groundwave*[1]
City business or factory areas	10 to 50 mv/m
City residential areas	2 to 10 mv/m
Rural—all areas during winter or northern areas during summer	0.1 to 0.5 mv/m
Rural—southern areas during summer	0.25 to 1.0 mv/m

[1] See appendix I for curves showing distance to various ground wave field intensity contours for different frequency and ground conductivities and annex I.

All these values are based on an absence of objectionable fading, either in changing intensity or selective fading, the usual noise level in the areas[5] and an absence of limiting interference from other broadcast stations. The values apply both day and night but generally fading or interference from other stations limits the primary service at night in all rural areas to higher values of field intensity than the values given.

In determining the population of the primary service area, it may be considered that the following signals are satisfactory to overcome man-made noise in towns of the population given.

[5] Standards have not been established for interference from atmospherics or man-made electric noise as no uniform method of measuring noise or static has been established. In any individual case objectionable interference from any source, except other broadcast signals, may be determined by comparing the actual noise interference reproduced during reception of a desired broadcast signal to the degree of interference that would be caused by another broadcast signal within 20 cycles of the desired signal and having a carrier ratio of 20 to 1 with both signals modulated 100 percent on peaks of usual programs. Standards of noise measurements and interference ratio for noise are now being studied.

TABLE II

Population:	Field intensity groundwave
Up to 2,500	0.5 mv/m
2,500 to 10,000	2.0 mv/m
10,000 and up	Values given in Table I.

These values are subject to wide variations in individual areas and especial attention must be given to interference from other stations. The values are not considered satisfactory in any case for service to the city in which the main studio of the station is located. The values in Table I shall apply except as individual consideration may determine.

All classes of broadcast stations have primary service areas subject to limitation by fading and noise, and interference from other stations to the contours set out for each class of station.

SECONDARY SERVICE

Secondary service is delivered in the areas where the skywave for 50 percent or more of the time has a field intensity of 500 uv/m or greater.[6] It is not considered that satisfactory secondary service can be rendered to cities unless the skywave approaches in value the groundwave required for primary service. The secondary service is necessarily subject to some interference and extensive fading whereas the primary service area of a station is subject to no objectionable interference or fading.[7] Class I stations only are assigned on the basis of rendering secondary service.

INTERMITTENT SERVICE

The intermittent service is rendered by the groundwave and begins at the outer boundary of the primary service area and extends to the value of signal where it may be considered as having no further service value. This may be down to only a few microvolts in certain areas and up to several millivolts in other areas of high noise level, interference from other stations, or objectionable fading at night. The intermittent service area may vary widely from day to night and generally varies from time to time as the name implies. Only Class I stations are assigned for protection from interference from other stations into the intermittent service area.

Section 3.23 provides that the several classes of broadcast stations may be licensed to operate unlimited time, limited time, daytime, sharing time, and specified hours, with full explanation given in the section.

Section 3.24 sets out the general requirements for obtaining an increase in facilities of a licensed station and for a new station. Section 3.24 (*b*) concerns the matter of interference that may be caused by a new assignment or increase in facilities of an existing assignment.

Objectionable interference from another broadcast station [8] is the degree of interference produced when, at a specified field intensity contour with respect to the desired station, the field intensity of an undesired station (or the root-sum-square value of field intensities of two or more stations on the same frequency) exceeds for ten (10) percent or more of the time the values set forth in these standards.

With respect to the root-sum-square values of interfering field intensities referred to herein, except in the case of Class IV stations on local channels, calculation is accomplished by considering the signals in order of decreasing magnitude, adding the squares of the values and extracting the square root of the sum, excluding those signals which are less than 50 percent of the RSS value of the higher signals already included.

The RSS value will not be considered to be increased when a new interfering signal is added which is less than 50 percent of the RSS value of the interference from existing stations, and which at the same time is not greater than the smallest signal included in the RSS value of interference from existing stations.

It is recognized that application of the above "50 percent exclusion" method of calculating the RSS interference may result in some cases in anomalies wherein the addition of a new interfering signal or the increase in value of an existing interfering signal will cause the exclusion of a previously included signal and may

[6] The secondary service area of a Class Ia station should be considered as having this limit only for determination of service in comparison with other stations.

[7] Standards have not been established for objectionable fading as such standards would necessarily depend on the receiver characteristics which have been changed considerably in this regard during the last several years. Selective fading causing audio distortion and the signal fading below the noise level are the objectionable characteristics of fading on modern design receivers. The AVC circuits in the better designed modern receivers in general maintain the audio output sufficiently constant to be satisfactory during most fading.

[8] See footnote 6.

cause a decrease in the calculated RSS value of interference. In order to provide the Commission with more realistic information regarding gains and losses in service (as a basis for determination of the relative merits of a proposed operation) the following alternate method for calculating the proposed RSS values of interference will be employed wherever applicable.

In the cases where it is proposed to add a new interfering signal which is not less than 50 percent of the RSS value of interference from existing stations or which is greater than the smallest signal already included to obtain this RSS value, the RSS limitation after addition of the new signal shall be calculated without excluding any signal previously included. Similarly, in cases where it is proposed to increase the value of one of the existing interfering signals which has been included in the RSS value, the RSS limitation after the increase shall be calculated without excluding the interference from any source previously included.

If the new or increased signal proposed in such cases is ultimately authorized, the RSS values of interference to other stations affected will thereafter be calculated by the "50 percent exclusion" method without regard to this alternate method of calculation.

Examples of RSS interference calculations:

1. Existing interferences:

Station No. 1	1.0 mv/m
Station No. 2	0.60 mv/m
Station No. 3	0.59 mv/m
Station No. 4	0.58 mv/m

The RSS value from Nos. 1, 2, and 3 is 1.31 mv/m; therefore interference from No. 4 is excluded for it is less than 50 percent of 1.31 mv/m

2. Station A receives interference from:

Station No. 1	1.0 mv/m
Station No. 2	0.60 mv/m
Station No. 3	0.59 mv/m

It is proposed to add a new limitation=0.68 mv/m. This is more than 50 percent of 1.31 mv/m, the RSS value of Nos. 1, 2, and 3. The RSS value of Station No. 1 and of the proposed station would be 1.21 mv/m which is more than twice as large as the limitation from Station No. 2 or No. 3. However, under the above provision the new signal and the three existing interferences are nevertheless calculated for purposes of comparative studies, resulting in an RSS value of 1.47 mv/m. However, if the proposed station is ultimately authorized, only No. 1 and the new signal are included in all subsequent calculations for the reason that Nos. 2 and 3 are less than 50 percent of 1.21 mv/m the RSS value of the new signal and No. 1.

3. Station A receives interference from:

Station No. 1	1.0 mv/m
Station No. 2	0.60 mv/m
Station No. 3	0.59 mv/m

No. 1 proposes to increase the limitation it imposes on Station A to 1.21 mv/m. Although the limitations from Stations Nos. 2 and 3 are less than 50 percent of the 1.21 mv/m limitation under the above provision, they are nevertheless included for comparative studies, and the RSS limitation is calculated to be 1.47 mv/m. However, if the increase proposed by Station No. 1 is authorized, the RSS value then calculated is 1.21 mv/m because Stations Nos. 2 and 3 are excluded in view of the fact that the limitations they impose are less than 50 percent of 1.21 mv/m.

Objectionable interference from a station on the same channel shall be considered to exist to a station when, at the field intensity contour specified in Table IV with respect to the class to which the station belongs, the field intensity of an interfering station (or the root-sum-square value of the field intensities of two or more interfering stations) operating on the same channel, exceeds for ten (10) percent or more of the time the value of the permissible interfering signal set forth opposite such class in Table IV.

Objectionable interference from a station on an adjacent channel shall be considered to exist to a station when, at the normally protected contour of a desired station, the field intensity of the groundwave of an undesired station operating on an adjacent channel (or the root-sum-square value of the field intensities of two or more such undesired stations operating on the same adjacent channel) exceeds a value specified in Table V.

For the purpose of calculating the presence and the degree of objectionable interference, stations of the several classes shall be assumed, in the absence of actual measurements or data on the design of the antenna system, to produce effective fields, for 1 kw of input power to the antenna, as follows:

TABLE III

Class of station:	Effective field
I	225 mv/m
II and III	175 mv/m
IV	150 mv/m

In case a directional antenna is employed, the interfering signal of a broadcasting station will vary in different directions, being greater than the above values in certain directions and less in others, depending upon the design and adjustment of the directional antenna system. To determine the interference in any direction, in the absence of actual interference measurements, the measured or calculated radiated field (unabsorbed field intensity at 1 mile from the array) must be used in conjunction with the appropriate propagation curves.[9]

The existence or absence of objectionable interference from stations on the same or adjacent channels shall be determined by one of the following methods:

(*a*) By actual measurements made according to the method hereafter described;

or, in the absence of such measurements:

(*b*) By reference to the propagation curves in Figure 1 or Figure 1–A and Appendix I.

The existence or absence of objectionable interference may be proved by field intensity measurements or recordings made with suitable apparatus, duly calibrated. Such field intensity measurements of skywave shall be made for a period of time not less than 10 days and an adequate check shall be made on the skywave signal of other stations to determine the general conditions of propagation while such measurements are taken.[10] In computing the fifty (50) percent skywave field intensity values of a Class I station of a given power and also in computing the ten (10) percent skywave field intensity of an alleged interfering Class I or Class II station on a clear channel, use shall be made of the appropriate graph set forth in figure 1 entitled "Average Skywave Field Intensity" (corresponding to the second hour after sunset at the recording station). These graphs are drawn for a radiated field of 100 mv/m at 1 mile on the horizontal plane from a 0.311λ antenna. In computing the ten (10) percent skywave field intensity of an alleged interfering station, other than Class I or Class II, at a specified distance, use shall be made of the appropriate curve in Figure 1-A entitled "10 percent Skywave Signal Range." This graph is drawn for a radiated field of 100 mv/m at 1 mile at the vertical angle pertinent to transmission by one reflection. This curve supersedes the ten (10) percent skywave curve of Figure 1, only for regional and local channels at the present time.[11] Adoption of revised skywave curves for use on clear channels will await the outcome of the Clear Channel Hearing (Docket No. 6741) and the negotiations for a new North American Regional Broadcasting Agreement.

The distance to any specified groundwave field intensity contour may be determined from appropriate groundwave curves plotted for the frequency under consideration and the conductivity and dielectric constant of the earth between the station and desired contour. The frequency and the conductivity of the earth must be considered in every case and where the distance is great, due allowance must be made for loss due to curvature of the earth. Figure 2 entitled "Groundwave Field Intensity," drawn for a frequency of 1000 kc, conductivity of 10^{-13} dielectric constant 15, and an effective field of 100 mv/m at 1 mile, may be employed when applicable.

[9] See annex II for further discussion and solution of a typical directional antenna case.

[10] See annex III for detailed requirements and also section on "Field Intensity Measurements in Allocation."

[11] The Commission will not authorize a directive antenna for a Class VI station assigned a local channel.

TABLE IV.—*Protected service contours and permissible interference signals for broadcast stations*

Class of station	Class of channel used	Permissible power	Signal intensity contour of area protected from objectionable interference [1]		Permissible interfering signal on same channel [2]	
			Day [3]	Night	Day [3]	Night [4]
Ia	Clear	50 kw	SC 100 uv/m; AC 500 uv/m	Not duplicated	5 uv/m	Not duplicated.
Ib	do	10 kw to 50 kw	SC 100 uv/m; AC 500 uv/m	500 uv/m (50 percent sky wave).	5 uv/m	25 uv/m
II	do	0.25 kw to 50 kw	500 uv/m	2500 uv/m[3] (groundwave)	25 uv/m	125 uv/m [5]
III-A	Regional	1 kw to 5 kw	500 uv/m	2500 uv/m (groundwave)	25 uv/m	125 uv/m
III-B	do	0.5 to 1 kw night and 5 kw day.	500 uv/m	4000 uv/m (groundwave)	25 uv/m	200 uv/m
IV	Local [6]	0.1 kw to 0.25 kw	500 uv/m	4000 uv/m (groundwave)	25 uv/m	200 uv/m

[1] When it is shown that primary service is rendered by any of the above classes of stations, beyond the normally protected contour, and when primary service to approximately 90 percent of the population (population served with adequate signal) of the area between the normally protected contour and the contour to which such station actually serves, is not supplied by any other station or stations, the contour to which protection may be afforded in such cases will be determined from the individual merits of the case under consideration. When a station is already limited by interference from other stations to a contour of higher value than that normally protected for its class, this contour shall be the established standard for such station with respect to interference from all other stations.

[2] For adjacent channels see Table V.

[3] Groundwave.

[4] Skywave field intensity for 10 percent or more of the time.

[5] These values are with respect to interference from all stations except Class Ib, which stations may cause interference to a field intensity contour of higher value. However, it is recommended that Class II stations be so located that the interference received from Class Ib stations will not exceed these values. If the Class II stations are limited by Class Ib stations to higher values, then such values shall be the established standard with respect to protection from all other stations.

[6] Class IV stations may also be assigned to regional channels according to section 3.29.

SC = Same channel.
AC = Adjacent channel.

The following table is to be used for determining the minimum ratio of the field intensity of a desired to an undesired signal for interference free service. In the case of a desired groundwave signal interfered with by two or more skywave signals on the same frequency, the RSS value of the latter is used.

TABLE V.—*Interference ratios*

Frequency separation of desired to undesired signals	Desired groundwave to—		Desired 50 percent skywave to undesired 10 percent skywave
	Undesired groundwave	Undesired 10 percent skywave	
0 kc	20:1	20:1	20:1
10 kc	1:1	1:5	(1)
20 kc	1:30		

[1] See footnote 3, p. 1.

From the above, it is apparent that in many cases stations operating on channels 10 and 20 kc apart may be operated with antenna systems side by side or otherwise in proximity without any indications of interference if the interference is defined only in terms of permissible ratios hereinbefore listed in Table V headed "Interference Ratios." As a practical matter, serious interference problems may arise when two or more stations with the same general service area are operated on channels 10, 20, and 30 kc apart.

Accordingly, no station will be licensed for operation with less than 40 kc separation from another station, if the area enclosed by the 25 mv/m groundwave contours of the two stations overlap. Frequency separation of 20 kc and 10 kc are considered inappropriate for stations with the same general urban coverage and therefore no station will be licensed for operation with less than 30 kc frequency separation if the area enclosed by the 25 mv/m groundwave contour of either one overlaps the area enclosed by the 2 mv/m groundwave contour of the other.

Two stations, one with a frequency twice that of the other, should not be assigned in the same groundwave service area unless special precautions are taken to avoid interference from the second harmonic of the lower frequency. In selecting a frequency, consideration should be given to the fact that occasionally the frequency assignment of two stations in the same area may bear such a relation to the intermediate frequency of some broadcast receivers as to cause so-called "image" interference. However, since this can usually be rectified by readjustment of the intermediate frequency of such receivers, the Commission in general will not take this kind of interference into consideration in allocation problems.

Two stations operating with synchronized carriers [12] and carrying the identical program

[12] NOTE.—Two stations are considered to be operated synchronously when the carriers are maintained within one-fifth of a cycle per second of each other and they transmit identical programs.

will have their groundwave service subject to some distortion in areas where the signals from the two stations are of comparable intensity. For the purpose of estimating coverage of such stations, areas in which the signal ratio is between 1 to 2 and 2 to 1 will not be considered as having satisfactory service.

Annex I

INTERFERENCE FROM GROUNDWAVE SIGNALS

Interference that may be caused by a proposed assignment or an existing assignment during day time should always be determined, when possible, by measurements on the frequency involved or on another frequency over the same terrain and by means of the curves in Figure 4, interpolated for the desired frequency.

In determining the interference from field intensity measurements, two general steps are necessary: First, establish the outer boundary of the protected service area of the desired station in the direction of the station that may cause interference with it. Second, at this boundary, measure the interfering signal from the undesired station. The ratio of the desired to the undesired signal given on page seven should be applied to the measured signals and if the required ratio is observed, then no interference is contemplated. The effective field of the antenna in the pertinent directions of the stations must be established and all measurements must be made in accordance with the section on "Field Intensity Measurements in Allocation."

In all cases where measurements taken in accordance with the requirements are not available,[13] the groundwave intensity must be determined by means of the conductivity of the terrain and the groundwave curves of field intensity versus distance. The conductivity of a given terrain may be determined by measurements of any broadcast signal traversing the terrain involved, or in case such measurements are not available, then conductivity must be taken from the map of ground conductivity in the United States, Figure 3. This map shows the conductivity throughout the entire United States by general areas of reasonably uniform conductivity. In areas of limited size, or over a particular path, the conductivity may vary widely from the values given. This map is to be used only when accurate and acceptable measurements have not been made.

If an interfering signal traverses areas for which more than one conductivity is given by the map, then conductivity for two-thirds the distance should be taken and in case this involves more than one value, then the highest predominating value should be assumed to prevail. Where the conductivity along a given path varies over wide limits, the previous method may give erroneous results, in which case the signal at any given point, for a given value of field intensity at 1 mile from the antenna in the direction concerned may be determined by determining and adding the attenuation in decibels of each section of the intervening path.[14]

Figure 4 gives the groundwave field intensity curves with field intensity plotted against distance for various values of conductivity and by blocks of frequencies. To cover the standard broadcast band some 20 graphs in all are required and are attached as Appendix I. In all cases the curves are plotted on the basis of 100 mv/m effective field at a mile. An example of determining the interference by this method follows:

It is desired to find the interference that a 5 kw Class III station on 990 kc may cause to a 1 kw class III station on 1000 kc. The stations are separated by 130 miles. It is assumed that both stations use nondirectional antennas[15] having such height as to produce an effective field for 1 kw of 175 mv/m.[16] From Figure 3, the conductivity at each station and intervening terrain is determined as 6×10^{-14}. The protection to Class III during daytime is to the 500 uv/m contour. The distance to the 500 uv/m groundwave contour of the 1 kw station is determined by the use of the

[13] The Commission will *not* authorize operation on a proposed assignment for the purpose of making measurements.

[14] For example, assuming three values of conductivity prevail such that for the frequency and distances concerned the signal is attenuated over the given conductivities 6, 8, and 14 db respectively or a total of 28 db over the entire path, then the signal at the point concerned for 100 mv/m at 1 mile would be $\frac{100}{25.119 \text{ (voltage ratio for 28 db)}}$ or 3.98 mv/m

[15] See Annex II in case of use of directional antennas.

[16] In all cases the effective field should be established from the dimensions of the radiating system. The value assumed here is in accordance with section 3.45 and the Standards of Good Engineering Practice promulgated pursuant thereto.

curves in Figure 4 as being 39.5 miles. Since these curves are plotted for 100 mv/m at a mile, to find the distance to the 500 uv/m contour of the 1 kw station, it is necessary to determine the distance on the appropriate curve to the

$$\left(\frac{100\times 500}{175}=285\right)$$

285 uv/m contour. Thus, the estimated radius of the service area for the desired station is established as 39.5 miles. Subtract this distance from the distance between the two stations, leaving 90.5 miles for the interfering signal to travel. Again from the appropriate curve in Figure 4 it is found that the signal from the 5 kw station at this distance would be 158 uv/m. Since the stations are separated by 10 kc, the undesired signal at that point can have a value up to 500 uv/m without interference, but if the interference signal had been found to be greater than this value, then interference would have been determined. For other channel separations the appropriate ratio of desired to undesired signal would have been used. This principle holds for all cases except where a skywave signal 10 percent or more of the time from the undesired station is in excess of 5 times the desired signal when the frequency separation is 10 kc. In this case the interference must be estimated on the basis of the skywave interference and the propagation curve in Figure 1 or Figure 1–A used to determine the interfering signals rather than Figure 4 for the groundwave signals.

ANNEX II

COMPUTATION ON INTERFERING SIGNAL FROM A DIRECTIONAL ANTENNA

In case of an antenna directional in the horizontal plane, the groundwave interference can be readily computed from the calculated horizontal pattern by determining the vectors toward the service area of the station to be protected and apply these values to the groundwave curves set out in Annex I.

For signals from stations operating on clear channels, in case of determining skywave interference from an antenna with a vertical pattern different from that on which Figure 1 is predicated, it is necessary to compare the appropriate vectors in the vertical plane.

The skywave curves entitled "Average Skywave Field Intensity" (corresponding to the second hour after sunset at the recording station) as shown in Figure 1 are based on antenna systems having height of 0.311 wavelength (112°) and producing a vertical pattern as shown in Figure 5. A nondirectional antenna system, as well as a directional antenna system having vertical patterns other than essentially the same as shown, must be converted to the pattern of a 0.311 wavelength antenna having the same field intensity at the critical angle as does the pattern of the antenna involved. Example:

Figure 6 is a graph entitled "Variation with Distance of Two Important Parameters in the Theory of Skywave Propagation." The curve for θ showing the angle above the horizon at which radiation occurs plotted against distance, must be used for this purpose. For instance, assuming the station with which interference may be expected is located at a distance of 450 miles from a proposed station, the critical angle of radiation as determined from this curve is approximately 15°. Therefore, if the vertical pattern of the proposed station in the direction of the other station is such that at 15° above the horizon the radiation is 1.3 times that from an antenna having a vertical pattern as shown in Figure 5 and producing the same field intensity at 1 mile in the horizontal plane, the interfering signal would be 1.3 times that determined from Figure 1 for an antenna having the same field intensity in the horizontal plane. That is, if the field intensity in the horizontal plane of the proposed station is 124 mv/m the interfering field intensity exceeded 10 percent of the time at the other station would be

$$140\times 1.30\times\frac{124}{100}\text{ or }225\text{ uv/m}$$

and would cause interference to the 4.5 mv/m groundwave contour of the existing station.

For signals from stations on regional and local channels, in computing the ten (10) percent skywave (interference) field intensity values of

Class III and Class IV stations,[17] Figure 1–A is to be used in place of Figure 1. Since Figure 1–A is predicated upon a radiated field of 100 mv/m at 1 mile in the pertinent direction, no comparison with the vertical pattern of a 0.311 wavelength antenna is to be made. Instead the appropriate radiated field in the vertical plane corresponding to the distance to the receiving station, divided by 100, is multiplied into the value of ten (10) percent skywave field intensity determined from Figure 1–A. There are two new factors to be considered, however, namely the variation of received field with latitude of the path and the variation of pertinent vertical angle due to variations of ionosphere height and ionosphere scattering.

Figure 1–A, "10 percent Skywave Signal Range Chart," shows the ten (10) percent skywave signal as a function of the latitude of the transmission path and the distance from a transmitting antenna with a radiated field of 100 mv/m at the pertinent angle for the distance. The latitude of the transmission path is defined as the geographic latitude of the midpoint between the transmitter and the receiver. Latitude 35° should be used in case the midpoint of the path lies below 35° N. and latitude 50° should be used in case the midpoint of the path lies above 50° N.

Figure 6–A, entitled "Angles of Departure vs. Transmission Range," is to be used in determining the angles in the vertical pattern of the antenna of an interfering station to be considered as pertinent to transmission by one reflection. Corresponding to any given distance, the curves 4 and 5 indicate the upper and lower angles within which the radiated field is to be considered. The maximum value of field intensity occurring between these angles will be used to determine the multiplying factor for the ten (10) percent skywave field intensity determined from Figure 1–A. (Curves 2 and 3 are considered to represent the variation due to the variation of the effective height of the E-layer while curves 4 and 5 extend the range of pertinent angles to include a factor which allows for scattering. The dotted lines are included for information only.)

[17] Certain simplifying assumptions may be made in the case of Class IV stations on local channels: See footnote 3a.

In the case of nondirectional vertical antennas, the vertical distribution of relative fields for several heights, assuming sinusoidal distribution of current along the antenna, is shown in Figure 5. In the case of directional antennas the vertical pattern in the great circle direction toward the point of reception in question must first be calculated. Then for the distance to the points, the upper and lower pertinent angles are determined from Figure 6–A. The ratio of the largest value of radiated field occurring between these angles, to 100 mv/m (for which Figure 1–A is drawn) is then used as the multiplying factor for the value of the field read from the curves of Figure 1–A. Note that while the accuracy of the curves is not as well established by measurements for distances less than 250 miles as for distances in excess of 250 miles, the curves represent the most accurate data available today. Pending accumulation of additional data to establish firm standards for skywave calculations in this range, the curves may be used. In cases where the radiation in the vertical plane, in the pertinent azimuth, contains a large lobe at a higher angle than the pertinent angle for one reflection, the method of calculating interference will not be restricted to that described above, but each such case will be considered on the basis of the best knowledge available.

For example, suppose it is desired to determine the amount of interference to a Class III station at Portland, Oregon, caused by another Class III station at Los Angeles, Calif., which is radiating a signal of 560 mv/m unattenuated at 1 mile in the great circle direction of Portland, using a 0.5 wavelength antenna. The distance is 825 miles. From Figure 6–A the upper and lower pertinent angles are 7° and 3.5° and, from Figure 5 the maximum radiation within these angles is 99 percent of the horizontal radiation or 554 mv/m at 1 mile. The latitude of the path is 39.8° N. and from Figure 1–A, the 10 percent skywave field at 825 miles is 0.050 mv/m for 100 mv/m radiated. Multiplying by 554/100 to adjust the value to the actual radiation gives 0.277 mv/m. At 20 to 1 ratio the limitation to the Portland station is to the 5.5 mv/m contour.

When the distance is large, more than one reflection may be involved and due consideration must be given each appropriate vector in the vertical pattern, as well as the constants of the earth where reflection takes place between the transmitting station and the service area to which interference may be caused.

Annex III

INTERFERENCE FROM SKYWAVE SIGNALS

Set out below is the detailed method of making measurements of the skywave signals to determine an interfering signal for 10 percent of the time.

The signal must be received on an acceptable field intensity meter duly calibrated and recorded on a continuous recording meter of suitable accuracy and sensitivity. Measurements at distances less than 350 miles from the station should be made with a vertical antenna only. At greater distances either a vertical antenna, loop, or other suitable antenna may be used. Two complete recording units are required so that two signals can be recorded simultaneously.

A monitor station on which interference free measurements can be made must be selected for simultaneous recordings. This station should be in the general direction of the principal station to be recorded. Preferably, such monitor station should have known antenna characteristics and the conductivity of the surrounding terrain should be known. The transmitters should be located in the same general area and the frequencies of the stations as close as possible. The reception of the two stations should be on the same antenna or on antennas in the same area so that both are influenced by the same surrounding objects.

Recordings may be made on both stations from sundown over the entire path until midnight at the recording station. These records should be analyzed for each night and for the entire period of recording and graphs drawn which show field intensity versus percent time. The 10 percent signal determined for the principal station for the entire period must be modified by a correction factor determined from a comparison of the 10 percent signal from the monitor station to the value determined from the 10 percent curve of Figure 1 for the same distance, power, and pertinent antenna characteristic. Thus, if the 10 percent signal from the Figure 1 10 percent curve is 500 uv/m and the measured 10 percent signal on the monitor station 350 uv/m, then the 10 percent signal from the principal station should be multiplied by the factor of 500/350 or 1.43 to determine the interfering signal. Recordings for at least 10 nights are required. If it is not practical to follow this procedure, due to interference to the reception of the principal station recorded, the following procedure is required:

Record the monitor station and the principal station during the earliest hour that the principal station can be recorded. The measurements must be for at least 1 continuous hour each night and preferably not less than 2 hours each night. In all cases the monitor station must be recorded simultaneously. These measurements must be taken for at least 10 nights. Establish the 10 percent value of the fields during the period when both are measured. The 10 percent value of the field for the principal station must be corrected in the following manner:

Compare the 10 percent value of the signal for the monitor station with the 10 percent value determined from Figure 1 for the same distance reduced to the same power for comparable radiation at the appropriate angle. Thus, if the 10 percent signal from the Figure 1 10 percent curve is 500 uv/m and the measured 10 percent signal on the monitor station is 400 uv/m then the 10 percent signal from the principal station should be multiplied by the correction factor of 500/400 or 1.25. The value obtained in this way is to be considered the interference value of signals for use in all allocation problems.

When it is claimed that the propagation over the path involved is normally less than the average, measurements must be made on two or more other stations of different paths for at least 30 days and the signals of all stations involved recorded in the above manner to establish that propagation conditions in general were normal and that the path under consideration was low as claimed due to some natural conditions. A full explanation of the theory or practical findings must be made.

In all other cases where the signal is substantially greater or less than the average determined from Figure 1, complete informa-

760684°—47——2

tion must be supplied as to why the signal measured has departed from the average. If the reason for this condition is based on the location of the antenna, its characteristics, the conductivity of the surrounding area or other natural limitations, a full explanation of the nature and character of such conditions must be supplied and also information as to whether the licensee could, by moving its station or by making other changes within its control, alter the situation so that the abnormal condition of propagation would no longer exist.

The interference signal determined by the above methods should be used to determine interference to a station in the same manner as the groundwave signals were employed, as set out in Annex I. These methods of measurement should be used to determine skywave service signal for 50 percent of the time.

2. FIELD INTENSITY MEASUREMENTS IN ALLOCATION

A. Field Intensity Measurements to Establish Effective Field Intensity at 1 Mile

Section 3.45 provides that certain minimum field intensities are acceptable in lieu of the required minimum physical vertical heights of the antennas proper. Also in other allocation problems, it is necessary to determine the effective field at 1 mile. The following requirements shall govern the taking and submission of data on the field intensity produced:

Beginning as near to the antenna as possible without including the induction field and to provide for the fact that a broadcast antenna not being a point source of radiation (not less than one wave length or 5 times the vertical height in the case of a single element, i. e., nondirectional antenna or 10 times the spacing between the elements of a directional antenna), measurements shall be made on eight or more radials, at intervals of approximately one-tenth mile up to 2 miles from the antenna, at intervals of approximately one-half mile from 2 miles to 6 miles from the antenna, at intervals of approximately 2 miles from 6 miles to 15 or 20 miles from the antenna, and a few additional measurements if needed at greater distances from the antenna. Where the antenna is rurally located and unobstructed measurements can be made, there shall be as many as 18 or 20 measurements on each radial. However, where the antenna is located in a city where unobstructed measurements are difficult to make, measurements shall be made on each radial at as many unobstructed locations as possible, even though the intervals are considerably less than stated above, particularly within 2 miles of the antenna. In cases where it is not possible to obtain accurate measurements at the closer distances (even out to 5 or 6 miles due to the character of the intervening terrain), the measurements at greater distances should be made at closer intervals.[18]

These data should be plotted for each radial in accordance with either of the two methods set forth below:

(1) Using log-log coordinate paper, plot field intensities as ordinate and distance as abscissa.

(2) Using semi-log coordinate paper, plot field intensity times distance as ordinate on the log scale and distance as abscissa on the linear scale.

However, regardless of which of these methods is employed, the proper curve to be drawn through the points plotted shall be determined by comparison with theoretical curves as follows: Plot theoretical curves (see paper by Mr. K. A. Norton, October 1936, Proc. I. R. E.) for several values of conductivities and dielectric constants, approximating the conductivity and dielectric constants indicated by the measurements on another sheet of the same coordinate paper. Place this sheet over the sheet on which the actual points have been plotted, hold to the light if necessary and adjust until the curve most closely matching the points is found. This curve should then be drawn on the sheet on which the points were plotted, together with the inverse distance curve corresponding to that curve. The field at 1 mile for the radial concerned shall be the ordinate on the inverse distance curve at 1 mile.

When all radials have been analyzed in this manner, a curve shall be plotted on polar coordinate paper from the fields obtained, which

[18] It is suggested that "wave tilt" measurements may be made to determine and compare locations for taking field intensity measurements, particularly to determine that there are no abrupt changes in ground conductivity or that reflected waves are not causing abnormal intensities.

gives the inverse distance field pattern at 1 mile. The radius of a circle, the area of which is equal to the area bounded by this pattern, is the effective field. (See section 3.16.)

While making the field intensity survey, the output power of the station shall be maintained at the licensed power as determined by the direct method. To do this it is necessary to determine accurately the total antenna resistance (the resistance variation method, the substitution method or bridge method is acceptable) and to measure the antenna current by means of an ammeter of acceptable accuracy.[19]

Complete data taken in conjunction with the field intensity measurements shall be submitted to the Commission in affidavit form including the following:

(1) Tabulation by number of each point of measurement to agree with the map required in (2) below and the field intensity meter reading, the attenuation constant, the field intensity (E), the distance from the antenna (D) and the product of the field intensity and distance (ED) (if data for each radial are plotted on semi-logarithmic paper, see above) for each point of measurement.

(2) Map showing each point of measurement numbered to agree with tabulation required above.

(3) Description of method used to take field intensity measurements.

(4) The family of theoretical curves used in determining the curve for each radial properly identified by conductivity and dielectric constants.

(5) The curves drawn for each radial and the field intensity pattern (see subsection B 5 *a*, *b*, and *c*).

(6) Antenna resistance measurement:

a. Antenna resistance at operating frequency.

b. Description of method employed.

c. Tabulation of complete data.

d. Curve showing antenna resistance versus frequency.

(7) Antenna current or currents maintained during field intensity measurements.

(8) Description, accuracy, date, and by whom each instrument was last calibrated.

[19] See section 3.54 and "Further Requirements for Direct Measurement of Power" and "Indicating Instruments Pursuant to Section 3.58."

(9) Name, address, and qualifications of the engineer making the measurements.

(10) Any other pertinent information.

B. Field Intensity Measurements to Establish Performance of Directional Antennas

Section 3.33 (*b*) requires that proof of performance of directional antenna systems be submitted before any operation during the regular broadcast day may be permitted. These data shall be taken upon proper request and authorization therefor during the experimental period, and shall show that the pattern obtained is essentially the same as that predicted by the application and required by terms of the authorization, and that any specific requirements set out are fully met.

To establish this performance, measurements shall be made in accordance with the preceding section A along sufficient number of radials to establish the effective field from the antenna system. In the case of a relatively simple directional antenna pattern, approximately eight radials in addition to the radials in the directions the field intensity values are specified by the authorization are sufficient. However, when more complicated patterns are involved, that is, patterns having several or sharp lobes or nulls, measurements shall be taken along as many additional radials as necessary to establish the pattern definitely.

In cases where the authorization requires a showing that actual field intensities of specified values be obtained in the various portions of the service area, sufficient measurements throughout these areas shall be made to show that at least the values specified are obtained. (See paragraph 2*d* of this section.)

In either of the above cases the following information shall be submitted in triplicate, even though such information was submitted with the original application:

(1) Complete description of antenna array.

a. Number of elements.

b. Manufacturer's name and type of each element (i. e., guyed or self-supporting, triangular or square, uniform cross-section or tapered, etc.).

c. If top loaded, give details.

d. Height of vertical lead of each element in feet (height above base insulator or base, if grounded).

e. Over-all height in feet of each element above ground level.

f. Over-all height in feet of each element above mean sea level.

g. Orientation of array with respect to true north and time (specify degrees leading or lagging) and space phasing of elements. (Space phasing should be given in feet as well as in degrees.)

h. Details of ground system for each element (length and number of radials, dimensions of ground screen, if used, and depth buried).

i. Current in each element (at point where antenna ammeter is located) and current and resistance at point of common input to the antenna system.[20]

j. Schematic sketch and description of method of feeding power to elements, including phasing and coupling equipment and locations of antenna ammeters (both regular, point of common input, and remote) in the circuits.

k. If not fully described above, give complete details and sketches if needed.

l. Full description of painting and lighting installed on each element.

m. If phase monitor is employed, state phase readings (specifying whether leading or lagging) and ratio of current indications for each element.[21]

(2) Horizontal field intensity patterns for each power involved showing:

a. Directional field intensity at 1 mile and effective field intensity from the antenna determined from the field intensity measurements as set forth above.

b. Direction true north shall be shown at zero azimuth.

c. Direction of each station or city specified in the instrument of authorization in which direction a limiting field was specified and the actual field intensity obtained in each of such directions (all directions shall be determined by accurate calculation or from Lambert Conformal Conic Projection Map such as United States Coast and Geodetic Survey Map No. 3060a, or map of equal accuracy, and all distances shall be determined by accurate calculation or from United States Albers Equal Area Projection Map, Scale $\frac{1}{2,500,000}$ or map of equal accuracy. These may be obtained from the United States Coast and Geodetic Survey and from the United States Department of Interior, Geological Survey, for the sums of 40 cents and $1, respectively).

d. Actual field intensity contours for 25, 10, and 5 mv/m and any other contours specified by the instrument of authorization on a map having the largest practical scale. These contours need not be shown for distances over 15 miles from the antenna except that the field intensity contours on the far sides of the business and residential areas of the city in which the main studio is located shall be shown. This does not waive the requirement for measurements at greater distance under A above.

(3) Complete tabulation of all data used in plotting the above patterns.

(4) Any other pertinent information.

(5) Plotting of field intensity patterns:

a. All patterns shall be plotted on standard letter-size polar coordinate paper (main engraving approximately 7″ x 10″).

b. All patterns shall be plotted to the largest scale possible on the paper specified in (*a*) above, using divisions and subdivisions having values of 1, 2, 2.5, or 5 times 10^x. (No other values shall be used.)

c. All values of field intensity less than 10 percent of the r. m. s. field intensity of the pattern shall be shown on an enlarged scale in accordance with (*a* and *b*) above.

As a check on the shape of the field intensity pattern obtained in accordance with the above, it is suggested that measurements be taken on each of the radials at approximately 1 mile from the antenna system for operation, both directional and nondirectional, and the ratios of these values plotted on polar coordinate paper in accordance with the above specifications.

[20] See "Further Requirements for Direct Measurement of Power" and "Construction, General Operation, and Safety of Life Requirements."

[21] See "Indicating Instruments Pursuant to Section 3.58."

C. Measurement of the Field Intensity of Broadcast Stations for Presentation in Support of Applications or Evidence at Hearings Before the Commission

Section 3.24 requires that among other things an application for a new standard broadcast station or increase in facilities of an existing station make a satisfactory showing that objectionable interference will not be caused to an existing station or stations.

In the determination of such interference in accordance with section 3.28, actual measurements will take precedence over theoretical values provided such measurements are properly taken and presented.

When measurements of either groundwave signal intensity or skywave signal intensity are presented in evidence, they shall be supported by a field intensity survey of the station observed, which survey should be sufficiently complete in accordance with sections A and B above to determine the field at 1 mile in the pertinent directions for that station.

When measurements are made on skywave signal intensity (either service or interference) they shall be graphic recordings as follows:

(1) Recordings shall be made on 10 or more nights for sufficient periods each night to obtain reasonable average values.[22]

(2) Observations shall be made on other stations to determine whether skywave transmission conditions are normal or not.

(3) Scales on the graphic paper shall be such as to permit easy reading of both time and field intensity, and calibration shall be clearly indicated.

(4) Pertinent notes, such as predominance of signal of a certain station, when recording composite signals shall be made on the recording.

(5) Full description shall be given the point where recordings were made (geographically as well as field intensity of the station to which interference is being determined).

(6) Full explanation of to what extent signals from other stations on the same channel affected the accuracy of the recordings and what steps, if any, were taken to eliminate or compensate for such signals.

If the observed station is owned or controlled by the party on whose behalf the measurements are made, then, in addition to the above, detailed reports on the measurement of the antenna resistance and on the amount of power actually radiated (as determined by the direct method) during the course of the field intensity measurements shall be presented. The applicant (or participant) shall also furnish a complete description of the antenna and ground system in use at the transmitting station during the period of observations and a statement as to whether or not this is the identical equipment regularly used by the station.

When measurements of both the "desired" and "undesired" station are made in one area to determine the point where objectionable interference from groundwave signals occurs, several measurements of each station shall be made within a few miles of the point where the ratio of signals is that selected as the appropriate ratio for the determination of objectionable interference.

All information on the above, including description and accuracy of equipment used, when and by whom last calibrated, and the name and qualifications of the engineer making the measurements, when filed with an application, shall be in affidavit form. At the time of the hearing on applications involving such observations, the applicant should be prepared to present, as sworn testimony, complete data on the above.

3. DATA REQUIRED WITH APPLICATIONS INVOLVING DIRECTIONAL ANTENNA SYSTEMS

Section 3.33 (a) requires that an application for authority to install a directional antenna specify a definite site and that full details of the directional antenna are given with the application. Any application not complete in these details will be returned to the applicant as "defective" under section 1.72.

In order to comply with the above and to permit proper consideration of any application involving a directional antenna, the following shall be submitted in triplicate, properly verified by the engineer designing the antenna, with each such application:

(1) Name, address, and qualifications of the engineer.

[22] See Annex III in section "Engineering Standards of Allocation" for detailed requirements.

(2) Complete description of the proposed antenna system.

a. Number of elements.

b. Type of each element [i. e., guyed or self-supporting, uniform cross section or tapered (specify base width), grounded or insulated, etc.].

c. If top loaded, give details.

d. Height of vertical lead of each element in feet (height above base insulator or base, if grounded).

e. Over-all height in feet of each element above ground level.

f. Over-all height in feet of each element above mean sea level.

g. Orientation of array with respect to true north and time phasing of fields from elements (specify degrees leading or lagging) and space phasing of elements (identifying elements). (Space phasing should be given in feet, as well as in degrees.)

h. Details of ground system for each element (length and number of radials, dimensions of ground screen, if used, and depth buried).

i. Ratio of fields from elements (identifying elements).

j. If not fully described above, give complete details and sketches if needed.

(3) Calculated horizontal field intensity patterns for each power involved showing:

a. Directional field intensity at 1 mile and effective field.

b. Direction true north shall be shown at zero azimuth.

c. Direction and distance to each existing station with which interference may be involved, operating either directional or nondirectional (all directions shall be determined by accurate calculation or from Lambert Conformal Conic Projection Map such as United States Coast and Geodetic Survey Map No. 3060a, or map of equal accuracy, and all distances shall be determined by accurate calculation or from United States Albers Equal Area Projection Map, scale $\frac{1}{2,500,000}$ or map of equal accuracy. These may be obtained from the United States Coast and Geodetic Survey and the United States Department of Interior, Geological Survey, for the sums of 40 cents and $1, respectively).

d. Calculated field intensity contours for 250, 25, and 5 mv/m and the population residing within each of such contours in addition to the information required by section 29 (*d*) of F. C. C. Form 301, on a map having the largest practical scale.

(4) Calculated vertical field intensity patterns (for nighttime power) in the direction of each minimum and the maximum and in the direction of each station with which nighttime interference may be involved, operating either directional or nondirectional for angles from 0° to 90° above the ground plane, based on the groundwave field intensity at 1 mile from the antenna for the direction involved.

(5) Data used in computing the above patterns including:

a. Formula used for calculating both horizontal and vertical patterns, and sample calculations. (Derivation of formula if other than standard is used.)

b. All assumptions made and basis therefor, including electrical height, current distribution and efficiency of each element, and ground conductivities.

c. Complete tabulation of calculation data used in plotting patterns, including data for determination of r. m. s. value of horizontal and directional patterns.

(6) Any other pertinent information.

(7) Plotting of field intensity patterns:

a. All patterns shall be plotted on standard letter-size polar coordinate paper (main engraving approximately 7″ x 10″).

b. All patterns shall be plotted to the largest scale possible on the paper specified in section (*a*) above using scale divisions and subdivisions having values of 1, 2, 2.5, or 5 items 10^x. (No other values shall be used.)

c. All values of field intensity less than 10 percent of the effective field intensity of the pattern shall be shown on an enlarged scale in accordance with (*a* and *b*) above.

d. In the event actual inverse distance field intensities expected to be determined in practice (that is, the values determined from actual measurements particularly in sharp nulls) are different from the above calculated values, the expected values as well as the calculated values shall be shown on both the full patterns and the enlarged sections.

4. LOCATIONS OF TRANSMITTERS OF STANDARD BROADCAST STATIONS

Section 3.24 (*e*) requires that the location of the transmitter shall comply with the requirements of good engineering practice. There are set out below the general requirements considered appropriate at this time. These standards will change as the art progresses and changes will be made in accordance with the best information available.

All applications for approval of transmitter sites for regular broadcast stations must be submitted on F. C. C. Form 304. In some cases the applicant may be required to submit additional information, including the results of a field intensity survey, particularly where there is any question as to whether the area can be served properly from the proposed location or where the population of the blanket area is too large.

F. C. C. Form 304 requires among other things that triplicate copies of the following be submitted:

(*a*) Map or maps having reasonable scales (not less than one-half inch per mile) clearly showing:

(1) Proposed location and present location if existing station;

(2) The character of the surrounding areas, particularly the retail business, wholesale business, manufacturing, residential, and unpopulated areas (by symbols, cross-hatching, colored crayons, or other means);

(3) The density and distribution of population;

(4) The heights of all tall buildings or other structures in the vicinity of the antenna, indicating their location and how marked for air navigation;

(5) The location of airports, airways, and other radio stations, including receiving stations, except broadcast or amateur;

(6) The terrain and types of soil.

(*b*) Aerial photograph or photographs taken of the proposed location of the antenna showing clearly the character of the area within the 250 mv/m contour. (Ordinary photographs will be accepted if they clearly show the terrain to the 250 mv/m contour and are taken in at least eight directions from the site: north, northeast, east, etc.)

Where available, United States Geological Survey topography quadrangle sheets should be submitted. In the event the map submitted does not give the topography, the height above sea level of the proposed location, hills, ridges, and other obstructions should be shown. A statement as to whether or not other obstructions in the vicinity are painted and lighted or otherwise marked should always be made. In some cases additional maps, sketches, or descriptions may be necessary to show clearly the conditions. Attention is invited to the fact that the submission of complete and accurate information will materially expedite action on a proposed location, as well as enable the Commission to reach a correct decision thereon.

Aerial photographs of adequate scale are normally considerably superior to photographs taken from the proposed site. However, if the latter clearly show the character of the surrounding area, they are acceptable. Photographs taken from a location lower than the surrounding terrain or where the view is obstructed by immediately surrounding objects are of little value. Taking the photographs from a step ladder or other support will aid materially.

As a guide, the Engineering Department has established certain engineering principles based on the extensive experience of the Engineering Department and all data available along this line, including that presented at the informal engineering hearings of October 5, 1936, January 18, 1937, and June 6, 1938.

The four primary objectives to be obtained in the selection of a site for a transmitter of a broadcast station are as follows:

(1) To serve adequately the center of population in which the studio is located and to give maximum coverage to adjacent areas.

(2) To cause and experience minimum interference to and from other stations.

(3) To present a minimum hazard to air navigation consistent with objectives 1 and 2.

(4) To fulfill certain other requirements given below.

The following table is offered as a general guide to be used in determining the approximate site of broadcast transmitters:

area that may be permitted in the blanket area. In general, broadcast transmitters operating with approximately the same power can be grouped in the same approximate area and thereby reduce the interference between them.

If the city is of irregular shape, it is often possible to take advantage of this in selecting a suitable location that will give a maximum coverage and at the same time maintain a minimum of people within the blanket area. The maps giving the density of population will be a key to this. The map giving the elevation by contours will be a key to the obstructing hills between the site and city. The map of the soil conditions will assist in determining the efficiency of the radiating system that may be erected and the absorption of the signal encountered in the surrounding area.

Another factor to be considered is the relation of the site to airports and airways. There are no regulations or laws with respect to distance from airports and airways, but a distance of 3 miles from each is used as a guide. In case a suitable location is found at less distance than this, it may be satisfactory if the towers are suitably painted and lighted in conformity with the requirements of the Civil Aeronautics Administration, or if the towers are not higher than the surrounding objects. The latter is normally considered poor engineering practice; however, in selecting a site the local aeronautical authorities should always be consulted if there is any question concerning erecting a hazard to aviation, and in case of towers over 200 feet high this should always be done. In passing on a location and antenna installation, the Engineering Department refers each case to the Civil Aeronautics Administration for its recommendation. The action of the Administration will be materially expedited by the district airline inspector and local representatives of the airports and airlines forwarding their approval or comments to the Civil Aeronautics Administration, Washington, D. C.

In finally selecting the site, consideration must be given to the required space for erecting an efficient radiating system, including the ground or counterpoise (see section 3.45). It is the general practice to use direct grounds consisting of a radial buried wire system. If the area is such that it is not possible to get such ground system in soil that remains moist throughout the year, it probably will be found better to erect a counterpoise. (Such a site should be selected only as a last resort.) It, like the antenna itself, must of course be designed properly for the operating frequency and other local conditions.

While an experienced engineer can sometimes select a satisfactory site for a 100-watt station by inspection, it is necessary for a higher power station to make a field-intensity survey to determine that the site selected will be entirely satisfactory. There are several facts that cannot be determined by inspection that make a survey very desirable for all locations removed from the city. Often two or more sites may be selected that appear to be of equal promise. It is only by means of field-intensity surveys taken with a transmitter at the different sites or from measurements on the signal of nearby stations traversing the terrain involved that the most desirable site can be determined. There are many factors regarding site efficiency that cannot be determined by any other method.

The site selected should meet the following conditions:

(1) A minimum field intensity of 25 to 50 mv/m will be obtained over the business or factory areas of the city.

(2) A minimum field intensity of 5 to 10 mv/m will be obtained over the most distant residential section.

(3) The absorption of the signal is the minimum for any obtainable sites in the area. As a guide in this respect the absorption of the signals from other stations in that area should be followed, as well as the results of tests on other sites.

(4) The population within the blanket radius (250 mv/m) does not exceed that specified by Table A.

When making the final selection of a site, the need for a field-intensity survey to establish the exact conditions cannot be stressed too strongly. The selection of a proper site for a broadcast station is an important engineering problem and can only be done properly by experienced radio engineers.

5. MINIMUM ANTENNA HEIGHTS OR FIELD INTENSITY REQUIREMENTS

Section 3.45 requires that all applicants for new, additional, or different broadcast facilities and all licensees requesting authority to move the transmitter of an existing station, shall specify a radiating system, the efficiency of which complies with the requirements of good engineering practice for the class and power of the station.

The specifications deemed necessary to meet the requirements of good engineering practice at the present state of the art are set out in detail below.

The licensee of a standard broadcast station requesting a change in power, time of operation, frequency, or transmitter location must also request authority to install a new antenna system or to make changes in the existing antenna system which will meet the minimum height requirements, or submit evidence [23] that the present antenna system meets the mimimum requirements with respect to field intensity, before favorable consideration will be given thereto. In the event it is proposed to make substantial changes in an existing antenna system, the changes shall be such as to meet the minimum height requirements or will be permitted subject to the submission of field intensity measurements showing that it meets the minimum requirements with respect to effective field intensity.

These minimum actual physical vertical heights of antennas permitted to be installed are shown by curves A, B, and C of Figure 7 as follows:

A. Class IV stations, 150 feet [24] or a minimum effective field intensity of 150 mv/m for 1 kw (100 watts, 47.5 mv/m and 250 watts, 75 mv/m)

B. Class II and III stations, or a minimum effective field intensity of 175 mv/m for 1 kw.

C. Class I stations, or a minimum effective field intensity of 225 mv/m for 1 kw.

The heights given on the graph for the antenna apply regardless of whether the antenna is located on the ground or on a building. Except for the reduction of shadows, locating the antenna on a building does not necessarily increase the efficiency and where the height of the building is in the order of a quarter wave the efficiency may be materially reduced.

To obtain the maximum efficiency of which any antenna is capable a good ground system must be employed (a counterpoise may be substituted under certain conditions).

At the present development of the art, it is considered that where a vertical radiator is employed with its base on the ground, the ground system should consist of buried radial wires at least one-fourth wavelength long. There should be as many of these radials evenly spaced as practicable and in no event less than 90. (120 radials of 0.35 to 0.4 of a wavelength in length and spaced 3° is considered an excellent ground system and in case of high base current, a base screen of suitable dimensions should be employed.)

It should be borne in mind that the above specifications are the minimum and where possible better antenna and ground systems should be installed.

In case it is contended that the required antenna efficiency can be obtained with an antenna of height or ground system less than the minimum specified, a complete field intensity survey [25] must be supplied to the Commission showing that the field intensity at a mile without absorption fulfills the minimum requirements. This field survey must be made by a qualified engineer using equipment of acceptable accuracy.

The main element or elements of a directional antenna system shall meet the above minimum requirements with respect to height or effective field intensity. No directional antenna system will be approved which is so designed that the effective field of the array is less than the minimum prescribed for the class of station concerned, or in case of a Class I station less than 90 percent of the groundwave field which would be obtained from a perfect antenna of the height specified by Figure 7 for operation on frequencies below 1000 kc., and in the case of a Class II or III station less than 90 percent of the groundwave field which would be obtained from a perfect antenna of the height specified

[23] See Field Intensity Measurements in Broadcast Allocation, section A.

[24] This height applies to a Class IV station on a local channel only. In case a Class IV station is assigned a regional channel Curve A shall apply.

[25] See Field Intensity Measurements in Broadcast Allocation, section A.

by Figure 7 for operation on frequencies below 750 kc.

In all cases of new construction where concentric transmission line is used between the transmitter and antenna, such line shall be installed in duplicate with adequate switching facilities for immediate connection of the second line in case of failure of the first line, or permanently installed auxiliary facilities such as an auxiliary transmitter and antenna system, auxiliary antenna system or other means whereby operation may be continued in the event of failure of the transmission line.

Before any changes are made in the antenna system, it is necessary to submit full details to the Commission for approval. These data may be submitted by letter.

6. STANDARD LAMPS AND PAINTS

Section 3.45 (*d*) requires that the antenna and supporting structure shall be painted and illuminated in accordance with the specifications supplied by the Commission pursuant to section 303 (*q*) of the Communications Act of 1934.

These individual specifications are issued for and attached to each authorization for an installation.[26] The details of the specifications depend on the degree of hazard presented by the particular installation. The following standard lamps and paints shall be used for the type of marking specified:

(*a*) *Painting.*—Each tower shall be painted throughout its height with alternate horizontal bands of international orange and white, terminating with orange bands at both top and bottom. (Orange yellow No. 5 color card, supplement to U. S. Army Quartermaster Corps Specifications No. 3–1.) The width of the orange bands shall be approximately one-seventh of the height of any structure less than 250 feet in height, and between 30 and 40 feet for structures over 250 feet in height. The width of the white bands shall be one-half that of the orange bands.

(*b*) *Lighting.*—(1) Towers, the over-all heights of which do not exceed 200 feet, shall be lighted as follows:

At the top of each tower there shall be installed two 100-watt lamps, enclosed in aviation red prismatic obstruction light globes. At least one of these lamps shall burn continuously from sunset to sunrise. When only one lamp is operated, the circuit shall be equipped with a relay for instant automatic switchover to the other lamp in case of lamp failure.

[26] Specifications normally attached to authorization.

At both the one-third and two-thirds levels of each tower there shall be installed two 100-watt lamps enclosed in aviation red prismatic obstruction light globes, at each level, one each on diagonally opposite corners of the structure.

All 100-watt lamps shall be type A–21 clear bulb traffic signal lamps (2,000 hours or equal).

All lamps shall be enclosed in aviation red prismatic obstruction light globes, and all lighting shall be exhibited from sunset to sunrise.

* * * * *

Special conditions of terrain and location with respect to airports or airways may require additional lighting of the character hereinafter specified for towers the over-all height of which exceeds 200 feet.

* * * * *

(2) Towers, the over-all heights of which exceed 200 feet but do not exceed 300 feet, shall be lighted as follows:

At the top of each tower there shall be installed a hazard beacon similar and equal in effectiveness to the standard 300 m./m. airways electric lantern. This beacon shall flash and shall be equipped with two 500-watt lamps (both lamps to burn simultaneously) and aviation red color shades. The 300 m./m. electric code beacon shall be equipped with a flashing mechanism producing 40 flashes per minute, having a luminous period of 1 second, and a period of darkness of one-half second.

The one-third and two-thirds levels of the tower shall be marked by 100-watt obstruction lights the same as specified for towers not exceeding 200 feet in height.

* * * * *

Towers over 300 feet in height (and less than 300 feet in height where special conditions obtain) may be required to install additional marking as follows:

GENERAL

Under particularly hazardous conditions and in areas of heavy air traffic, it may be necessary to add a 24-inch, 500- or 1000-watt red rotating beacon equipped with an automatic lamp changer, to mark the installation. The beacon may be installed on the roof of the transmitter building, provided the point will afford proper visibility, otherwise it may be necessary to install the beacon on a separate tower of proper height or on the radio tower itself. The recommended setting of this rotating beacon is such that the center line of the light beam shall be approximately 3° above horizontal.

Adequate red warning lights shall be placed on the structure or structures during the period of construction and until the specified obstruction lights are installed and in operation.

Under certain conditions it may be required to have the lighting controlled by a light-sensitive control device, the adjustment being such that lights will be turned on at a north sky light intensity level of 20-foot candles and turned off at a north sky light intensity level of 40-foot candles.

Under certain conditions it may be required to install and operate a radio obstruction marker of a type to be specified.

Foregoing specifications require that at both the one-third and two-thirds levels of the structure there shall be installed two 100-watt lamps enclosed in aviation red prismatic obstruction light globes, at each level, one each on diagonally opposite corners of the structure.

Under certain conditions and in the case of triangular and other towers of unusual design, it may be required to install 100-watt lamps enclosed in aviation red prismatic obstruction light globes at various corners and levels throughout the height of the structure in such manner that adequate visibility and definition would be obtained from all angles of approach.

Towers of excessive height or peculiar (unusual) design will be made the subject of special investigation and analysis to determine proper marking and lighting.

In addition to the standard marking and lighting of the main structure, towers using guy wires will be made the subject of special study to determine proper marking and lighting of the guy wires.

The specifications relative to obstruction marking and lighting of radio towers of a certain height are general, and in locations of extreme hazard to air navigation, it may be required to install additional equipment on any height tower, in order to obtain suitable protection.

(*a*) Type A–21, 100-watt traffic signal, clear, medium screw base lamps enclosed in aviation red prismatic obstruction light globes shall be employed in all cases where 100-watt lamps are specified.

(*b*) Type PS–30, 200-watt general lighting service, clear, mogul prefocus base lamps shall be employed in all cases where code beacons with 200-watt lamps are specified.

(*c*) Type PS–40, 500-watt general lighting service, clear, mogul prefocus base lamps shall be employed in all cases where code beacons with 500-watt lamps are specified.

(*d*) Type T–24, 500-watt aviation lighting service, clear, mogul bi-post base lamps shall be employed in all cases where rotating beacons with 500-watt lamps are specified.

(*e*) Type T–20, 1000-watt aviation lighting service, clear, mogul bi-post base lamps shall be employed in all cases where rotating beacons with 1000-watt lamps are specified.

(*f*) The tower paint shall be kept in good condition and repainted as often as necessary to maintain this condition. Towers now painted black and yellow shall, when repainting is necessary, be painted in accordance with the present standards.[26]

7. FURTHER REQUIREMENTS FOR DIRECT MEASUREMENT OF POWER

Section 3.54 states that the antenna input power determined by direct measurement is the square of the antenna current times the antenna resistance at the point where the current is measured and at the operating frequency, and sets forth certain requirements relative to the determination of the resistance and measurement of the antenna current.

The Commission does not specify any particular method of making antenna resistance measurements. Measurements made by any standard method will be accepted, provided satisfactory evidence is submitted in accordance with the following as to the procedure used, accuracy of the instruments, and qualifications of the engineer conducting the measurements.

The resistance variation method, substitution method, and bridge method are acceptable methods for measuring the total antenna resistance and the following general instructions are given as a guide.

The apparatus required is as follows:

(*a*) Radio frequency generator to cover the frequency range necessary, power 50 watts or required power when using bridge method.

(*b*) Wavemeter for broadcasting frequency, accuracy 0.25 percent.

(*c*) Decade resistor having steps of units, tens, and hundreds ohms resistance, or equivalent, accuracy, 1.0 percent.

(*d*) Radio frequency galvanometer or milliammeter of approved type, accuracy 2.0 percent.

(*e*) Approved tuning condenser of approximately 0.001 MFD capacity and tuning inductance of approximately 60 MH.

(*f*) Or suitable bridge if this method is used.

The broadcast transmitter is not usually satisfactory for use as the source of radio frequencies. The maximum power dissipated in the antenna while making measurements should not be over 10 percent of the power available from the radio-frequency generator.

[26] Specifications normally attached to authorization.

An accurate determination of the antenna resistance can only be made by taking a series of measurements each for a different frequency. From 10 to 12 resistance measurements covering a band 50 to 60 kc. wide with the operating frequency near the middle of the band must be made to give data from which accurate results may be obtained. The values measured should be plotted with frequency as abscissa and resistance in ohms as ordinate and a smooth curve drawn. The point on the ordinate where this curve intersects the operating frequency gives the value of the antenna resistance.

In order to comply with the provisions of section 3.54 the following data should be submitted in duplicate to the Commission in affidavit form, accompanied by duplicate copies of F. C. C. Form 306 properly executed:

(1) Complete data taken.

(2) The graph drawn.

(3) Description of method used to take readings (include schematic circuit diagrams of the measurement circuit and of the antenna system showing point of measurement and location in circuit of both regular and remote antenna ammeters).

(4) Manufacturer's name of each calibrated instrument used and manufacturer's rated accuracy.

(5) Accuracy, date and by whom each instrument was last calibrated.

(6) Qualifications of engineer making measurements.

Licensees of broadcast stations authorized to employ directional antenna systems desiring to determine the operating power by direct measurement of the antenna power shall determine the resistance by the following method:

Measure the resistance at the point of common radio frequency input to the directional antenna system. The following conditions and procedure shall obtain:

(*a*) The antenna shall be finally adjusted for the required pattern.

(*b*) The reactance at the operating frequency and at the point of measurement shall be adjusted to zero or as near thereto as practical.

(*c*) Suitable radio-frequency bridge or other method shall be employed to determine the resistance and reactance at the point of common radio frequency input in the same manner as set forth above for a single antenna.

(*d*) Resistance and reactance measurements at approximately 5, 10, 15, and 20 kc. on each side of the operating frequency shall be made. The values measured shall be plotted and the resistance at the operating frequency determined in the same manner as for a single-element antenna.

(*e*) A permanently installed antenna ammeter shall be placed in each element of the system as well as at the point of measurement of resistance, with the remote reading ammeters[27] located in the transmitter room. The application for authority to determine power by the direct method shall specify not only the current at the point of resistance measurement for the authorized input power (I^2R in accordance with section 3.54 and (*f*) below), but also the current of each element of the system when adjusted for the required pattern and for the authorized operating power.

(*f*) The license for a station of power of 5 kw. or under, which employs a directional antenna and determines the power by the direct method, will specify the antenna resistance as 92.5 percent of that determined at the point of common input in accordance with the above. The resistance specified for stations of a power over 5 kw. will be 95 percent of that determined at the point of common input.

8. POWER RATING OF VACUUM TUBES

Section 3.42 requires that the maximum rated carrier power of a standard broadcast transmitter shall be determined as the sum of the applicable power ratings of the vacuum tubes employed in the last radio stage. The approved power ratings of vacuum tubes for operation in the last radio stages of broadcast transmitters are fixed as set out in the following tables:

[27] In all cases regular antenna ammeters and remote antenna ammeters shall comply with the requirements of section 3.58 and "Indicating Instruments Pursuant to Section 3.58."

TABLE A.[1]—*Power rating of vacuum tubes for high-level modulation or plate modulation in the last radio stage*

Power rating (watts)	Amperex	Collins	De-Forest	Eitel Mc-Cullough	Federal Telegraph	General Electric Co.	Heintz & Kaufman	Hygrade Sylvania	Machlett Labs.	R. C. A. Mfg. Co.	Raytheon Production Corp.	Sheldon Electric Co.	Taylor Tubes, Inc.	United Electronics	Western Electric	Westinghouse Electric & Mfg. Co.
50	....	....	....	35-T 50-T	....	GL-276-A	HK-54 158	....	....	808	RK-32 RK-35 RK-37 RK-47 RK-51 RK-52	35-T	T-40 T-55	....	211-D 211-E 248-A 276-A	
75	HF-100 203-A 211 838 852 860	C-203-A C-211	503-A 511 552 560	....	F-303-A F-311-A F-352-A	GL-203-A GL-211 GL-242-C GL-835 GL-838 GL-860	154	203-A 211 852 860	ML-203-A ML-211 ML-838	203-A 211 838 850 852 860	RK-58	....	203-A 211	UE-100 203-A 211 261-A 303-A 311 361-A 838 852 938 952	242-A 242-B 242-C 260-A 261-A 284-A 295-A	WL-195 WL-196 WL-203-A WL-211 WL-469 WL-838 WL-850 WL-860
100	....	....	....	100-TH 100-TL 75-T	F-102-A F-108-A	....	152-L 254	....	....	....	RK-36 RK-38 RK-48	100-TH	TW-75	....	....	WL-460 WL-468
125	HF-200 203-H 211-C 211-D 211-H 805 810 813	C-200 C-201 C-211-D	....	150-T 4-125-A	F-123-A	GL-803 GL-805 GL-810	....	....	....	4-125-A/4D21 803 805 810	RK-57 RK-28-A	....	HD-203A T-125 TW-150 805	HV-18 805 810 905	....	WL-463 WL-803 WL-805 WL-810
250	204-A HF-300 212-E	C-204-A C-300	504-A 561 571	4-250-A 152-TL 152-TH	F-127-A F-204-A F-212-E F-331-A	GL-204-A GL-806 GL-861	304-H 304-L 354 HK-354-A HK-354-C HK-354-D HK-354-E HK-354-F 454-H 454-L	204-A 212-D 831 861	ML-204-A	204-A 806 831 861	RK-63	....	T-200 204-A 814 822	KU-23 204-A 212-E 304-A 312-E	212-D 212-E	WL-204-A WL-806 WL-861
350	270-A 849	....	549	250-TH 250-TL 300-T	F-100-A F-849	GL-849	....	849....	ML-849	849	....	250-TH	....	849 949	270-A	WL-849
500	251-A 833-A	....	....	304-TL 304-TH 450-TL 450-TH	....	GL-833	255 654 854-H 854-L	....	ML-833-A	833 833-A	....	450-TH	....	....	251-A 357-A 357-B	WL-833 WL-833-A
750	279-A 849-A 849-H 851	C-849-A C-849-H	551	500-T	F-121-A F-351-A	GL-851	2054-A	851	ML-849-A ML-851	851	....	....	....	949-A 949-H 851 951	279-A 379-A	WL-851
1000	846	....	....	750-TL 750-TH	F-128-A F-346-A	GL-846	1054-L 1554	846	ML-846	846	....	....	....	846	....	WL-846
2500	228-A 1652 HF-3000 ZB-3200	....	520-B 520-M	1500-T	F-328-A F-328-B F-348 F-3652-A	GL-207 GL-889	3054	820-B	ML-889-A ML-889-RA ML-891-R	520-B 1652	....	....	....	207	228-A	WL-473 WL-889-R

See footnote at end of table D.

TABLE A.[1]—*Power rating of vacuum tubes for high-level modulation or plate modulation in the last radio stage*—Continued

Power rating (watts)	Amperex	Collins	De-Forest	Eitel Mc-Cullough	Federal Telegraph	General Electric Co.	Heintz & Kaufman	Hygrade Sylvania	Machlett Labs.	R. C. A. Mfg. Co.	Raytheon Production Corp.	Sheldon Electric Co.	Taylor Tubes, Inc.	United Electronics	Western Electric	Westinghouse Electric & Mfg. Co.
5000	207 220-C 343-A 343-R 848 863 891 892 892-R	....	507 548 563	2000-T 3X2500A3 3X2500F3	F-126-A F-129-B F-129-R F-307-A F-320-A F-320-B F-343-A F-348-A F-363-A F-891 F-892 F-892-R	GL-891 GL-892 GL-892-R	....	207 848 863	ML-207 ML-891 ML-892 ML-892-R	207 848 863 891 892 892-R	....	....	....	....	220-B 220-C 343-A 220-CA 343-AA	WL-207 WL-891 WL-892 WL-892-R
10,000	232-B 342-A	....	....	....	F-101-B F-110-A F-110-X F-116-A F-131-A F-131-R F-328-B F-332-A F-332-B F-332-C F-342-A F-342-R F-358-A	GL-880 GL-893	....	....	ML-880 ML-893-A ML-893-AR	858 893-AR 839-R	....	....	....	....	232-A 232-B 232-BA 342-A	WL-858 WL-893 WL-893-R WL-899
25,000	....	....	....	3X12500A3	F-117-B F-124-A F-124-R 7C-30 9C-31	....	....	....	....	9C22	....	....	....	....	....	WL-880 WL-895-R
40,000	....	....	....	....	F-862 F-898	GL-862 GL-898	....	....	....	862 898	....	....	....	....	298-A	WL-862 WL-898
100,000	....	....	....	....	....	....	....	....	....	....	....	....	....	....	320-A	

TABLE B.[1]—*Power rating of vacuum tubes for low-level modulation or last radio stage operating as linear power amplifier*

Power rating (watts)	Amperex	Collins	De-Forest	Eitel Mc-Cullough	Federal Telegraph	General Electric Co.	Heintz & Kaufman	Hygrade Sylvania	Machlett Labs.	R. C. A. Mfg. Co.	Raytheon Production Corp.	Sheldon Electric Co.	Taylor Tubes, Inc.	United Electronics	Western Electric	Westinghouse Electric & Mfg. Co.
25	....	....	....	75-T	....	GL-203-A	154	....	ML-203-A	203-A	RK-32 RK-35 RK-37 RK-47 RK-51	....	T-55 TW-75 203-A 211 211-C	....	....	WL-203-A
50	HF-200 203-H 211-H 242-C	....	....	100-TH 100-TL 150-T 152-TH 152-TL	F-123-A	GL-242-C GL-803 GL-810	152-L HK-354 HK-354-A HK-354-C HK-354-D HK-354-E HK-354-F	....	....	803 806 810	RK-36 RK-38 RK-57 RK-58 RK-28-A RK-48	100-TH	T-125 TW-150 HD-203-A	....	242-B 242-C	WL-803 WL-810

75	HF-300 212-E 204-A	....	504-A	....	F-127-A F-204-A F-212-E	GL-204-A	257 454-H 454-L	204-A 212-D	ML-204-A	204-A	RK-63	....	T-200 204-A 814 822	204-A 212-E 304-A 312-E	212-D 212-E	WL-204-A
100	....	....	....	....	....	....	304-H 304-L									
125	270-A 849	....	549	250-TH 250-TL 300-T 304-TH 304-TL 450-TL 450-TH	F-100-A F-849	GL-833 GL-849	654 854-H 854-L	849	ML-833-A ML-849	833 833-A 849	....	250-TH 450-TH	....	849 949	270-A	WL-833 WL-833-A WL-849
250	251-A 849-A 849-H	C-849-A C-849-H	551	500-T	F-121-A F-128-A F-351-A	GL-851	255 1054-L 1554	851	ML-849-A ML-851	851	....	....	....	851 951	251-A	WL-851
350	851	....	....	750-TL 750-TH												
500	279-A 846	....	....	1000-UHF 1500-T	F-346-A	GL-846	2054-A 3054	846	ML-846	846	....	....	....	....	279-A 379-A	WL-473 WL-846
1000	228-A 228-R 1652 ZB-3200	....	520-B 520-M	2000-T	F-328-A F-328-B F-3652-A	....	....	820-B	....	520-B 1652	....	....	....	....	228-A	
1250	....	....	....	....	....	GL-889	....	....	ML-889 ML-889-R ML-891							
2500	207 220-C 343-A 343-R 863 892 892-R	....	507 569	....	F-126-A F-131-A F-307-A F-320-A F-320-B F-343-A F-363-A F-892 F-892-R	GL-207 GL-892 GL-892-R	....	207 863	ML-207 ML-892 ML-892-R	207 863 892	....	....	....	....	220-B 220-C 220-CA 343-A 343-AA	WL-207 WL-889 WL-892
5000	....	....	....	....	F-237-BA F-358-A	GL-858	....	....	....	858	....	....	....	....	232-BA	WL-858
8500	232-B 342-A	....	....	....	F-101-B F-110-A F-110-X F-116-A F-131-A F-332-A F-332-B F-332-C F-342-A	....	....	....	ML-893-AR	....	....	....	....	....	232-A 232-B 342-A	WL-893-R
10000	....	....	....	....	....	GL-880 GL-893	....	....	ML-880 ML-893-A	893-AR	....	....	....	....	....	WL-893 WL-899
12500	....	....	....	....	F-117-B F-124-A											
25000	....	....	....	....	F-862 F-898	GL-862 GL-898	....	....	....	862 898	....	....	....	....	298-A	WL-862 WL-898
75000	....	....	....	....	....	....	....	....	....	....	....	....	....	....	320-A	

See footnote at end of table D.

760684°—47——3

Table BC.[1]—*Power rating of vacuum tubes for low-level modulation in the last radio stage operating as linear power amplifier where efficiency approaches that of Class C operation*

Power rating (watts)	Amperex	Collins	De-Forest	Eitel Mc-Cullough	Federal Telegraph	General Electric Co.	Heinz & Kaufman	Hygrade Sylvania	Machlett Labs.	R. C. A. Mfg. Co.	Raytheon Production Corp.	Sheldon Electric Co.	Taylor Tubes, Inc.	United Electronics	Western Electric	Westinghouse Electric & Mfg. Co.
250													822		357-A 357-B	
2500															220-CA	
5000															232-BA	

Table C.[1]—*Power rating of vacuum tubes for grid modulation in the last radio stage (operating efficiency 25 percent)*

Power rating (watts)	Amperex	Collins	De-Forest	Eitel Mc-Cullough	Federal Telegraph	General Electric Co.	Heinz & Kaufman	Hygrade Sylvania	Machlett Labs.	R. C. A. Mfg. Co.	Raytheon Production Corp.	Sheldon Electric Co.	Taylor Tubes, Inc.	United Electronics	Western Electric	Westinghouse Electric & Mfg. Co.
25				75-T									822			
50	212-E 241-B 270-A			250-TH 250-TL	F-212-E		304-H 304-L 354 HK-354-A HK-354-C 454-H 454-L				RK-63	250-TH	T-200 TW-150		212-E 270-A	
100				300-T			654									
125				450-TL 500-T 750-TL			255 854-H 854-L					450-TH				
250				1000-UHF			1054-L 1554									
350				1500-T												
500				2000-T			3054									

Table D.[1]—*Power rating of vacuum tubes for grid modulation in the last radio stage (operating efficiency 35 percent)*

Power rating (watts)	Amperex	Collins	DeForest	Eitel Mc-Cullough	Federal Telegraph	General Electric Co.	Heintz & Kaufman	Hygrade Sylvania	Machlett Labs.	R. C. A. Mfg. Co.	Raytheon Production Corp.	Sheldon Electric Co.	Taylor Tubes, Inc.	United Electronics	Western Electric	Westinghouse Electric & Mfg. Co.
25													TW-75			
50				152-TL 152-TH	F-212-E	212-E.									242-C	
125				304-TL 304-TH												
250	849-A 849-H															
1000					F-328-A										228-A	
2500	343-R 892 892-R	C892			F-307-A F-892 F-892-R					892						
10000																WL-895-R

[1] These tables apply only to tube ratings for use in the last radio stage of broadcast transmitters and may not be applicable to any other service.

If in an application to the Commission a vacuum tube of a type number and power rating not given in the foregoing tables is specified for operation in the last radio stage, it may be accepted provided there is also submitted to and approved by the Commission the manufacturer's rating of the vacuum tube for the system of modulation or class of service contemplated. These data must be supplied by the manufacturer. (See section 3.42 and "Requirements for Approval of Power Rating of Vacuum Tubes.")

9. REQUIREMENTS FOR APPROVAL OF POWER RATING OF VACUUM TUBES

Section 3.42 (*c*) requires that only vacuum tubes of approved rating be employed in the last radio stages of standard broadcast transmitters and that such approved ratings will be given only upon submission of the ratings by the manufacturer.

These ratings shall be supplied under oath in the following table form:

TABLE (A, B, C, or D).—*Class of operation*

[State whether for plate modulation in the last radio stage, low level modulation, or grid modulation in the last radio stage. See section 3.52]

Type of tube	Epn	Epmn	Ipn	Ipmn	RL	Ec	Power rating
----------	----	----	----	----	----	----	----
----------	----	----	----	----	----	----	----
----------	----	----	----	----	----	----	----
----------	----	----	----	----	----	----	----
----------	----	----	----	----	----	----	----

The value of Epn and Ipn are those values that are recommended by the manufacturers for operation at the power rating specified. The values of Epmn and Ipmn are the maximum continuous operating values that the manufacturers will stand by their guarantee on the tube specified when used in the class of service above set out.

The power ratings given above are to apply when the following conditions and limitations as to operation prevail:

(1) The vacuum tubes are to be used in the last radio stage of standard broadcast transmitters.

(2) On the broadcast frequencies of 550 to 1,600 kc., inclusive.

(3) The percentage of amplitude distortion or harmonic generation by the entire transmitter (from microphone terminals to antenna outputs) is not to be over 10 percent at 100 percent modulation. The radio harmonics are not to exceed the amount considered in accordance with good engineering practice. (See section 3.46 and "Construction, General Operation and Safety of Life Requirements" to comply with section 3.46.)

(4) The ventilation, cooling, general condition of circuits with respect to tuning, impedance match, and maintenance are to be those encountered in the average broadcast station and in accordance with good engineering practice. The operation, general maintenance, and adjustments are to be those ordinarily encountered in a broadcast station.

(5) The regulation of the power supply is to be that which has been found to exist throughout the United States where broadcast stations are located or may be located.

(6) Table A should give the power rating for use in transmitter employing plate modulation in last radio stage under the above specified conditions. (See section 3.52, Table A.)

(7) Table B should give the rating for use in transmitter employing low level modulation under the above specified conditions. (See section 3.52, Table B.)

(8) Tables C and D should give the power rating for use in transmitter employing grid modulation in the last radio stage under the above specified conditions and plate efficiencies of 25 and 35 percent, respectively. (Request for approval of ratings for grid modulation in the last radio stage should specify whether the operating efficiency is to be 25 percent or 35 percent. No tube will be approved for both efficiencies. See section 3.52, Table C.)

(9) The operating power of the transmitter is to be determined by sections 3.51, 3.52, 3.53, and 3.54.

(10) Due consideration will be given to the general standard of rating so that tubes manufactured by different firms but having practically the same absolute characteristics will have approximately the same power rating.

(11) The power rating should be an even power step as recognized by the Commission's plan of allocation (100 watts, 250 watts, 500 watts, 1000 watts, 5 kw., 10 kw., 25 kw., 50 kw.), or other ratings established in "Power Rating of Vacuum Tubes." If any other rating is desired, it will be necessary to support the request with satisfactory reasons therefor.

10. PLATE EFFICIENCY OF LAST RADIO STAGE

Section 3.53 requires that in computing the operating power of standard broadcast stations by the indirect method the efficiency factors specified in section 3.52 shall apply in all cases and no distinction will be recognized due to the operating power being less than the maximum rated carrier power.[28]

In compliance with this rule, standard broadcast stations permitted to determine the operating power by the indirect method in accordance with section 3.51 (*b*) and to employ greater daytime power than nighttime power shall maintain the same operating efficiency for both daytime and nighttime operations.[29]

To determine whether this condition obtains, the following procedure should be used:

The apparent antenna resistance should be computed from the daytime (highest power) operating constants and then the nighttime power in the antenna determined from the I^2R, using the apparent resistance previously determined. If this computed antenna power agrees with the nighttime operating power determined by the indirect method within plus or minus 5 percent, the station is considered as complying with the requirement of maintaining the same operating efficiency. In case the antenna current is subject to variation due to weather or other conditions, an attempt should be made to arrive at an average value for the purpose of the computations referred to herein.

11. OPERATING POWER TOLERANCE

Section 3.57 requires that except in case of emergency beyond the control of the licensee, the operating power of each standard broadcast station shall be maintained within the prescribed limits of the licensed power.

Each station shall be operated at all times as near to the authorized power as practicable. However, in order to provide for variations in the power supply or other factors affecting the operating power which would necessitate continual adjustment to keep the operating power exactly the same as the authorized power, the operating power may be permitted to vary from 5 percent above to 10 percent below the authorized power for periods of short duration.

In addition to maintaining the operating power within the above limitations, broadcast stations employing directional antenna systems shall maintain the ratio of the antenna currents in the elements of the system within 5 percent of that specified by the terms of the license or other instrument of authorization.

[28] See section 3.52, Table A.

[29] When different last radio stages with different systems of modulation are employed for the two powers, the same principle shall apply, that is, the power shall be determined by the plate input times the proper efficiency factor and the antenna current shall change in proportion to the square root of the change in power within 5 percent.

12. CONSTRUCTION, GENERAL OPERATION, AND SAFETY OF LIFE REQUIREMENTS

Section 3.46 requires that the transmitter proper and associated transmitting equipment of each broadcast station shall be designed, constructed, and operated in accordance with the Standards of Good Engineering Practice in addition to the specific requirements of the Rules and Regulations of the Commission.

The specifications deemed necessary to meet the requirements of the Rules and Regulations and good engineering practice with respect to design, construction, and operation of standard broadcast stations are set forth below. These specifications will be changed from time to time as the state of the art and the need arises for modified or additional specifications.

A. *Design.*—The general design of standard broadcast transmitting equipment [main studio microphone (including telephone lines, if used, as to performance only [30]) to antenna output] shall be in accordance with the following specifications. For the points not specifically covered below, the principles set out shall be followed:

The equipment shall be so designed that:

(1) The maximum rated carrier power (determined by section 3.42) is in accordance with the requirements of section 3.41.

(2) The equipment is capable of satisfactory operation at the authorized operating power or the proposed operating power with modulation of at least 85 to 95 percent with no more distortion than given in (3) below.

(3) The total audio frequency distortion from microphone terminals, including microphone amplifier, to antenna output does not exceed 5 percent harmonics (voltage measurements of arithmetical sum or r. s. s.) when modulated from 0 to 84 percent, and not over 7.5 percent harmonics (voltage measurements of arithmetical sum or r. s. s.) when modulating 85 percent to 95 percent (distortion shall be measured with modulating frequencies of 50, 100, 400,

[30] In cases where telephone lines are not available to give the performance as required in these specifications a relay transmitter may be authorized to supersede the lines.

1000, 5000 and 7500 cycles up to tenth harmonic or 16,000 cycles, or any intermediate frequency that readings on these frequencies indicate is desirable).

(4) The audio frequency transmitting characteristics of the equipment from the microphone terminals (including microphone amplifier unless microphone frequency correction is included in which event proper allowance shall be made accordingly) to the antenna output does not depart more than 2 decibels from that at 1000 cycles between 100 and 5000 cycles.

(5) The carrier shift (current) at any percentage of modulation does not exceed 5 percent.

(6) The carrier hum and extraneous noise (exclusive of microphone and studio noises) level (unweighted r. s. s.) is at least 50 decibels below 100 percent modulation for the frequency band of 150 to 5000 cycles and at least 40 decibels down outside this range.

(7) The transmitter shall be equipped with suitable indicating instruments in accordance with the requirements of section 3.58 and any other instruments necessary for the proper adjustment and operation of the equipment.

(8) Adequate provision is made for varying the transmitter power output between sufficient limits to compensate for excessive variations in line voltage, or other factors which may affect the power output.

(9) The transmitter is equipped with automatic frequency control equipment capable of maintaining the operating frequency within the limit specified by section 3.59.

a. The maximum temperature variation [31] at the crystal from the normal operating temperature shall not be greater than:

1. Plus or minus 0.1° C. when an *X* or *Y* cut crystal is employed, or

2. Plus or minus 1.0° C. when low temperature coefficient crystal [32] is employed.

b. Unless otherwise authorized, a thermometer shall be installed in such manner that the temperature at the crystal can be accurately measured within 0.05° C. for *X* or *Y* cut crystal or 0.5° for low temperature coefficient crystal.

c. It is preferable that the tank circuit of the oscillator tube be installed in the temperature controlled chamber.

(10) Means are provided for connection and continuous operation of approved modulation monitor and approved frequency monitor.

a. The radio frequency energy for operation of the approved frequency monitor shall be obtained from a radio-frequency stage prior to the modulated stage unless the monitor is of such design as to permit satisfactory operation when otherwise connected and the monitor circuits shall be such that the carrier is not heterodyned thereby.

(11) Adequate margin is provided in all component parts to avoid overheating at the maximum rated power output.

B. *Construction.*—In general, the transmitter shall be constructed either on racks and panels or in totally enclosed frames [33] protected as required by article 810 of the National Electrical Code [34] and as set forth below:

(1) Means shall be provided for making all tuning adjustments, requiring voltages in excess of 350 volts to be applied to the circuit, from the front of the panels with all access doors closed.

(2) Proper bleeder resistors or other automatic means shall be installed across all the condenser banks to remove any charge which may remain after the high voltage circuit is opened (in certain instances the plate circuit of the tubes may provide such protection; however, individual approval of such shall be obtained by the manufacturer in case of standard equipment, and the licensee in case of composite equipment).

(3) All plate supply and other high voltage equipment, including transformers, filters, rectifiers and motor generators, shall be protected

[31] Explanations of excessive frequency deviations will not be accepted when temperature variations are in excess of the values specified below.

[32] See "Use of Low Temperature Coefficient Crystals by Broadcast Stations."

[33] The final stages of high power transmitters may be assembled in open frames provided the equipment is enclosed by a protective fence.

[34] The pertinent sections of article 810 of the National Electrical Code read as follows:

"8191. *General.*—Transmitters shall comply with the following:

"*a. Enclosing.*—The transmitter shall be enclosed in a metal frame or grille, or separated from the operating space by a barrier or other equivalent means, all metallic parts of which are effectually connected to ground.

"*b. Grounding of controls.*—All external metallic handles and controls accessible to the operating personnel shall be effectually grounded. No circuit in excess of 150 volts shall have any parts exposed to direct contact. A complete dead-front type of switchboard is preferred.

"*c. Interlocks on doors.*—All access doors shall be provided with interlocks which will disconnect all voltages in excess of 350 volts when any access door is opened."

so as to prevent injury to operating personnel.

a. Commutator guards shall be provided on all high voltage rotating machinery (coupling guards on motor generators, although desirable, are not required).

b. Power equipment and control panels of the transmitter shall meet the above requirements (exposed 220 volt AC switching equipment on the front of the power control panels is not recommended; however, is not prohibited).

c. Power equipment located at a broadcast station but not directly associated with the transmitter (not purchased as part of same), such as power distribution panels, control equipment on indoor or outdoor stations and the substations associated therewith, are not under the jurisdiction of the Commission; therefore, section 3.46 does not apply.

d. It is not necessary to protect the equipment in the antenna tuning house and the base of the antenna with screens and interlocks, provided the doors to the tuning house and antenna base are fenced and locked at all times, with the keys in the possession of the operator on duty at the transmitter. Ungrounded fencing or wires should be effectively grounded, either directly or through proper static leaks. Lightning protection for the antenna system is not specifically required but should be installed.

e. The antenna, antenna lead-in, counterpoise (if used), etc., shall be installed so as not to present a hazard. The antenna may be located close by or at a distance from the transmitter building. A properly designed and terminated transmission line should be used between the transmitter and the antenna when located at a distance.[35]

(4) Metering equipment:[36]

a. All instruments having more than 1,000 volts potential to ground on the movement shall be protected by a cage or cover in addition to the regular case. (Some instruments are designed by the manufacturer to operate safely with voltages in excess of 1,000 volts on the movement. If it can be shown by the manufacturer's rating that the instrument will operate safely at the applied potential, additional protection is not necessary.)

b. In case the plate voltmeter is located on the low potential side of the multiplier resistor with one terminal of the instrument at or less than 1000 volts above ground, no protective case is required. However, it is good practice to protect voltmeters subject to more than 5000 volts with suitable over-voltage protective devices across the instrument terminals in case the winding opens.

c. The antenna ammeters (both regular and remote and any other radio frequency instrument which it is necessary for the operator to read) shall be so installed as to be easily and accurately read without the operator having to risk contact with circuits carrying high potential radio frequency energy.

C. *Wiring and shielding.*—(1) The transmitter panels or units shall be wired in accordance with standard switchboard practice, either with insulated leads properly cabled and supported or with rigid bus bar properly insulated and protected.

(2) Wiring between units of the transmitter, with the exception of circuits carrying radio frequency energy, shall be installed in conduits or approved fiber or metal raceways to protect it from mechanical injury.

(3) Circuits carrying low level radio frequency energy between units shall be either concentric tube, two wire balanced lines, or properly shielded to prevent the pickup of modulated radio frequency energy from the output circuits.

(4) Each stage (including the oscillator) preceding the modulated stage shall be properly shielded and filtered to prevent unintentional feedback from any circuit following the modulated stage (an exception to this requirement may be made in the case of high level modulated transmitters of approved manufacture which have been properly engineered to prevent reaction).

(5) The crystal chamber, together with the conductor or conductors to the oscillator circuit shall be totally shielded.

[35] In all cases of new construction where a concentric transmission line is used between the transmitter and antenna, such line shall be installed in duplicate with adequate switching facilities for immediate connection of the second line in case of failure of the first line, or permanently installed auxiliary facilities such as an auxiliary transmitter and antenna system, auxiliary antenna system or other means whereby operation may be continued in the event of failure of the transmission line. It is also recommended that spare antenna and transmission line ammeters identical with those installed be kept on hand.

[36] In addition to the following requirements, instruments shall meet the requirements of section 3.58 and "Indicating Instruments Pursuant to Section 3.58."

(6) The monitors and the radio frequency lines to the transmitter shall be thoroughly shielded.

D. *Installation.*—(1) The installation shall be made in suitable quarters.

(2) Since an operator must be on duty during operation, suitable facilities for his welfare and comfort shall be provided.

E. *Spare tubes.*—A spare tube of every type employed in the transmitter and frequency and modulation monitors shall be kept on hand. When more than one tube of any type are employed, the following table determines the number of spares of that type required:

Number of each type employed:	Spares required
1 or 2	1
3 to 5	2
6 to 8	3
9 or more	4

F. *Operation.*—In addition to the specific requirements of the rules governing standard broadcast stations, the following operating requirements shall be observed:

(1) The maximum percentage of modulation shall be maintained at as high level as practicable without causing undue audio frequency harmonics, which shall not be in excess of 10 percent when operating with 85 percent modulation.

(2) Spurious emissions, including radio frequency harmonics, and audio frequency harmonics, shall be maintained at as low a level as practicable at all times in accordance with good engineering practice.

(3) In the event interference is caused to other stations by modulating frequencies in excess of 7500 cycles or spurious emissions, including radio frequency harmonics and audio frequency harmonics outside the band plus or minus 7500 cycles of the authorized carrier frequency, the licensee shall install equipment or make adjustments which limit the emissions to within this band or to such an extent above 7500 cycles as to reduce the interference to where it is no longer objectionable.

(4) The operating power shall be maintained within the limits of 5 percent above and 10 percent below the authorized operating power and shall be maintained as near as practicable to the authorized operating power.

(5) Licensees of broadcast stations employing directional antenna systems shall maintain the ratio of the currents in the elements of the array within 5 percent of that specified by the terms of the license or other instrument of authorization.

(6) In case of excessive shift in operating frequency during warm-up periods, the crystal oscillator shall be operated continuously. The automatic temperature control circuits should be operated continuously under all circumstances.

G. *Studio equipment.*—The studio equipment shall be subject to all the above requirements where applicable except as follows:

(1) If it is properly covered by an underwriter's certificate, it will be considered as satisfying the safety requirements.

(2) Section 8191 of article 810 of the National Electrical Code shall apply for voltages only when in excess of 500 volts.

No specific requirements are made relative to the design and acoustical treatment. However, the studios and particularly the main studio should be in accordance with the standard practice for the class of station concerned, keeping the noise level as low as reasonably possible.

13. INDICATING INSTRUMENTS PURSUANT TO SECTION 3.58

Section 3.58 requires that each standard broadcast station shall be equipped with suitable indicating instruments of accepted accuracy to measure the antenna current, direct plate circuit voltage, and the direct plate circuit current of the last radio stage.

The following requirements and specifications shall apply to indicating instruments used by standard broadcast stations in compliance with this rule:

A. Instruments indicating the plate current or plate voltage of the last radio stage (linear scale instruments), shall meet the following specifications:

(1) Length of scale shall be not less than 2$\frac{3}{10}$ inches.

(2) Accuracy shall be at least 2 percent of the full scale reading.

(3) The maximum rating of the meter shall be

such that it does not read off scale during modulation.

(4) Scale shall have at least 40 divisions.

(5) Full scale reading shall not be greater than five times the minimum normal indication.

B. Instruments indicating the antenna current shall meet the following specifications:

(1) Instruments having logarithmic or square law scales.

(*a*) Shall meet same requirements as 1, 2, and 3 above for linear scale instruments.

(*b*) Full scale reading shall not be greater than three times the minimum normal indication.

(*c*) No scale division above one-third full scale reading (in amperes) shall be greater than one-thirtieth of the full scale reading. (Example: An ammeter meeting requirement (*a*) above having full scale reading of 6 amperes is acceptable for reading currents from 2 to 6 amperes, provided no scale division between 2 and 6 amperes is greater than one-thirtieth of 6 amperes, 0.2 ampere.)

(2) Radio frequency instruments having expanded scales.

(*a*) Shall meet same requirements as 1, 2, and 3 for linear scale instruments.

(*b*) Full scale reading shall not be greater than five times the minimum normal indication.

(*c*) No scale division above one-fifth full scale reading (in amperes) shall be greater then one-fiftieth of the full scale reading. (Example: An ammeter meeting the requirement (*a*) above is acceptable for indicating currents from 1 to 5 amperes, provided no division between 1 and 5 amperes is greater than one-fiftieth of 5 amperes, 0.1 ampere.)

(*d*) Manufacturers of instruments of the expanded scale type must submit data to the Commission showing that these instruments have acceptable expanded scales, and the type number of these instruments must include suitable designation.

(3) Remote reading antenna ammeters may be employed and the indications logged as the antenna current in accordance with the following:

(*a*) Remote reading antenna ammeters may be provided by:

1. Inserting second thermocouple directly in the antenna circuit with remote leads to the indicating instrument.

2. Inductive coupling to thermocouple or other device for providing direct current to indicating instrument.

3. Capacity coupling to thermocouple or other device for providing direct current to indicating instrument.

4. Current transformer connected to second thermocouple or other device for providing direct current to indicating instrument.

5. Using transmission line current meter at transmitter as remote reading ammeter. See paragraph (*h*) below.

6. Using indications of phase monitor for determining the ratio of antenna currents in the case of directional antennas, provided the indicating instruments in the unit are connected directly in the current sampling circuits with no other shunt circuits of any nature.

(*b*) A thermocouple type ammeter meeting the above requirements shall be permanently installed in the antenna circuit. (This thermocouple ammeter may be so connected that it is short circuited or open circuited when not actually being read. If open circuited, a make-before-break switch must be employed.)

(*c*) The remote ammeter shall be connected at the same point in the antenna circuit as the thermocouple ammeter and shall be so connected and calibrated as to read in amperes within 2 percent of this meter over the entire range above one-third or one-fifth full scale. See sections B 1 (*c*) and B 2 (*c*) above respectively.

(*d*) The regular antenna ammeter shall be above the coupling to the remote meter in the antenna circuit so it does not read the current to ground through the remote meter.

(*e*) All remote meters shall meet the same requirements as the regular antenna ammeter with respect to scale accuracy, etc.

(*f*) Calibration shall be checked against the regular meter at least once a week.

(*g*) All remote meters shall be provided with shielding or filters as necessary to prevent any feed-back from the antenna to the transmitter.

(*h*) In the case of shunt excited antennas, the transmission line current meter at the transmitter may be considered as the remote antenna ammeter provided the transmission line is terminated directly into the excitation circuit feed line, which shall employ series tuning only (no shunt circuits of any type shall be employed), and insofar as practicable, the type and scale of the transmission line meter should be the same as those of the excitation circuit feed line meter (meter in slant wire feed line or equivalent).

(*i*) Remote reading antenna ammeters employing vacuum tube rectifiers are acceptable provided:

1. The indicating instruments shall meet all the above requirements for linear scale instruments.
2. Data are submitted under oath showing the unit has an over-all accuracy of at least 2 percent of the full scale reading.
3. The installation, calibration, and checking are in accordance with the above requirements.

(*j*) In the event there is any question as to the method of providing or the accuracy of the remote meter, the burden of proof of satisfactory performance shall be upon the licensee and the manufacturer of the equipment.

C. Stations determining power by the indirect method may log the transmission line current in lieu of the antenna current provided the instrument meets the above requirements for antenna ammeters, and further provided that the ratio between the transmission line current and the antenna current is entered each time in the log. In case the station is authorized for the same operating power for both day and nighttime operation, this ratio shall be checked at least once daily. Stations which are authorized to operate with nighttime power different from the daytime power shall check the ratio for each power at least once daily.

D. No instruments indicating the plate current or plate voltage of the last radio stage, the antenna current or the transmission line current when logged, in lieu of the antenna current, shall be changed or replaced without written authority of the Commission, except by instruments of the same make, type, maximum scale readings, and accuracy. Requests for authority to change an instrument may be made by letter or telegram giving the manufacturer's name, type number, serial number and full scale reading of the proposed instrument and the values of current or voltage the instrument will be employed to indicate. Requests for temporary authority to operate without an instrument or with a substitute instrument may be made by letter or telegram stating the necessity therefor and the period involved.

E. No instrument, the seal of which has been broken, or the accuracy of which is questionable, shall be employed. Any instrument which was not originally sealed by the manufacturer that has been opened shall not be used until it has been recalibrated and sealed in accordance with the following: Repairs and recalibration of instruments shall be made by the manufacturer, by an authorized instrument repair service of the manufacturer or by some other properly qualified and equipped instrument repair service. In either case the instrument must be resealed with the symbol or trade mark of the repair service and a certificate of calibration supplied therewith.

F. Since it is usually impractical to measure the actual antenna current of a shunt excited antenna system, the current measured at the input of the excitation circuit feed line is accepted as the antenna current.

G. Recording instruments may be employed in addition to the indicating instruments to record the antenna current and the direct plate current and direct plate voltage of the last radio stage provided that they do not affect the operation of the circuits or accuracy of the indicating instruments. If the records are to be used in any proceedings before the Commission as representation of operation with respect to plate or antenna current and plate voltage only, the accuracy must be the equivalent of the indicating instruments and the calibration shall be checked at such intervals as to insure the retention of the accuracy.

H. The function of each instrument shall be clearly and permanently shown on the instrument itself or on the panel immediately adjacent thereto.

14. REQUIREMENTS FOR TYPE APPROVAL OF BROADCAST TRANSMITTERS AND AUTOMATIC FREQUENCY CONTROL EQUIPMENTS

Sections 3.41 to 3.64 govern the design, construction, and technical operation of standard broadcast equipment. In order to facilitate filing of and action on applications for construction permits specifying equipment of standard manufacture, the Commission will approve, as complying with the technical requirements, such equipment by type, subject to the following conditions and in accordance with the following procedure:

(*a*) Approval of equipment by the Commission is only to the effect that insofar as can be determined from the data supplied the equipment complies with the current requirements of good engineering practice and the technical Rules and Regulations of the Commission. The approval may be withdrawn upon subsequent inspection or operation showing the equipment is not as represented or does not comply with the technical Rules and Regulations of the Commission and the requirements of good engineering practice.

(*b*) Such approval shall not be construed to mean that the equipment will be satisfactory as the state of the art progresses and/or as the Rules and Regulations of the Commission may be changed as deemed advisable.

(*c*) Applicants specifying equipment of approved manufacture need not submit detailed descriptions and diagrams where the correct type number is specified, provided the equipment, including the antenna tuning unit, is identical with that approved.

(*d*) In passing on equipment, no consideration is given by the Commission to patent rights.

(*e*) For approval of standard broadcast transmitters, manufacturers shall submit F. C. C. Form 301, completed with respect to all pertinent sections and the data set forth below, both of which shall be verified before a notary public.

1. Photograph or drawings or any other evidence that construction is in accordance with the requirements of good engineering practice.
2. Data and curves showing over-all audio frequency response from 30 to 7500 cycles for approximately 25-, 50-, 85-, and 100- (if obtainable) percent modulation (reference frequency, 1000 cycles).
3. Data on audio frequency harmonics for 25-, 50-, 85-, and 100-percent modulation for the fundamental frequencies of 50, 100, 400, 1000, 5000, and 7500 cycles (either arithmetical sum or root-sum-square values up to tenth harmonic or 16,000 cycles).
4. Percentage carrier shift (current) for 25-, 50-, 85-, and 100-percent modulation.
5. Carrier hum and extraneous noise generated within the equipment and measured as the level below 100-percent modulation throughout audio spectrum or by bands.
6. Percentage of each measurable radio frequency harmonic generated under expected normal operating conditions or in the first installation.
7. How output power is varied to compensate for power supply voltage variations.
8. Data and curves on frequency stability for variations in ambient temperatures over the range encountered in practice.
9. Data and curves on frequency stability for variations in power supply voltage from 85 to 115 percent normal values.
10. Net sale price.

(*f*) For approval of automatic frequency control equipment or automatic temperature control chambers, manufacturers shall complete F. C. C. Form 305 with respect to all pertinent sections and the data set forth below, both of which shall be verified before a notary public.

1. Photograph or drawings or any other evidence.
2. Data and curves on frequency stability for variations in ambient temperatures over maximum range encountered in practice.
3. Data and curves on frequency stability for variations in power supply voltage from 85 to 115 percent normal values.
4. Net sale price.

15. REQUIREMENTS FOR APPROVAL OF FREQUENCY MONITORS

Section 3.60 requires that the licensee of each standard broadcast station have in operation at the transmitter a frequency monitor independent of the frequency control of the transmitter. The frequency monitor shall be approved by the Commission and shall have a stability and accuracy at least five parts per million.

A. General Requirements and Approval

There are several ways or means by which it can be determined whether the frequency of the emitted carrier wave is within the required limits of the assigned frequency. However, one of the commonest ways is by means of a local piezo oscillator of known frequency producing a beat with the emitted wave used in conjunction with an instrument to indicate the resultant beat frequency. The visual indicator [37] is the only method now in common use by which it is considered that the frequency of the beat may be determined with the required degree of accuracy. Approval of a frequency monitor will be given based upon data taken by the Laboratory Division of the F. C. C. Any manufacturer desiring to submit a monitor for approval shall supply the Commission with full details. If the specifications appear to meet the requirements, the Commission will authorize the Laboratory Division to issue shipping instructions. The shipping charges to and from the Laboratory at Laurel, Md., shall be paid by the manufacturer.

In approving a frequency monitor, based upon the tests by the Laboratory, the Commission merely recognizes that the type of monitor has the inherent capability of functioning in compliance with section 3.60, if properly constructed, maintained, and operated. The Commission accepts no responsibility beyond this and further realizes that these monitors may have a limited range over which the visual indicator will determine deviations. Accordingly, it is necessary that adjunct equipment be used to determine major deviations.[37]

No change whatsoever will be permitted in the monitors sold under approval number issued by the Commission except when the licensee or the manufacturer is specifically authorized to make such changes.

When it is desired to make any change, either mechanical or electrical, the details shall be submitted to the Commission for its consideration.

Approval is given subject to withdrawal if the unit proves defective in service and cannot be relied upon under usual conditions of maintenance and operation encountered in the average standard broadcast station. Withdrawal of approval means that no further units may be installed by standard broadcast stations for the purpose of complying with section 3.60, but will not affect units already sold, unless it is found that there has been an unauthorized change in design or construction, or the material or workmanship is defective. All manufacturers of approved frequency monitors shall keep a list of sale numbers of the monitors sold to licensees of standard broadcast stations under the assigned approval number, and shall advise the Commission upon shipment of the monitor to the standard broadcast station.

B. General Specifications

The general specifications that frequency monitors shall meet before they will be approved by the Commission are as follows:

(1) The unit shall have an accuracy of at least five parts per million under ordinary conditions (temperature, humidity, power supply, and other conditions which may affect its accuracy) encountered in standard broadcast stations throughout the United States.

(2) The range of the indicating device shall be at least from 50 cycles below to 50 cycles above the assigned frequency. (When used by stations required by section 3.59 to maintain an operating frequency within 20 cycles of the assigned frequency, the range may be less than from 50 cycles above to 50 cycles below zero deviation but in no event shall the scale be less than from 20 cycles above to 20 cycles below zero deviation.)

(3) The scale of the indicating device shall be so calibrated as to be read accurately within at least 1 cycle.

(4) The unit shall be equipped with an automatic temperature control chamber (preferably enclosing the tank circuits of the oscillator) such that the maximum temperature variation at the crystal from the normal operating temperature shall not be greater than,

(a) Plus or minus 0.05° C. when *X* or *Y* cut crystal is employed, or

(b) Plus or minus 0.5° C. when low temperature coefficient crystal is employed.

(5) Unless otherwise specifically authorized, the instrument shall be equipped with a ther-

[37] In addition to the visual indicator, the range of which is necessarily limited in order to obtain the required accuracy, an aural indicator should also be employed to indicate frequency deviations beyond the range of the visual indicator, particularly where the visual indicator is so designed that the indication becomes zero when the deviations become considerably greater than the range of the instrument. When it is desired to make any change, either mechanical or electrical, the details shall be submitted to the Commission for its consideration.

mometer such that the temperature can be accurately measured within 0.025° C. for *X* or *Y* cut crystal or 0.25° C. for low temperature coefficient crystal.

(6) The monitor circuit shall be such that it may be continuously operated and the emitted carrier of the station is not heterodyned thereby.

(7) Means shall be provided for adjustment of the temperature or other means for correction of the indications of the monitor to agree with the external standard.

C. Tests To Be Made by the Laboratory Division of the F. C. C.

The tests to be made by the Laboratory will include the determination of the following:

(1) *Accuracy.*—(*a*) Oscillator frequency, as received.

(*b*) Constancy of oscillator frequency, as measured several times in 1 month.

(*c*) Accuracy of readings of frequency-difference instrument.

(*d*) Functioning of frequency adjustment device.

(*e*) Effects on frequency of changing tubes and of voltage variations.

(2) *Temperature control stability.*—(*a*) Effect on frequency of variation of room temperature through a range not to exceed 10° to 35° C.

(3) *Sensitivity.*—(*a*) Response of indicating instrument to small changes of frequency.

(4) *General construction.*—(*a*) Inspection to determine ability to stand shipment and service.

(*b*) Special tests to determine quality of construction, such as effect of tilting or tipping on frequency.

(5) *Miscellaneous performance.*—(*a*) Various, depending on character of apparatus (e. g., changes after stopping and starting, effect of varying coupling with transmitter, etc.).

The equipment will be operated in a test in the same way and the same conditions under which it will be used in service as specified by the manufacturer. The manufacturer shall supply to the Laboratory Division all instructions or services which will be supplied to the purchaser of the equipment. The equipment, as submitted, shall be adjusted for operation in connection with broadcast stations operating on 1600 kc.

16. REQUIREMENTS FOR APPROVAL OF MODULATION MONITORS

Section 3.55 (*b*) requires all broadcast stations to have in operation a modulation monitor approved by the Commission and section 3.55 (*d*) states that the Commission will from time to time publish the specifications, requirements, and list of approved modulation monitors. The specifications and requirements for approval are set out below. For a list of approved modulation monitors, attention is invited to Commission release "List of Approved Modulation Monitors."

Approval will be given based on the test data taken by the Laboratory Division of the F. C. C. Any manufacturer desiring to submit a monitor for approval shall supply the Commission with full details and if the specifications appear to meet the requirements, the Commission will authorize the Laboratory Division to issue shipping instructions. The shipping charges to and from the Laboratory at Laurel, Md., shall be paid by the manufacturer.

The specifications that the modulation monitor shall meet before it will be approved by the Commission are as follows:

(1) A DC meter for setting the average rectified carrier at a specific value and to indicate changes in carrier intensity during modulation.

(2) A peak indicating light or similar device that can be set at any predetermined value from 50 to 120 percent modulation to indicate on positive peaks, and/or from 50 to 100 percent negative modulation.

(3) A semi-peak indicator with a meter having the characteristics given below shall be used with a circuit such that peaks of modulation of duration between 40 and 90 milliseconds are indicated to 90 percent of full value and the discharge rate adjusted so that the pointer returns from full reading to 10 percent of zero within 500 to 800 milliseconds. A switch shall be provided so that this meter will read either positive or negative modulation and, if desired, in the center position it may read both in a full-wave circuit.

-The characteristics of the indicating meter are as follows:

Speed.—The time for one complete oscillation of the pointer shall be 290 to 350 milliseconds.

The damping factor shall be between 16 and 200. The useful scale length shall be at least 2.3 inches. The meter shall be calibrated for modulation from 0 to 110 percent and in decibels below 100 percent with 100 percent being 0 DB.

The accuracy of the reading on percentage of modulation shall be ±2 percent for 100 percent modulation, and ±4 percent of full scale reading at any other percentage of modulation.

(4) The frequency characteristics curve shall not depart from a straight line more than ±½ DB from 30 to 10,000 cycles. The amplitude distortion or generation of audio harmonics shall be kept to a minimum.

(5) The modulation meter shall be equipped with appropriate terminals so that an external peak counter can be readily connected.

(6) Modulation will be tested at 115 volts ±5 percent and 60 cycles, and the above accuracies shall be applicable under these conditions.

(7) All specifications not already covered above, and the general design, construction, and operation of these units must be in accordance with good engineering practice.

17. USE OF LOW TEMPERATURE COEFFICIENT CRYSTALS BY BROADCAST STATIONS

Section 3.62 requires that authority from the Commission shall be obtained before installing new automatic frequency control equipment or making changes in existing automatic frequency control equipment that may affect the precision of the frequency control. Therefore, licensees of standard broadcast stations desiring to install crystals of the low temperature coefficient type must obtain authorization therefor from the Commission. Requests for such authority may be made by letter specifying the manufacturer's name (see list of manufacturers of approved crystals below) and the guaranteed temperature coefficient and accuracy of calibration.

Use of a properly ground low temperature coefficient crystal normally materially increases the frequency stability, particularly where the equipment is subject to wide variations in ambient temperature. Where a crystal of this type is installed in the automatic frequency control unit but not in the approved frequency monitor, the stability of the control unit becomes considerably better than that of the monitor and unless care is exercised in making frequency adjustments, off frequency operation may occur. Therefore, it is recommended that when the crystal in the frequency control unit is changed to one of the low temperature coefficient type, a crystal of equal or better temperature coefficient and accuracy be installed in the monitor, authority for which may be requested by letter in the same manner as for installation in the automatic frequency control unit.

Manufacturers desiring approval of crystals of the low temperature coefficient type must submit under oath data on several such typical crystals manufactured by them showing that the temperature coefficient is not in excess of three parts per million per degree centigrade, and further affirming that no crystal of this type having a temperature coefficient in excess of this value will be supplied to any broadcast station and that all crystals so supplied will be ground to within five parts per million of the assigned frequency of the station for the normal operating temperature specified.

MANUFACTURERS OF LOW TEMPERATURE COEFFICIENT CRYSTALS WHICH HAVE BEEN ACCEPTED BY THE COMMISSION

American Piezo Supply Co., Kansas City, Mo.

Bellefonte Eng. Labs., Bellefonte, Pa.

Bliley Electric Co., Union Station Bldg., Erie, Pa.

Cambridge Thermonic Corp., Cambridge, Mass.

Collins Radio Co., Cedar Rapids, Iowa.

Commercial Radio Equipment Co., 216 East Seventy-fourth Street, Kansas City, Mo.

Electrical Products Corp., Oakland, Calif.

Hipower Crystal Co., 2035 West Charleston Street, Chicago, Ill.

Hollister Crystal Co., Merriam, Kans.

James Knights Co., Sandwich, Ill.

Piezo Electric Laboratories, New Dorp, N. Y.

Precision Crystal Laboratories, P. O. Box 326, Springfield, Mass.

Precision Piezo Service, Baton Rouge, La.

Premier Crystal Labs., Inc., 53–63 Park Row, New York, N. Y.

R. C. A. Mfg. Co., Camden, N. J.

Scientific Research Laboratories, Hyattsville, Md.

Silver City Crystal Co., Meriden, Conn.

Theodore S. Valpey, Holliston, Mass.

Western Electric Co., New York, N. Y.

William W. L. Burnett, San Diego, Calif.

18. MONEY REQUIRED TO CONSTRUCT AND COMPLETE ELECTRICAL TESTS OF STATIONS OF DIFFERENT CLASSES AND POWERS

Section 3.24 (*c*) requires that an applicant for standard broadcast station show that it is financially qualified to construct and operate the proposed station:

It is considered that the money specified below is required to construct and complete electrical tests of a new standard broadcast station of the class and power indicated, in accordance with the requirements of the Rules and Regulations of the Commission and good engineering practice.

Power and class of station:	*Money required*
100 watts, Class IV	$6, 500
250 watts, Class IV	8, 500
250 watts, Class II	10, 000
500 watts, Class II and III	22, 500
1,000 watts, Class II and III	25, 000
5 kw, Class II or III	40, 000
10 kw, Class I or II	65, 000
25 kw, Class I or II	175, 000
50 kw, Class I or II	200, 000

Attention is invited to the fact that the above figures are considered the minimum required for satisfactory installation, including the transmitter, antenna system, monitoring equipment and equipment for one large and one small studio of average dimensions, and equipment including microphones, speech input equipment, and usual acoustical treatment, but exclusive of the cost of land and buildings and organization and development costs in more elaborate installations including directional antenna would increase the cost accordingly.

19. USE OF COMMON ANTENNA BY STANDARD BROADCAST STATIONS OR ANOTHER RADIO STATION

Section 3.45 (*e*) permits the simultaneous use of the same antenna or antenna structure by two standard broadcast stations or a standard broadcast station and a station of another service or class only when both are licensed to the same licensee.

Such simultaneous use may be authorized to the same licensee provided:

(1) Complete verified engineering data are submitted showing that satisfactory operation of each station will be obtained without adversely affecting the operation of the other station.

(2) The requirements of section 3.45 (*a*) and (*b*) are met with respect to the minimum antenna height or field intensity for each standard broadcast station concerned.

20. USE OF FREQUENCY AND MODULATION MONITORS AT AUXILIARY BROADCAST TRANSMITTERS

Sections 3.60 and 3.55 (*b*) require that each standard broadcast station have approved frequency and modulation monitors in operation at the transmitter.

The following shall govern the installation of approved *frequency* and *modulation* monitors at auxiliary transmitters of standard broadcast stations in compliance with these rules:

In case the auxiliary transmitter location is at a site different from that of the main transmitter, an approved *frequency* monitor shall be installed at the auxiliary transmitter except when the frequency of the auxiliary transmitter can be monitored by means of the frequency monitor at the main transmitter.

The licensee will be held strictly responsible for any frequency deviation of the auxiliary transmitter in excess of 20 cycles from the assigned frequency, even though exempted by the above from installing an approved frequency monitor. Furthermore, whenever the auxiliary transmitter is operated without a frequency monitor under this exemption, it shall be monitored by means of the frequency monitor at the main transmitter.

Installation of an approved *modulation* monitor at the location of the auxiliary transmitter, when different from that of the main transmitter, is optional with the licensee. However, when it is necessary to operate the auxiliary transmitter beyond 2 calendar days, a modulation monitor shall be installed and operated at the auxiliary transmitter. The monitor (if taken from the main transmitter) shall be reinstalled at the main transmitter immediately upon resumption of operation of the *main transmitter*.

In all cases where the auxiliary transmitter and the main transmitter have the same location, the same frequency and modulation monitors may be used for monitoring both transmitters, provided they are so arranged as to be switched readily from one transmitter to the other.

Standard broadcast stations not complying with these requirements cannot be considered as operating in compliance with the rules governing such operation.

21. APPROVED FREQUENCY MONITORS

Section 3.60 requires that each standard broadcast station shall have in operation at the transmitter an approved frequency monitor [38] independent of the frequency control of the transmitter.

The following frequency monitors have been approved as in compliance with the specifications issued pursuant to section 3.60:

Manufacturer's name	Type	Approval No.
General Radio Co	25-A	1461
RCA Victor Co	311-A, 311-AB	1462
General Radio Co	25-AB	1463
Western Electric Co	1-C	1464
Doolittle Radio, Inc	FD-1A	1465
General Electric Co	98X402	1466
General Radio Co	1181-A	1467
RCA Manufacturing Co	WF-48A	1468

22. APPROVED MODULATION MONITORS

Section 3.55 (*b*) requires that each standard broadcast station shall have an approved modulation monitor in operation at the transmitter.

The following modulation monitors have been approved as in compliance with the specifications issued pursuant to section 3.55 (*d*):

Manufacturer's name	Type	Approval No.
General Radio Co	731-A or B	1551
RCA Manufacturing Co	66A	1552
Do	66B	1553
Do	66D	1554
General Radio Co	1931-A	1555
Gates Radio Co	MO-2639	1556
RCA Manufacturing Co	WM-43A	1557

[38] These monitors have a limited range over which the visual indicator will operate and accordingly it is necessary that auxiliary aural means be provided in conjunction with the monitor to indicate deviations beyond the range of the visual indicator such as may occur because of defective transmitting apparatus or other causes. In approving the monitors the Commission expects that this auxiliary equipment will be used by all broadcast licensees and will not accept as satisfactory explanations of any frequency deviation which may occur simply on the basis that it was not indicated by the monitor.

23. APPROVED EQUIPMENT

Sections 3.41 to 3.64 govern the design, construction, and technical operation of standard broadcast equipment. There is listed below the equipment which has been approved as in compliance with these rules in accordance with the provisions of "Requirements for Type Approval of Broadcast Transmitters and Automatic Frequency Control Equipment."

American Piezo Supply Co., P. O. Box 8112, Plaza Station, Kansas City, Mo.:

Type No. C–X–7–C, automatic frequency control unit.

Bliley Electric Co., 203 Union Station Building, Erie, Pa.:

Type No. BC46T, automatic temperature control unit.
Type No. TC92, automatic temperature control unit.
Type No. TC93, automatic temperature control unit.

Collins Radio Co., Cedar Rapids, Iowa.:

Type No. 10S–2, automatic frequency control unit.
Type No. 20H, 1000-watt, broadcast transmitter.
Type No. 20HA, 1000-watt, broadcast transmitter.
Type No. 20J, 1000-watt, broadcast transmitter.
Type No. 20K, 1000-watt, broadcast transmitter.
Type No. 20T, 500–1000-watt, broadcast transmitter.
Type No. 21A, 5000-watt, broadcast transmitter.
Type No. 21D, 5000-watt, broadcast transmitter.
Type No. 21DA, 5000-watt, broadcast transmitter.
Type No. 21DX, 5000-watt, broadcast transmitter.
Type No. 40DA, automatic frequency control unit.
Type No. 40E, automatic frequency control unit.
Type No. 300C, 250-watt, broadcast transmitter.
Type No. 300C–1, 250-watt, broadcast transmitter.
Type No. 300E, 100-watt, broadcast transmitter.
Type No. 300FA, 250-watt, broadcast transmitter.
Type No. 300G, 100–250-watt, broadcast transmitter

Doolittle Radio Inc., 7421 South Loomis Boulevard, Chicago, Ill.:

Type No. OB–5, automatic frequency control unit (includes Type TC–1 ATCU).
Type No. OB–6, automatic frequency control unit.
Type No. TC–1, automatic temperature control unit (includes Type 2–A ATCC).
Type No. 100–B, 100-watt, broadcast transmitter (includes Type OB–2 or OB–5 AFCU).
Type No. 250–B, 250-watt, broadcast transmitter (includes Type OB–2 or OB–5 AFCU).
Type No. 1000–B, 1000-watt, broadcast transmitter.

Federal Telegraph Co., Newark, N. J.:

Type No. 162–A, 50,000-watt, broadcast transmitter.
Type No. 163–A, 5,000-watt, broadcast transmitter.
Type No. 165–A, 5,000-watt, broadcast transmitter.

Type No. 196–A, 5,000-watt, broadcast transmitter.
Type No. 197–A, 50,000-watt, broadcast transmitter.

Gates Radio Co., Quincy, Ill.:

Type No. 25–A, automatic frequency control unit.
Type No. 100–A, 100-watt, broadcast transmitter.
Type No. 250–A, 250-watt, broadcast transmitter.
Type No. 500–A, 500-watt, broadcast transmitter.
Type No. BC–1E, 1000-watt, broadcast transmitter.
Type No. BC–250D, 250-watt, broadcast transmitter.
Type No. 250–C, 250-watt, broadcast transmitter.
Type No. 250–C–1, 250-watt, broadcast transmitter.
Type No. 1000–C, 1000-watt, broadcast transmitter.
Type No. 1–D, 1000-watt, broadcast transmitter.
Type No. S–101, 100-watt, broadcast transmitter.
Type No. S–251, 250-watt, broadcast transmitter.
Type No. BC–5A, 5000-watt, broadcast transmitter.

General Electric Co., Schenectady, N. Y.:

Type No. 32C401–G30, automatic temperature control unit.
Type No. BT-20–A, 250-watt, broadcast transmitter.
Type No. BT–21–A, 1000-watt, broadcast transmitter.
Type No. BT–22- A, 5000-watt, broadcast transmitter.
Type No. BT–23–A, 10,000-watt, broadcast transmitter.
Type No. BT–25–A, 50,000-watt, broadcast transmitter.
Type No. XT–1–A, 1000 watt, broadcast transmitter.

Piezo Electric Laboratories, 612 Rockland Avenue, New Dorp, N. Y.:

Type No. TC–210, automatic temperature control oven and relay unit.
Type No. TC–350, automatic temperature control oven and relay unit.
Type No. OB–10, oscillator and amplifier unit (oscillator and first buffer. No ATCU or crystal).

Precision Piezo Service, 427 Asia Street, Baton Rouge, La.:

Type No. 50M, automatic temperature control unit.

Premier Crystal Laboratories, Inc., 53–63 Park Row, New York, N. Y.:

Type No. 350–A, automatic frequency control unit.

R. C. A. Victor, Inc., Camden, N. J.:

Type No. UL–4292, automatic frequency control unit.
Type No. UL–4392, automatic frequency control unit.
Type No. 100–E, 100-watt, broadcast transmitter.
Type No. 100–G, 100-watt, broadcast transmitter.
Type No. 100–H, 100-watt, broadcast transmitter.
Type No. BTA–250L, 250-watt, broadcast transmitter.
Type No. 250–D, 250-watt, broadcast transmitter.
Type No. 250–E, 250-watt, broadcast transmitter.
Type No. 250–F, 250-watt, broadcast transmitter.
Type No. 250–G, 250-watt, broadcast transmitter.
Type No. 250–K, 250-watt, broadcast transmitter.
Type No. BTA–1L, 1,000-watt, broadcast transmitter.
Type No. BTA–1LA, 1,000-watt, broadcast transmitter.
Type No. 1–E, 1,000-watt, broadcast transmitter.
Type No. 1–E–A, 1,000-watt, broadcast transmitter.
Type No. 1–G, 1,000-watt, broadcast transmitter.
Type No. 1–K, 1,000-watt, broadcast transmitter.
Type No. ET–4300, 1,000-watt, broadcast transmitter.
Type No. BTA–5F, 5,000-watt, broadcast transmitter.
Type No. 5–D, 5,000-watt, broadcast transmitter.
Type No. 5–D–1, 5,000-watt, broadcast transmitter.
Type No. 5–D–2, 5,000-watt, broadcast transmitter.
Type No. 5–DX, 5,000-watt, broadcast transmitter.
Type No. 5–E, 5,000-watt, broadcast transmitter.
Type No. BTA–10F, 10,000-watt, broadcast transmitter.
Type No. 10–C–A, 10,000-watt, broadcast transmitter.
Type No. 10–C–B, 10,000-watt, broadcast transmitter.
Type No. 10–D, 10,000-watt, broadcast transmitter.
Type No. 10–DX, 10,000-watt, broadcast transmitter.
Type No. 10–E, 10,000-watt, broadcast transmitter.
Type No. BTA–50F, 50,000-watt, broadcast transmitter.
Type No. 50–D, 50,000-watt, broadcast transmitter.
Type No. 50–D, 50,000-watt, power amplifier.
Type No. 50–E, 50,000-watt power amplifier.

Raytheon Manufacturing Co., Chicago, Ill.:

Type No. RA–250, 250-watt, broadcast transmitter.
Type No. RA–1000, 1,000-watt, broadcast transmitter.
Type No. RA–5, 5,000-watt, broadcast transmitter.

Transmitter Equipment Mfg. Co., Inc., 345 Hudson Street, New York 14, N. Y.:

Type No. 250 BCA, 250-watt, broadcast transmitter.

Theodore S. Valpey, Holliston, Mass.:

Type No. CBC–0, automatic temperature control unit.

Western Electric Co., 195 Broadway, New York, N. Y.:

Type No. 700–B, automatic frequency control unit.
Type No. 700–C, automatic frequency control unit.
Type No. 702–A, automatic frequency control unit.
Type No. 310–A, 100-watt, broadcast transmitter.
Type No. 310–B, 250-watt, broadcast transmitter.
Type No. 310–C, 500-watt, broadcast transmitter.
Type No. 310–D, 1,000-watt, broadcast transmitter.
Type No. 350C–1, 100-watt, broadcast transmitter.

Type No. 351E-1, 250-watt, broadcast transmitter.
Type No. 451A-1, 250-watt, broadcast transmitter.
Type No. 352E-1 500-watt, broadcast transmitter.
Type No. 353E-1, 1 000-watt, broadcast transmitter.
Type No. 403A-1, 1,000-watt, broadcast transmitter.
Type No. 405A-1, 5,000-watt, broadcast transmitter.
Type No. 405A-2, 5,000-watt, broadcast transmitter.
Type No. 405B-1, 5,000-watt, broadcast transmitter.
Type No. 405B-2, 5,000-watt, broadcast transmitter.
Type No. 406A-1, 10,000-watt, broadcast transmitter.
Type No. 406A-2, 10,000 watt, broadcast transmitter.
Type No. 406A-3, 10,000-watt, broadcast transmitter.
Type No. 406B-1, 10,000-watt, broadcast transmitter.
Type No. 407A-1, 50,000-watt, broadcast transmitter.
Type No. 407A-2, 50,000-watt, broadcast transmitter.
Type No. 407A-3, 50,000-watt, broadcast transmitter.
Type No. 407A-4, 50,000-watt, broadcast transmitter.
Type No. 442A-1, 500-watt, broadcast transmitter.
Type No. 443A-1, 1000-watt, broadcast transmitter.

Westinghouse Electric and Mfg. Co., 2519 Wilkins Avenue, Baltimore, Md.:

Type No. LK-1, automatic frequency control unit.
Type No. LK-2, automatic frequency control unit.
Type No. 50-HG, 50,000-watt, broadcast transmitter.
Type No. 50-HG-1, 50,000-watt, broadcast transmitter.
Type No. 5-HV, 5,000-watt, broadcast transmitter.
Type No. 5-HV-1, 5,000-watt, broadcast transmitter.
Type No. 10-HV, 10,000-watt, broadcast transmitter.
Type No. 10-HV-1, 10,000-watt, broadcast transmitter.

24. STANDARD BROADCAST APPLICATION FORMS

The Communications Act of 1934, as amended, and the Rules and Regulations of the Commission require that application be made to the Commission for various authorizations. In order to be of aid to applicants, there are set out below the correct forms to be submitted in making application for various authorizations applicable to Standard Broadcast Stations.

F. C. C. Form 301, Application for Authority to Construct a New Broadcast Station or Make Changes in an Existing Broadcast Station.

F. C. C. Form 302, Application for New Broadcast Station License.

F. C. C. Form 303, Application for Renewal of Broadcast Station License.

F. C. C. Form 308, Application for Permit to Locate, Maintain, or Use Studio Apparatus for Production of Programs to be Transmitted or Delivered to Foreign Radio Stations.

760684°—47——4

F. C. C. Form 314, Application for Consent to Assignment of Radio Broadcast Station Construction Permit or License.

F. C. C. Form 315, Application for Consent to Transfer of Control of Corporation Holding Radio Broadcast Station Construction Permit or License.

F. C. C. Form 317, Application for Standard Broadcast Station Special Service Authorization or Extension Thereof (See Sec. 1.325).

F. C. C. Form 321, Application for Construction Permit to Replace Expired Permit.

F. C. C. Form 701, Application for Additional Time to Construct a Radio Station.

Informal requests (letters or telegrams) may be filed for requests:

(*a*) To operate additional time.

(*b*) To discontinue operation or services not covered by section 3.71.

(*c*) To operate with additional power.

(*d*) To operate with reduced power not covered by section 3.57.

(*e*) To operate for test purposes (to determine site, etc.).

(*f*) To rebroadcast programs of stations of other classes.

(*g*) Other special temporary operation beyond terms of existing license.

(*h*) Temporary operation without specified items of equipment, or with temporary, substitute, or auxiliary equipment.

(1) Operation without an approved frequency monitor.

(2) Operation without an approved modulation monitor.

(3) Operation without thermometer in automatic temperature control chamber.

(4) Operation without antenna ammeter, plate voltmeter, or plate ammeter.

(5) Operation with substitute ammeter, plate voltmeter, or plate ammeter.

(6) Operation with temporary antenna system.

(7) Operation with auxiliary transmitter as main transmitter.

(*i*) Operation with new or modified equipment pending repair of existing equipment, or pending receipt and action upon a formal application.

(*j*) Where formal application is not required, application for new or modified equipment or antenna system.

(*k*) Change of specifications for painting and lighting antenna towers where formal application is not required.

(*l*) Operation to determine power by direct method during program test period.

(*m*) Relocation of transmitter in same building.

(*n*) Operation with reduced power or time under sections 3.57 and 3.71.

(*o*) Approval of types of equipment as to compliance with outstanding rules or standards.

(*p*) All authorizations for equipment and program tests, or extensions thereof, where it appears that compliance has been had with the terms of the construction permit.

(*q*) Extensions of time within which to comply with technical requirements specified in authorizations, orders, and rules or releases of the Commission.

(*r*) Representations of compliance with technical requirements specified in authorizations, orders, rules, or releases (except formal applications).

(*s*) Operation with licensed, new or modified equipment at a temporary location with a temporary antenna system in case of an emergency when, due to causes beyond the control of the licensee, it becomes impossible to continue operating at the licensed location.

25. FIELD OFFICES OF THE COMMISSION

Section 3.57 and other rules of the Commission require that in certain instances, the inspector in charge of the district in which the station is located be advised of the conditions existing at the station. The following is a list of the radio districts, giving the address of each field office of the Commission and the territory embraced in each district:

Radio district	Address of the Engineer in charge	Territory within district	
		States	Counties
1	1600 Customhouse, Boston 9, Mass.	Connecticut	All counties.
		Maine	Do.
		Massachusetts	Do.
		New Hampshire	Do.
		Rhode Island	Do.
		Vermont	Do.
2	748 Federal Bldg., 641 Washington St., New York 14, N. Y.	New Jersey	Bergen, Essex, Hudson, Hunterdon, Mercer, Middlesex, Monmouth, Morris, Passaic, Somerset, Sussex, Union, and Warren.
		New York	Albany, Bronx, Columbia, Delaware, Dutchess, Green, Kings, Nassau, New York, Orange, Putnam, Queens, Rensselaer, Richmond, Rockland, Schenectady, Suffolk, Sullivan, Ulster, and Westchester.
3	1005 U. S. Customhouse, Philadelphia, 6, Pa.	Delaware	Newcastle.
		New Jersey	Atlantic, Burlington, Camden, Cape May, Cumberland, Gloucester, Ocean and Salem.
		Pennsylvania	Adams, Berks, Bucks, Carbon, Chester, Cumberland, Dauphin, Delaware, Lancaster, Lebanon, Lehigh, Monroe, Montgomery, Northampton, Perry, Philadelphia, Schuylkill, and York.
4	508 Old Town Bank Bldg., Gay St. and Fallsway, Baltimore 2, Md.	Delaware	Kent and Sussex.
		District of Columbia	All.
		Maryland	All counties.
		Virginia	Arlington, Clark, Fairfax, Fauquier, Frederick, Loudoun, Page, Prince William, Rappahannock, Shenandoah, and Warren.
		West Virginia	Barbour, Berkeley, Grant, Hampshire, Hardy, Harrison, Jefferson, Lewis, Marion, Mineral, Monongalia, Morgan, Pendleton, Preston, Randolph, Taylor, Tucker, and Upshur.
5	Room 402, New Post Office Bldg., Norfolk 10, Va.	North Carolina	All except district 6.
		Virginia	All except district 4.
6	411 Federal Annex, Atlanta 3, Ga.	Alabama	All except district 8.
		Georgia	All counties.
	Suboffice, P. O. Box 77 (214–218 Post Office Bldg.), Savannah, Ga.	North Carolina	Ashe, Avery, Buncombe, Burke, Caldwell, Cherokee, Clay, Cleveland, Graham, Haywood, Henderson, Jackson, McDowell, Macon, Madison, Mitchell, Polk, Rutherford, Swain, Transylvania, Watauga, and Yancey.
		South Carolina	All counties.
		Tennessee	Do.
7	P. O. Box 150 (312 Federal Bldg.), Miami 1, Fla.	Florida	All except district 8.
	Suboffice, 409–410 Post Office Bldg., Tampa 2, Fla.		
8	400 Audubon Bldg., New Orleans 16, La.	Alabama	Mobile and Baldwin.
		Arkansas	All counties.
		Florida	Escambia.
		Louisiana	All counties.
		Mississippi	Do.
		Texas	City of Texarkana only.

Radio district	Address of the Engineer in charge	Territory within district: States	Territory within district: Counties
9	324 U. S. Appraisers Bldg., 7300 Wingate St., Houston 11, Tex. Suboffice, P. O. Box 1527 (329 Post Office Bldg.), Beaumont, Tex.	Texas	Angelina, Aransas, Atascosa, Austin, Bandera, Bexar, Blanco, Brazoria, Brazos, Burleson, Caldwell, Calhoun, Cameron, Chambers, Colorado, Comal, De Witt, Duval, Dimmit, Edwards, Fayette, Fort Bend, Frio, Galveston, Gillespie, Goliad, Gonzales, Grimes, Guadalupe, Hardin, Hays, Harris, Hidalgo, Jackson, Jasper, Jefferson, Jim Hogg, Jim Wells, Karnes, Kenedy, Kendall, Kerr, Kinney, Kleberg, La Salle, Lavaca, Lee, Liberty, Live Oak, Matagorda, Madison, Maverick, McMullen, Medina, Montgomery, Nacadoches, Newton, Nueces, Orange, Polk, Real, Refugio, San Augustine, San Jacinto, San Patricio, Sabine, Starr, Travis, Trinity, Uvalde, Val Verde, Victoria, Walker, Waller, Washington, Webb, Wharton, Willacy, Williamson, Wilson, Zapata, Zavala, and Tyler.
10	P. O. Box 5238 (U. S. Terminal Annex Bldg.), Dallas 2, Tex.	New Mexico	All counties.
		Oklahoma	Do.
		Texas	All except district 9 and the city of Texarkana.
11	539 U. S. Post Office and Courthouse Bldg., Temple and Spring Sts., Los Angeles 12, Calif.	Arizona	All counties.
		California	Imperial, Inyo, Kern, Los Angeles, Orange, Riverside, San Bernardino, San Diego, San Luis Obispo, Santa Barbara, and Ventura.
	Suboffice, 230 U. S. Customhouse, San Diego 1, Calif.	Nevada	Clarke.
12	323-A Customhouse, San Francisco 26, Calif.	California	All except district 11.
		Nevada	All except Clarke.
13	406 Central Bldg., Portland 5, Oreg	Idaho	All except district 14.
		Oregon	All counties.
		Washington	Wahkiakum, Cowlitz, Clark, Skamania, and Klickitat.
14	801 Federal Office Bldg., Seattle 4, Wash.	Idaho	Benewah, Bonner, Boundary, Clearwater, Idaho, Kootenai, Latah, Lewis, Nez Perce, and Shoshone.
		Montana	All counties.
		Washington	All except district 13.
15	521 Customhouse, Denver 2, Colo	Colorado	All counties.
		Utah	Do.
		Wyoming	Do.
		Nebraska	Banner, Box Butte, Cheyenne, Dawes, Deuel, Garden, Kimball, Morrill, Scottsbluff, Sheridan, Sioux.
		South Dakota	Butte, Custer, Fall River, Lawrence, Meade, Pennington, Shannon, Washington.
16	208 Uptown Post Office and Federal Courts Bldg., 5th and Washington Sts., St. Paul 2, Minn.	Minnesota	All counties.
		Michigan	Alger, Baraga, Chippewa, Delta, Dickinson, Gogebic, Houghton, Iron, Keweenaw, Luce, Mackinac, Marquette, Menominee, Ontonagon, and Schoolcraft.
		North Dakota	All counties.
		South Dakota	All except district 15.
		Wisconsin	All except district 18.
17	838 U. S. Courthouse, Kansas City 6, Mo.	Iowa	All except district 18.
		Kansas	All counties.
		Missouri	Do.
		Nebraska	All except district 15.
18	246 U. S. Courthouse, Chicago 4, Ill	Illinois	All counties.
		Indiana	Do.
		Iowa	Allamakee, Buchanan, Cedar, Clayton, Clinton, Delaware, Des Moines, Dubuque, Fayette, Henry, Jackson, Johnson, Jones, Lee, Linn, Louisa, Muscatine, Scott, Washington, and Winneshiek.
		Wisconsin	Brown, Columbia, Calmet, Crawford, Dane, Dodge, Door, Fond du Lac, Grant, Green, Iowa, Jefferson, Keewanee, Kenosha, Lafayette, Manitowoc, Marinette, Milwaukee, Ozaukee, Ocente, Outgamie, Racine, Richland, Rock Sauk, Sheboygan, Walworth, Washington, Waukesha, and Winnebago.
		Kentucky	All except district 19.
19	1029 New Federal Bldg., Detroit 26, Mich.	Kentucky	Bath, Bell, Boone, Bourbon, Boyd, Bracken, Breathitt, Campbell, Carter, Clark, Clay, Elliott, Estill, Fayette, Fleming, Floyd, Franklin, Gallatin, Garrard, Grant, Greenup, Kenton, Harlan, Harrison, Jackson, Jessamine, Johnson, Knott, Knox, Laurel, Lawrence, Lee, Leslie, Letcher, Lewis, Lincoln, Madison, Magoffin, Martin, Mason, McCreary, Menifee, Montgomery, Morgan, Nicholas, Owen, Owsley, Pendleton, Perry, Pike, Powell, Pulaski, Robertson, Rockcastle, Rowan, Scott, Wayne, Whitely, Wolfe, and Woodford.
		Ohio	All counties.
	Suboffice, 541 Old Post Office Bldg., Cleveland 14, Ohio.	Michigan	All except district 16.
		West Virginia	All except district 4.
20	328 Federal Bldg., Buffalo 3, N. Y	New York	All except district 2.
		Pennsylvania	All except district 3.
21	609 Stangenwald Bldg., Honolulu 1, T. H.	Territory of Hawaii and outlying Pacific possessions, except Alaska and adjacent islands.	
22	P. O. Box 2987, (322-323 Federal Bldg.), San Juan 13, P. R.	Puerto Rico	
		Virgin Islands	
23	P. O. Box 1421, (7-8 Shattuck Bldg.), Juneau, Alaska. Suboffice, P. O. Box 644, (Room 39, Federal Bldg.), Anchorage, Alaska.	Alaska	

26. AVERAGE SUNRISE AND SUNSET TIMES

See mimeograph 85120, distributed on request.

APPENDIX I

GROUNDWAVE FIELD INTENSITY CHARTS

Graphs 1–20 show the computed values of groundwave field intensity as a function of the distance from the transmitting antenna. The groundwave field intensity is here considered to be that part of the vertical component of the electric field received on the ground which has not been reflected from the ionosphere nor the troposphere. These 20 charts were computed for 20 different frequencies, a dielectric constant of the ground equal to 15 for land and 80 for sea water (referred to air as unity) and for the ground conductivities (expressed in electromagnetic units$\times 10^{14}$ or expressed in mhos per meter$\times 10^{3}$) given on the curves. The curves show the variation of the groundwave field intensity with distance to be expected for transmission from a short vertical antenna at the surface of a uniformly conducting spherical earth with the ground constants shown on the curves; the curves are for an antenna power and efficiency such that the inverse distance field is 100 mv/m at 1 mile. The curves are valid at distances large compared to the dimensions of the antenna for other than short vertical antennas.

The inverse distance field (100 mv/m divided by the distance in miles) corresponds to the groundwave field intensity to be expected from an antenna with the same radiation efficiency when it is located over a perfectly conducting earth. To determine the value of the groundwave field intensity corresponding to a value of inverse distance field other than 100 mv/m at 1 mile, simply multiply the field intensity as given on these charts by the desired value of inverse distance field at 1 mile divided by 100; for example, to determine the groundwave field intensity for a station with an inverse distance field of 1700 mv/m at 1 mile, simply multiply the values given on the charts by 17. The value of the inverse distance field to be used for a particular antenna depends upon the power input to the antenna, the nature of the ground in the neighborhood of the antenna, and the geometry of the antenna. For methods of calculating the interrelations between these variables and the inverse distance field, see "The Propagation of Radio Waves Over the Surface of the Earth and in the Upper Atmosphere," Part II, by Mr. K. A. Norton, Proc. I. R. E., Vol. 25, September 1937, pp. 1203–1236.

At sufficiently short distances (say less than 35 miles), such that the curvature of the earth does not introduce an additional attenuation of the waves, the graphs were computed by means of the plane earth formulas given in the paper, "The Propagation of Radio Waves Over the Surface of the Earth and in the Upper Atmosphere," Part I, by Mr. K. A. Norton, Proc. I. R. E., Vol. 24, October 1936, pp. 1367–1387. At larger distances the additional attenuation of the waves which is introduced by the effect of the curvature of the earth was introduced by the methods outlined in the papers, "The Diffraction of Electromagnetic Waves from an Electrical Point Source round a Finitely Conducting Sphere, with Applications to Radiotelegraphy and the Theory of the Rainbow," by Balth van der Pol and H. Bremmer, Part I, Phil. Mag., Vol. 24, p. 141, July 1937, Part II, Phil. Mag., Vol. 24, p. 825, Suppl., November 1937, "Ergebrisse einer Theorie uber die Fortpflanzung elektromagnetischer Wellen uber eine Kugel endlicher Leitfahigkeit," by Balth van der Pol and H. Bremmer, Hochfrequenztechnik und Elektroakustik, Band 51, Heft 6, June 1938, "Further Note on the Propagation of Radio Waves over a Finitely Conducting Spherical Earth," by Balth van der Pol and H. Bremmer, Phil. Mag., Vol. 27, p. 261, March 1939. In order to allow for the refraction of the radio waves in the lower atmosphere due to the variation of the dielectric constant of the air with height above the earth, a radius of the earth equal to 4/3 the actual radius was used in the computations for the effect of the earth's curvature in the manner suggested by C. R. Burrows, "Radio Propagation over Spherical Earth," Proc. I. R. E., May 1935; i. e., the distance corresponding to a given value of attenuation due to the curvature of the earth in the absence of air refraction was multiplied by the factor $(4/3)^{\frac{2}{3}}=1.21$. The amount of this refraction varies from day to day and from season to season, depending on the air mass conditions in the lower atmosphere. If k denotes the ratio between the equivalent radius of the earth and the true radius, the following table gives the values of k for several typical air masses encountered in the United States.

Air mass type	k	
	Summer	Winter
Tropical Gulf—T_g	1.53	1.43
Polar Continental—P_c	1.31	1.25
Superior—S	1.25	1.25
Average	1.33	

It is clear from this table that the use of the average value of $k=4/3$ is justified in obtaining a single correction for the systematic effects of atmospheric refraction.

Provided the value of the dielectric constant is near 15, the curves of Graphs 1–20 may be compared with experimental data to determine the appropriate values of the ground conductivity and of the inverse distance field intensity at 1 mile. This is accomplished simply by plotting the measured fields on transparent log-log graph paper similar to that used for Graphs 1–20 and superimposing this chart over the Graph corresponding to the frequency involved. The log-log graph sheet is then shifted vertically until the best fit is obtained with one of the curves on the Graph; the intersection of the inverse distance line on the graph with the 1-mile abscissa on the chart determines the inverse distance field intensity at 1 mile. For other values of dielectric constant, the following procedure may be used for a determination of the dielectric constant of the ground, conductivity of the ground and the inverse distance field intensity at 1 mile. Graph 21 gives the relative values of groundwave field intensity *over a plane earth* as a function of the numerical distance p and phase angle b. On graph paper with coordinates similar to those of Graph 21, plot the measured values of field intensity as ordinates versus the corresponding distances from the antenna expressed in miles as abscissae. The data should be plotted only for distances greater than one wavelength (or, when this is greater, five times the vertical height of the antenna in the case of a single element, i. e., nondirectional antenna or 10 times the spacing between the elements of a directional antenna) and for distances less than $50/f_{mc}^{1/3}$ miles (i. e., 50 miles at 1 mc). Then, using a light box, place the sheet with the data plotted on it over the sheet with the curves of Graph 21 and shift the data sheet vertically and horizontally (making sure that the vertical lines on both sheets are parallel) until the best fit with the data is obtained with one of the curves on Graph 21. When the two sheets are properly lined up, the value of the field intensity corresponding to the intersection of the inverse distance line of Graph 21 with the 1 mile abscissa on the data sheet is the inverse distance field intensity at 1 mile, and the values of the numerical distance at 1 mile, p_1, and of b are also determined. Knowing the values of b and p_1 (the numerical distance at 1 mile), we may substitute in the following approximate formulas to determine the appropriate values of the ground conductivity and dielectric constant.

$$x \cong \frac{\pi}{p_1} \cdot (R/\lambda)_1 . \cos b \qquad (1)$$

$(R/\lambda)_1$ = Number of wavelengths in 1 mile.

$$\sigma_{e.m.u.} = \frac{x f_{mc}}{17.9731} \cdot 10^{-14} \qquad (2)$$

$\sigma_{e.m.u.}$ = Conductivity of the ground expressed in electromagnetic units.

f_{mc} = frequency expressed in megacycles.

$$\epsilon \cong x \tan b - 1 \qquad (3)$$

ϵ = dielectric constant of the ground referred to air as unity.

First solve for x by substituting the known values of p_1, $(R/\lambda)_1$, and $\cos b$ in equation (1). Equation (2) may then be solved for σ and equation (3) for ϵ). At distances greater than $50/f_{mc}^{1/3}$ miles the curves of Graph 21 do not give the correct relative values of field intensity since the curvature of the earth weakens the field more rapidly than these plane earth curves would indicate. Thus, no attempt should be made to fit experimental data to these curves at the larger distances.

At sufficiently short distances (say less than 35 miles at broadcast frequencies), such that the curvature of the earth does not introduce an additional attenuation of the waves, the curves of Graph 21 may be used for determining the ground wave field intensity for transmitting and receiving antennas at the surface of the earth for any radiated power, frequency, or set of ground constants in the following manner: First, lay off the straight inverse distance line corresponding to the power radiated on transparent log-log graph paper similar to that of Graph 21, labelling the ordinates of the chart in terms of field intensity and the abscissae in terms of distance. Next, by means of the formulas given on Graph 21, calculate the value of the numerical distance, p, at 1 mile and the value of b. Then superimpose the log-log chart over Graph 21, shifting it vertically until the inverse distance lines on both charts coincide and shifting it horizontally until the numerical distance at 1 mile on Graph 21 coincides with 1 mile on the log-log graph paper. The curve of Graph 21 corresponding to the calculated value of b is then traced on the log-log graph paper giving the field intensity versus distance in miles.

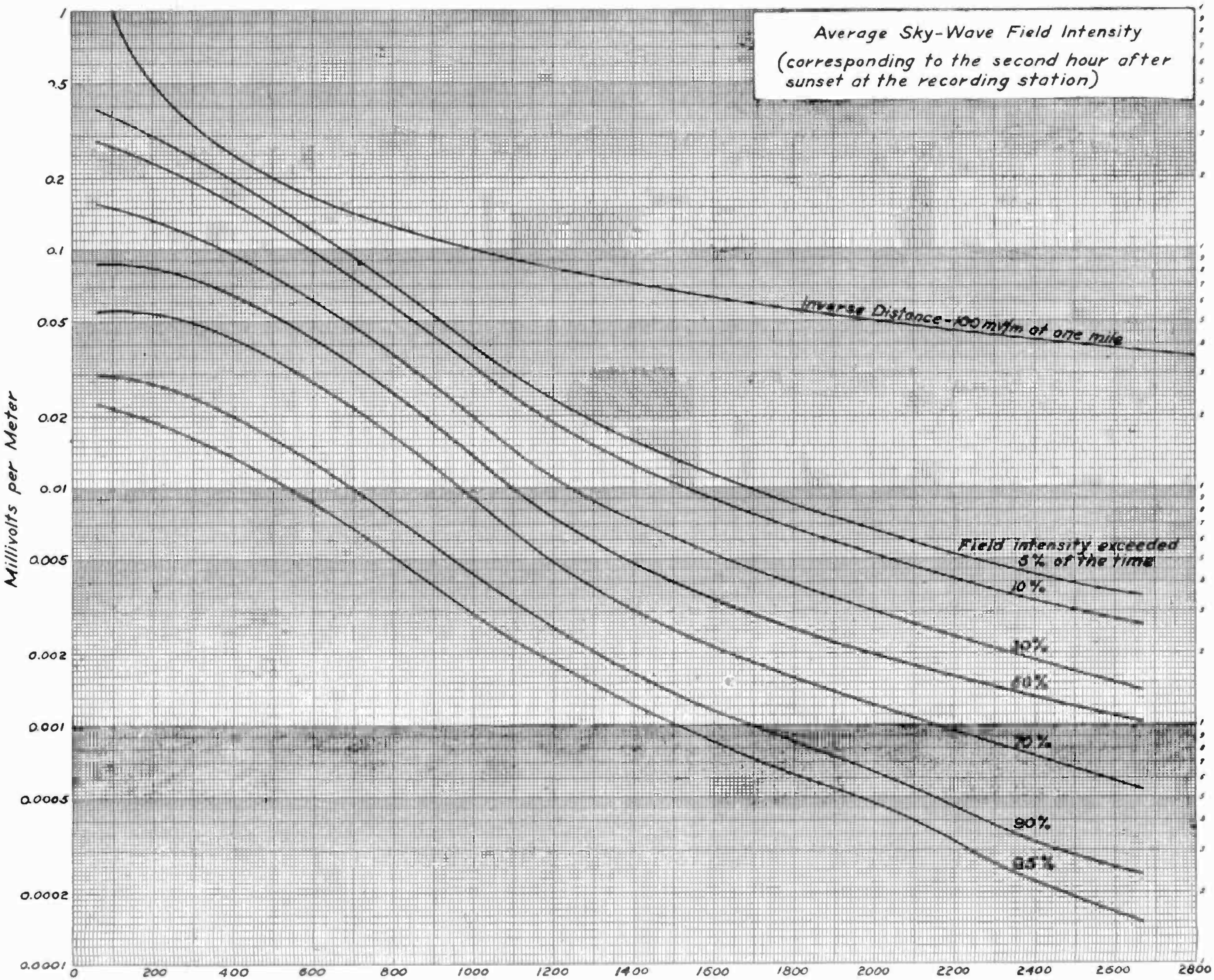
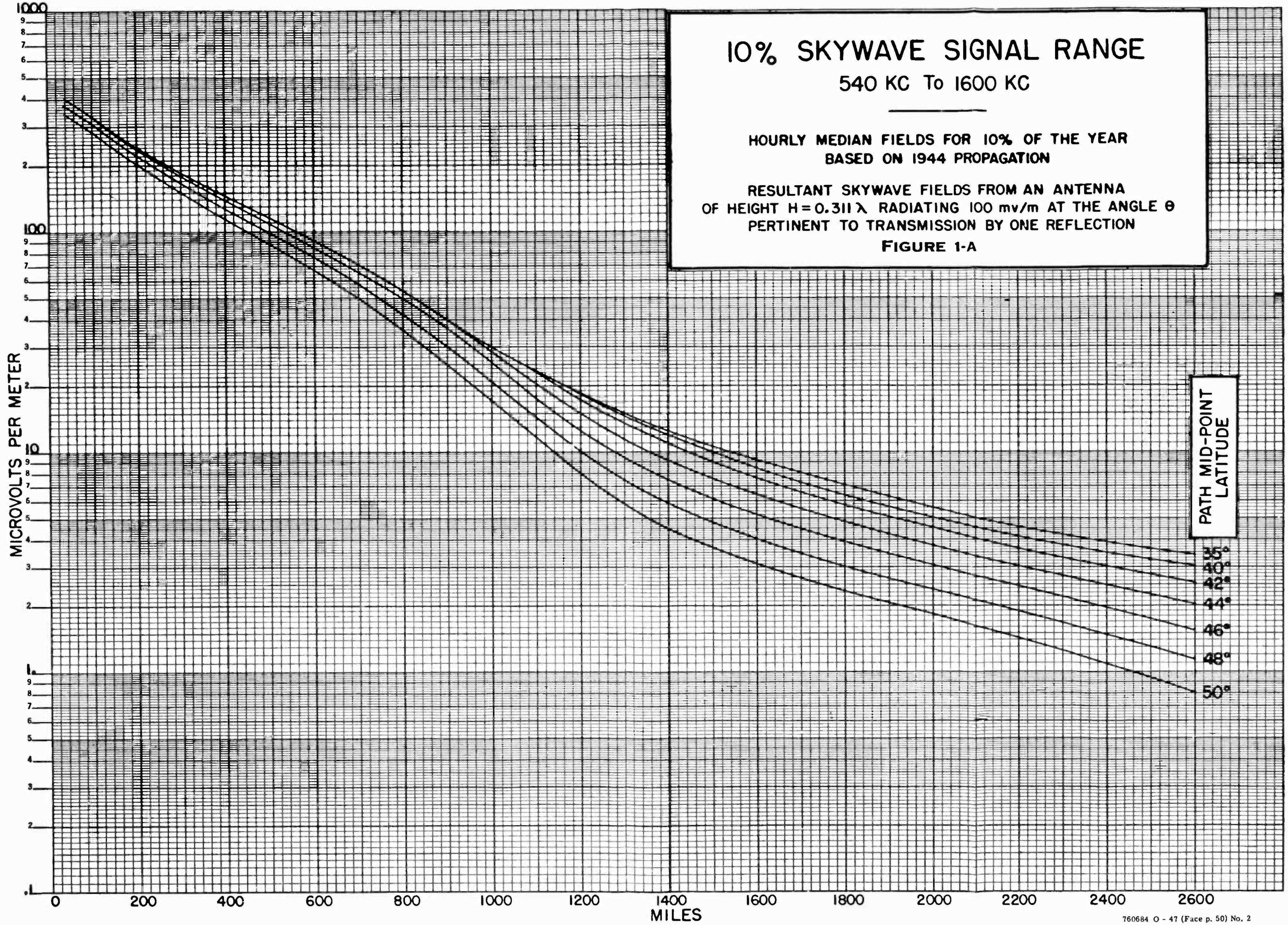
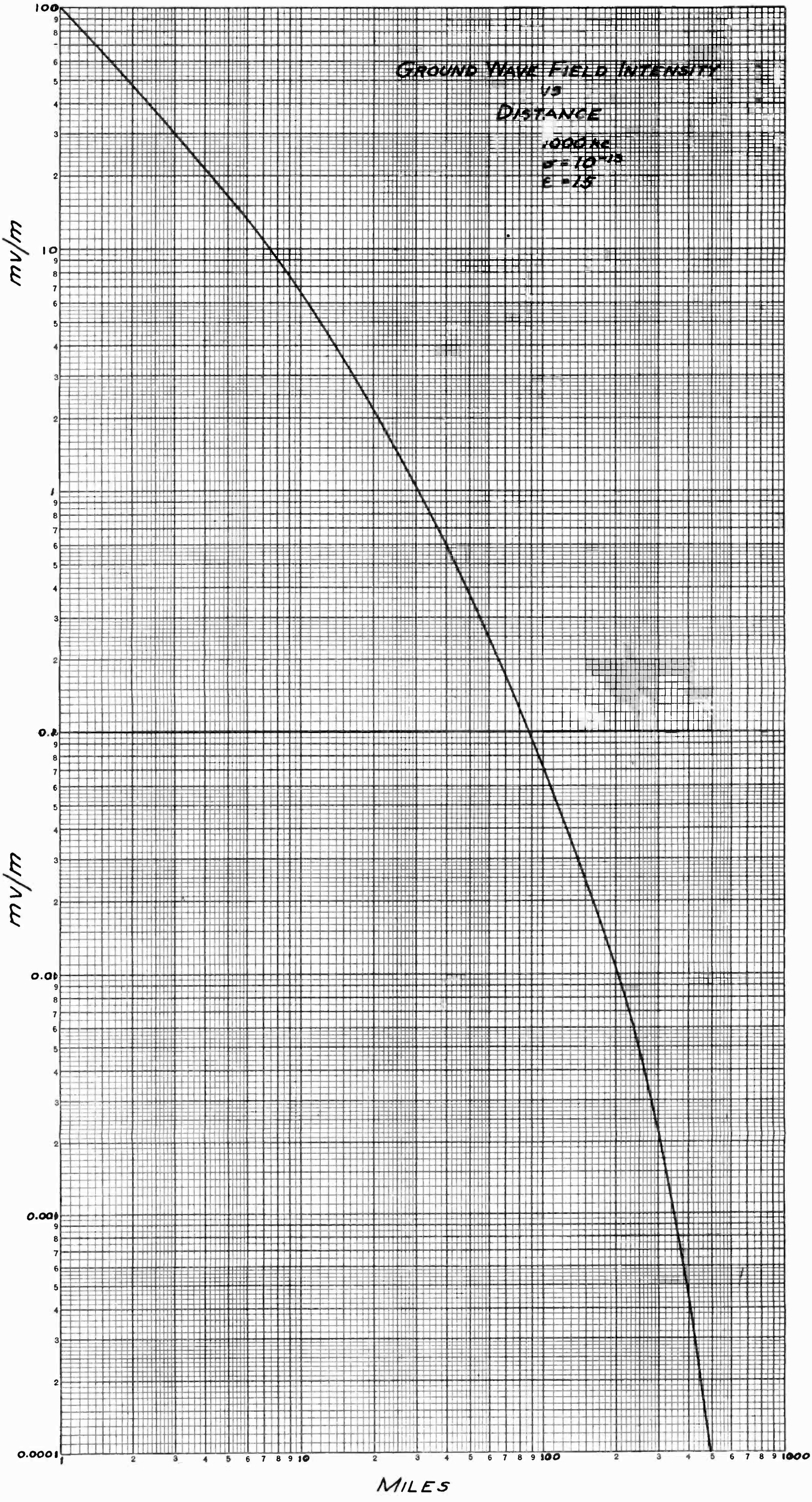


Figure 1

These curves are not considered to be sufficiently accurate for practical use for distances less than approximately 250 miles.



760684 O - 47 (Face p. 50) No. 2



GROUND WAVE FIELD INTENSITY
VS
DISTANCE
1000 kc
σ = 10^-13
ε = 15
mv/m
mv/m
MILES

Fig. 2

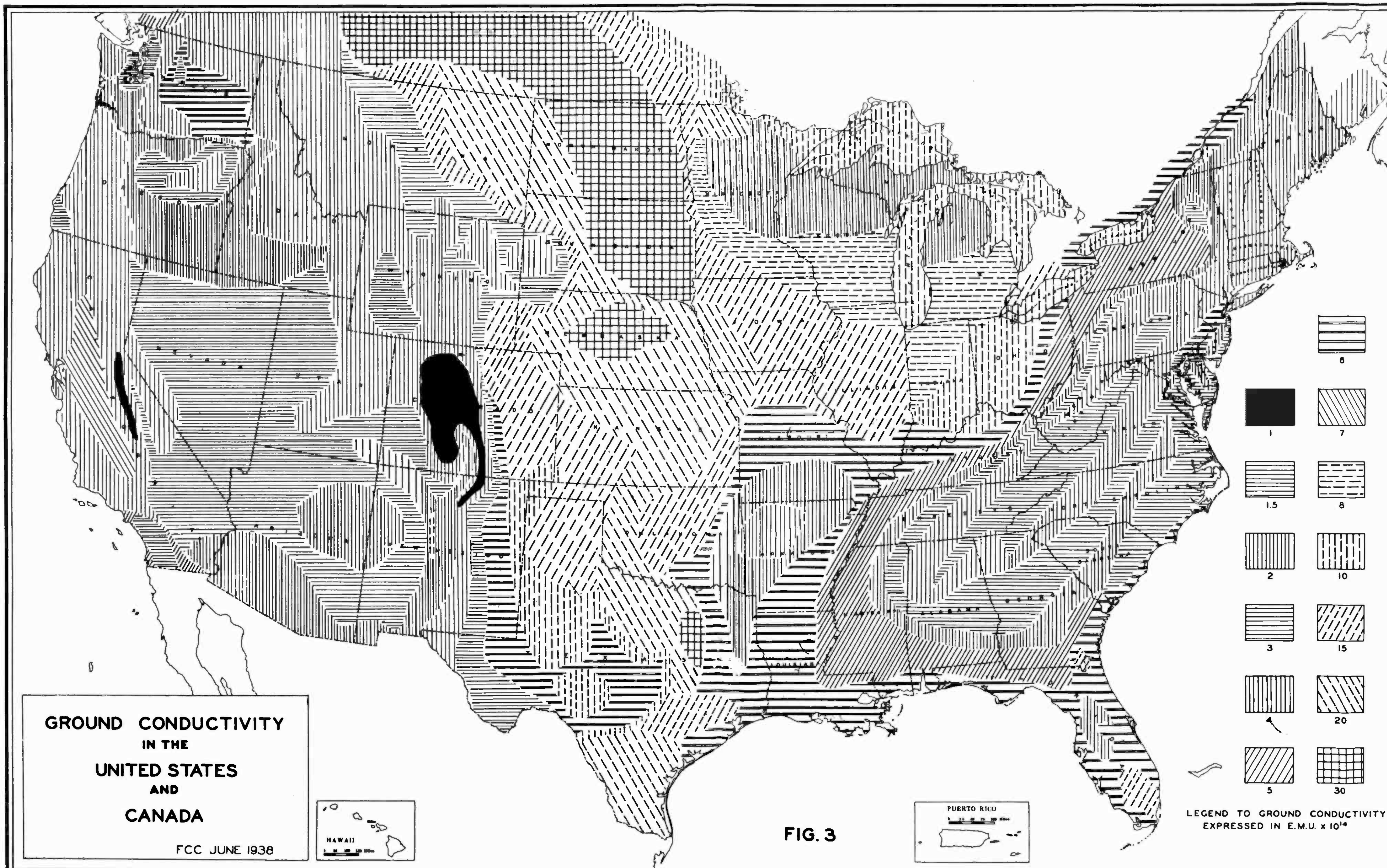


FIG. 3

760684 O - 47 (Face p. 50) No. 4

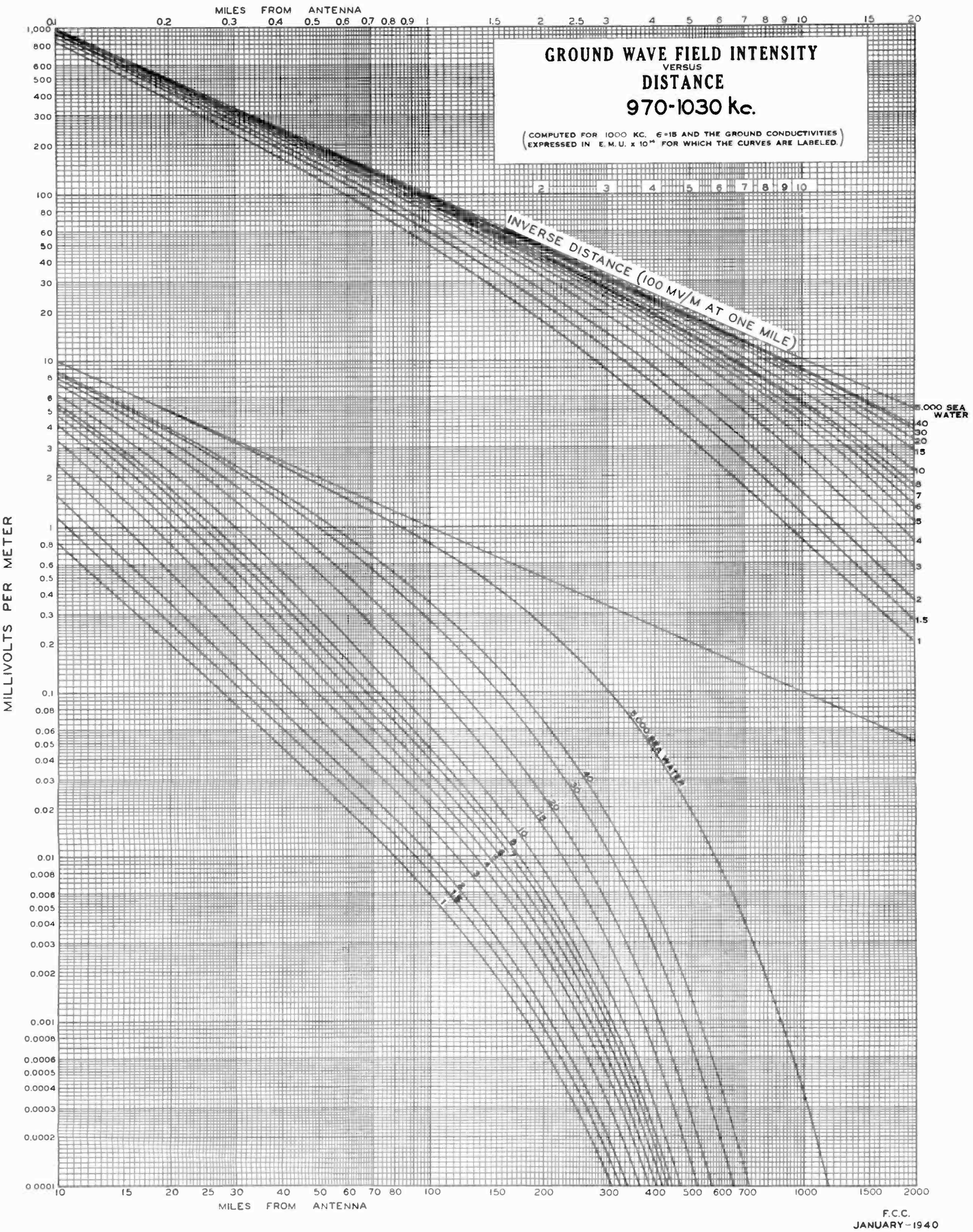
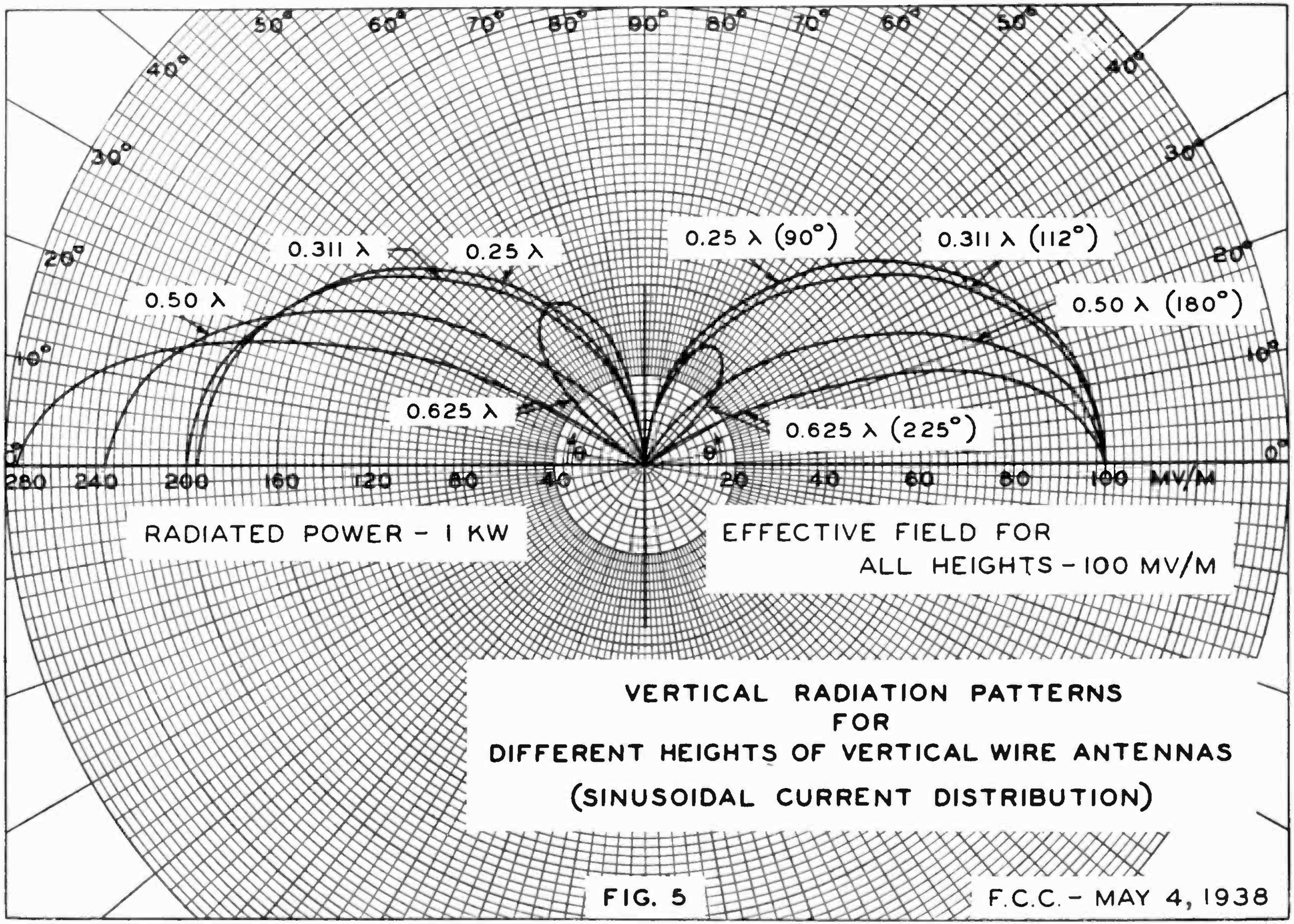

GROUND WAVE FIELD INTENSITY
VERSUS
DISTANCE
970-1030 Kc.
(COMPUTED FOR 1000 KC. ε=15 AND THE GROUND CONDUCTIVITIES EXPRESSED IN E.M.U. x 10⁻¹⁵ FOR WHICH THE CURVES ARE LABELED.)
INVERSE DISTANCE (100 MV/M AT ONE MILE)
MILES FROM ANTENNA
MILLIVOLTS PER METER
5,000 SEA WATER
F.C.C.
JANUARY-1940

FIGURE 4



VERTICAL RADIATION PATTERNS FOR DIFFERENT HEIGHTS OF VERTICAL WIRE ANTENNAS (SINUSOIDAL CURRENT DISTRIBUTION)

FIG. 5

760684 O - 47 (Face p. 50) No. 6

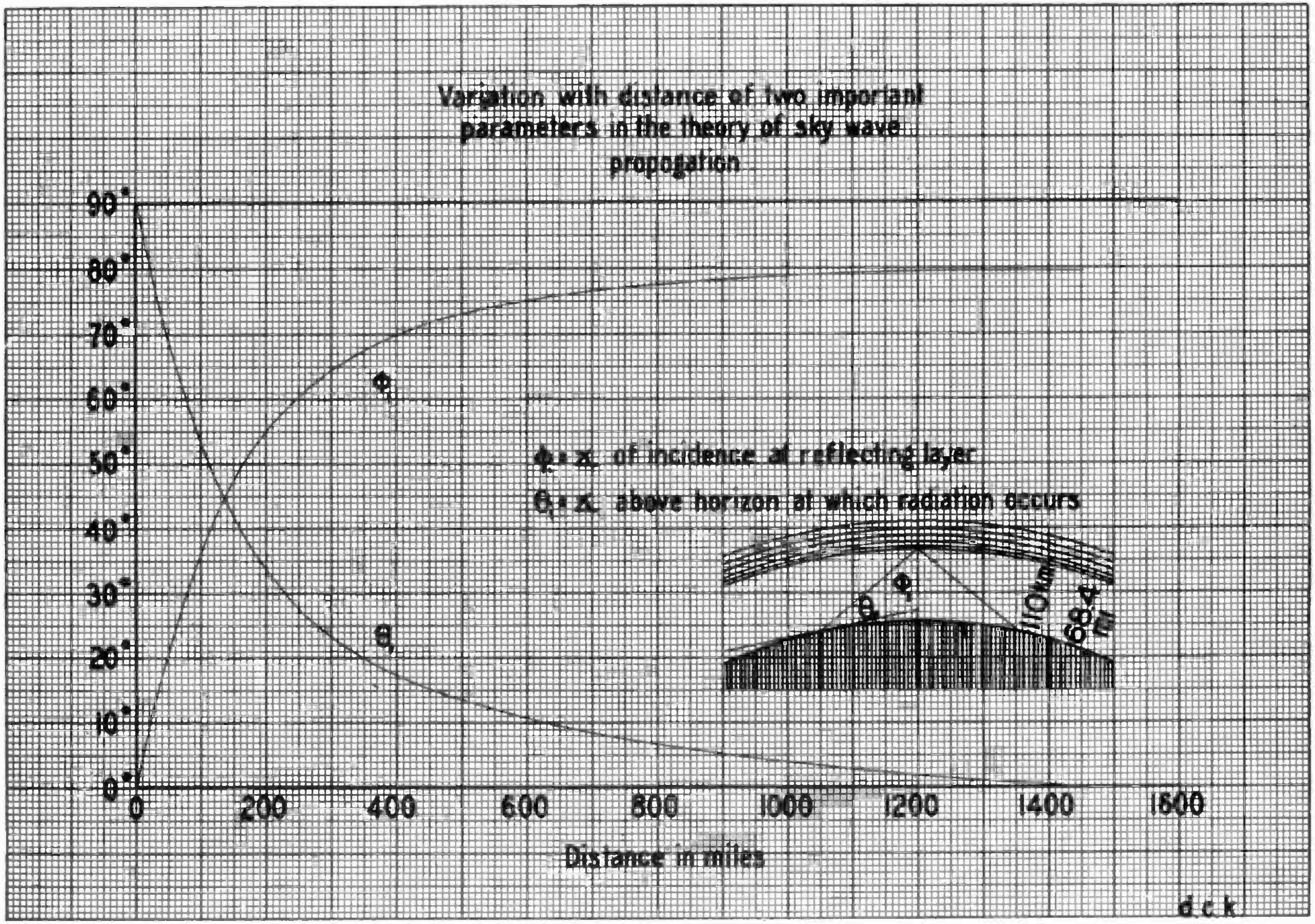
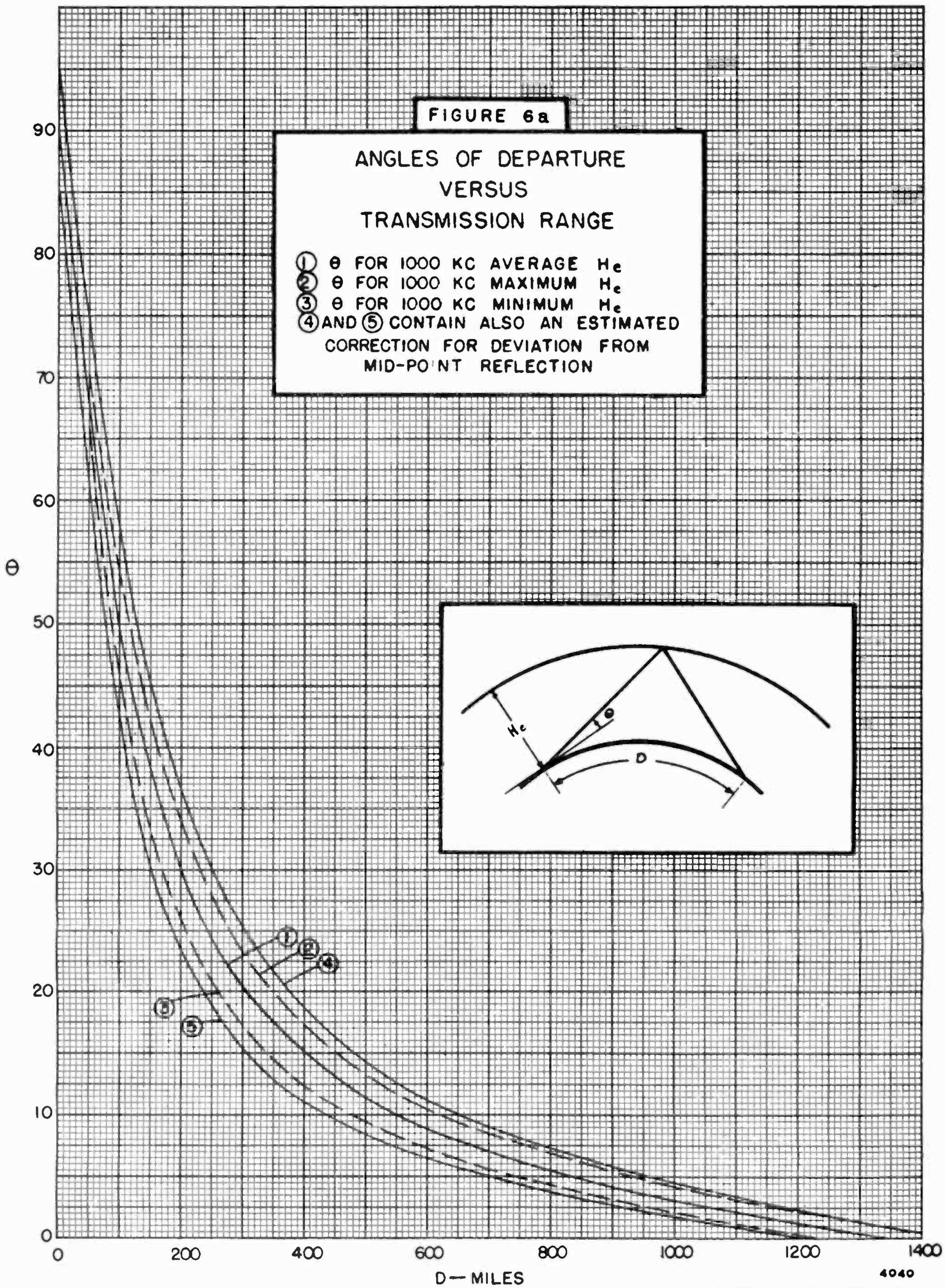
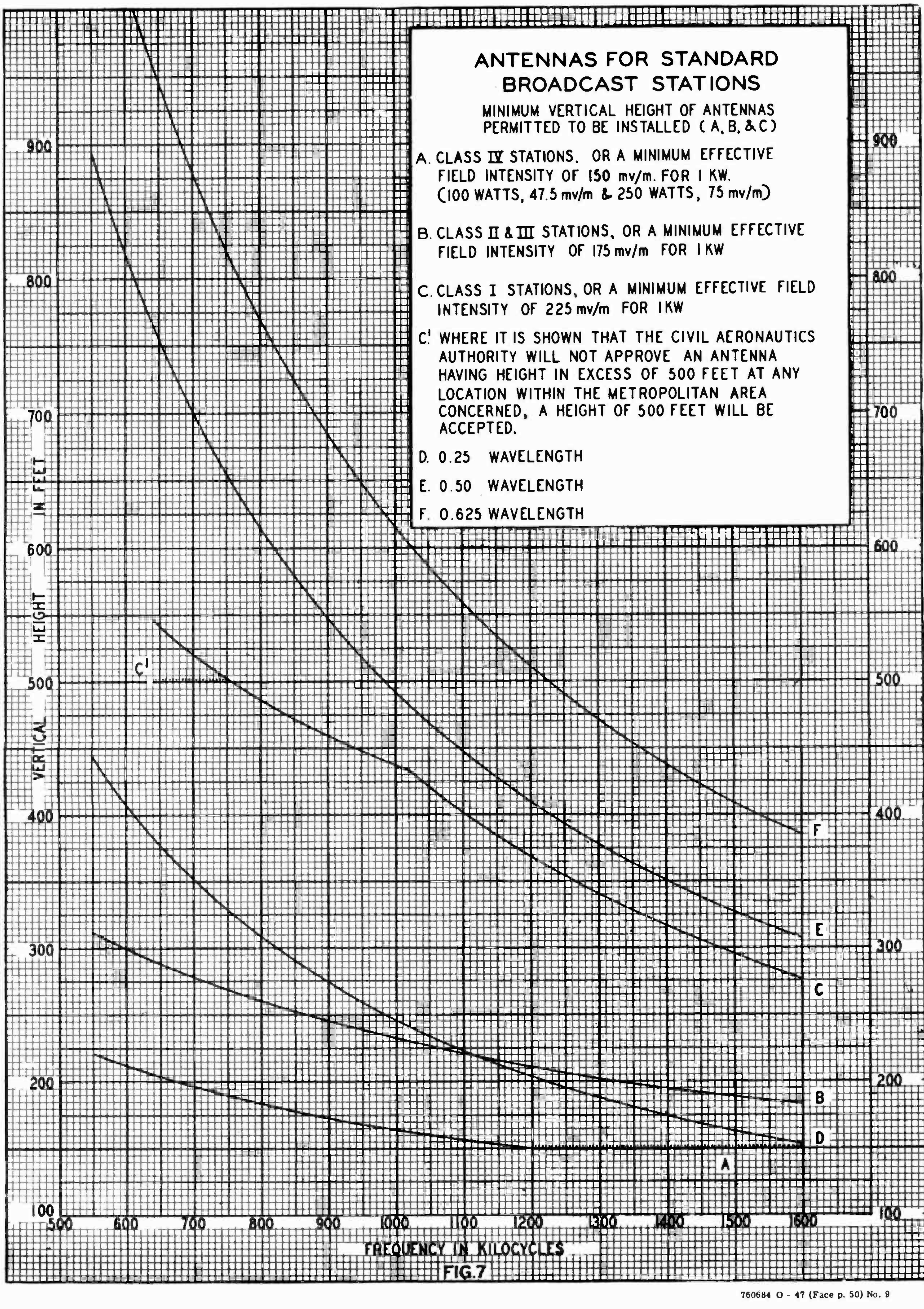

Variation with distance of two important parameters in the theory of sky wave propogation
90°
80°
70°
60°
50°
40°
30°
20°
10°
0°
0
200
400
600
800
1000
1200
1400
1600
Distance in miles
Φ
θ
Φ = ∡ of incidence at reflecting layer
θ = ∡ above horizon at which radiation occurs
110 km
68.4 mi
d.c.k

Fig. 6



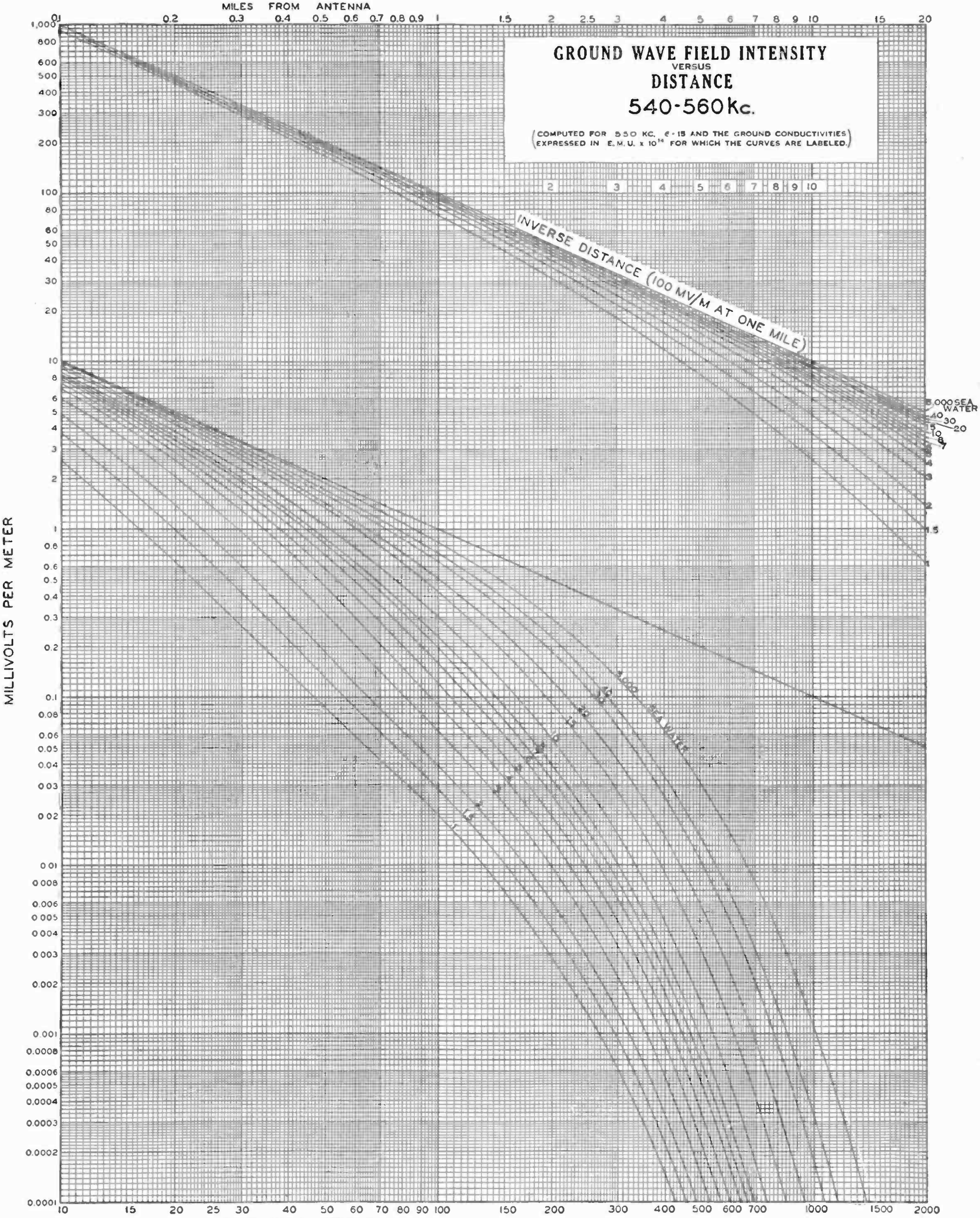
4040
760684 O - 47 (Face p. 50) No. 8



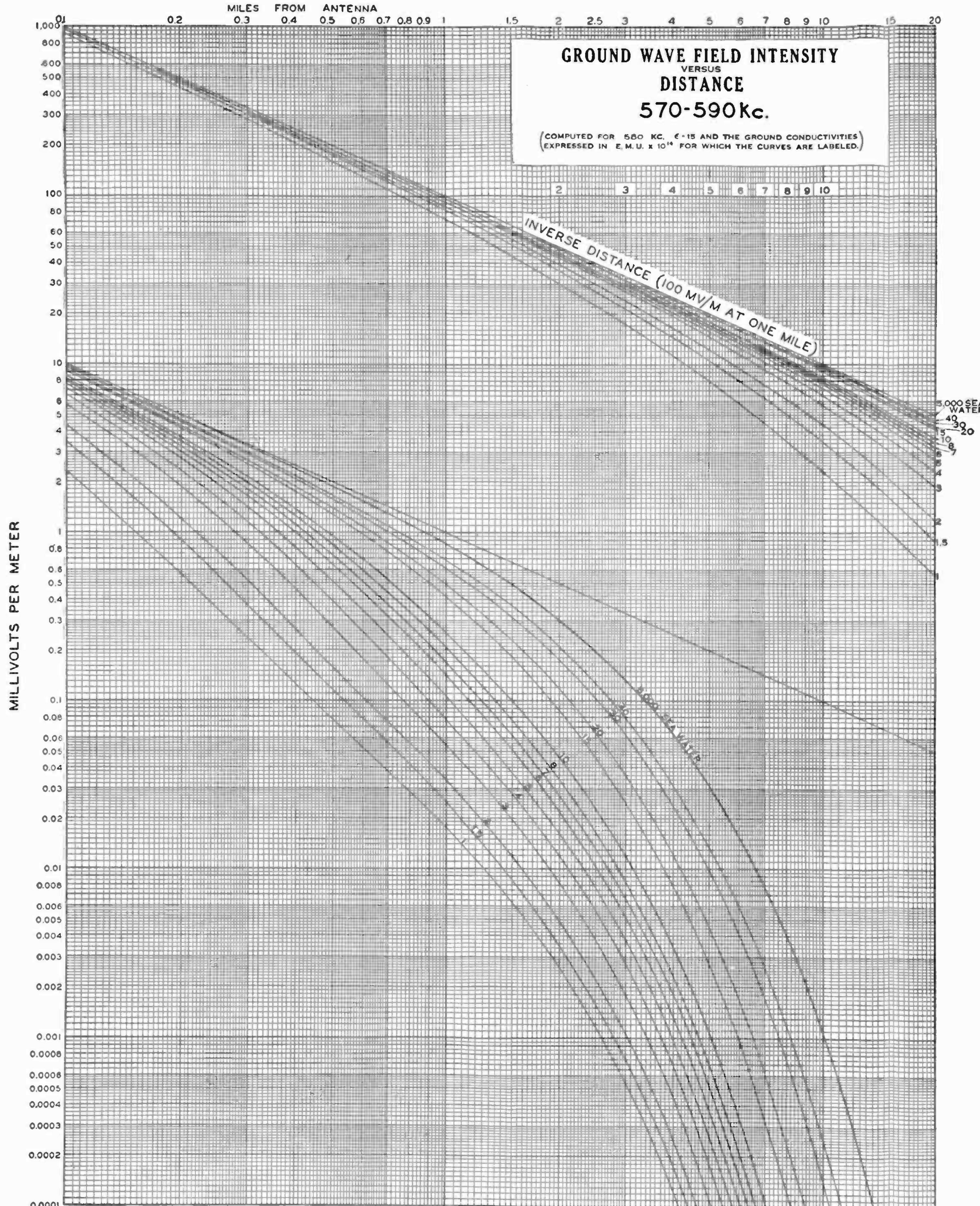
ANTENNAS FOR STANDARD BROADCAST STATIONS
MINIMUM VERTICAL HEIGHT OF ANTENNAS PERMITTED TO BE INSTALLED (A, B, & C)
A. CLASS IV STATIONS, OR A MINIMUM EFFECTIVE FIELD INTENSITY OF 150 mv/m. FOR 1 KW. (100 WATTS, 47.5 mv/m & 250 WATTS, 75 mv/m)
B. CLASS II & III STATIONS, OR A MINIMUM EFFECTIVE FIELD INTENSITY OF 175 mv/m FOR 1 KW
C. CLASS I STATIONS, OR A MINIMUM EFFECTIVE FIELD INTENSITY OF 225 mv/m FOR 1 KW
C'. WHERE IT IS SHOWN THAT THE CIVIL AERONAUTICS AUTHORITY WILL NOT APPROVE AN ANTENNA HAVING HEIGHT IN EXCESS OF 500 FEET AT ANY LOCATION WITHIN THE METROPOLITAN AREA CONCERNED, A HEIGHT OF 500 FEET WILL BE ACCEPTED.
D. 0.25 WAVELENGTH
E. 0.50 WAVELENGTH
F. 0.625 WAVELENGTH
VERTICAL HEIGHT IN FEET
100
200
300
400
500
600
700
800
900
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
FREQUENCY IN KILOCYCLES
A
B
C
C'
D
E
F

FIG.7

175

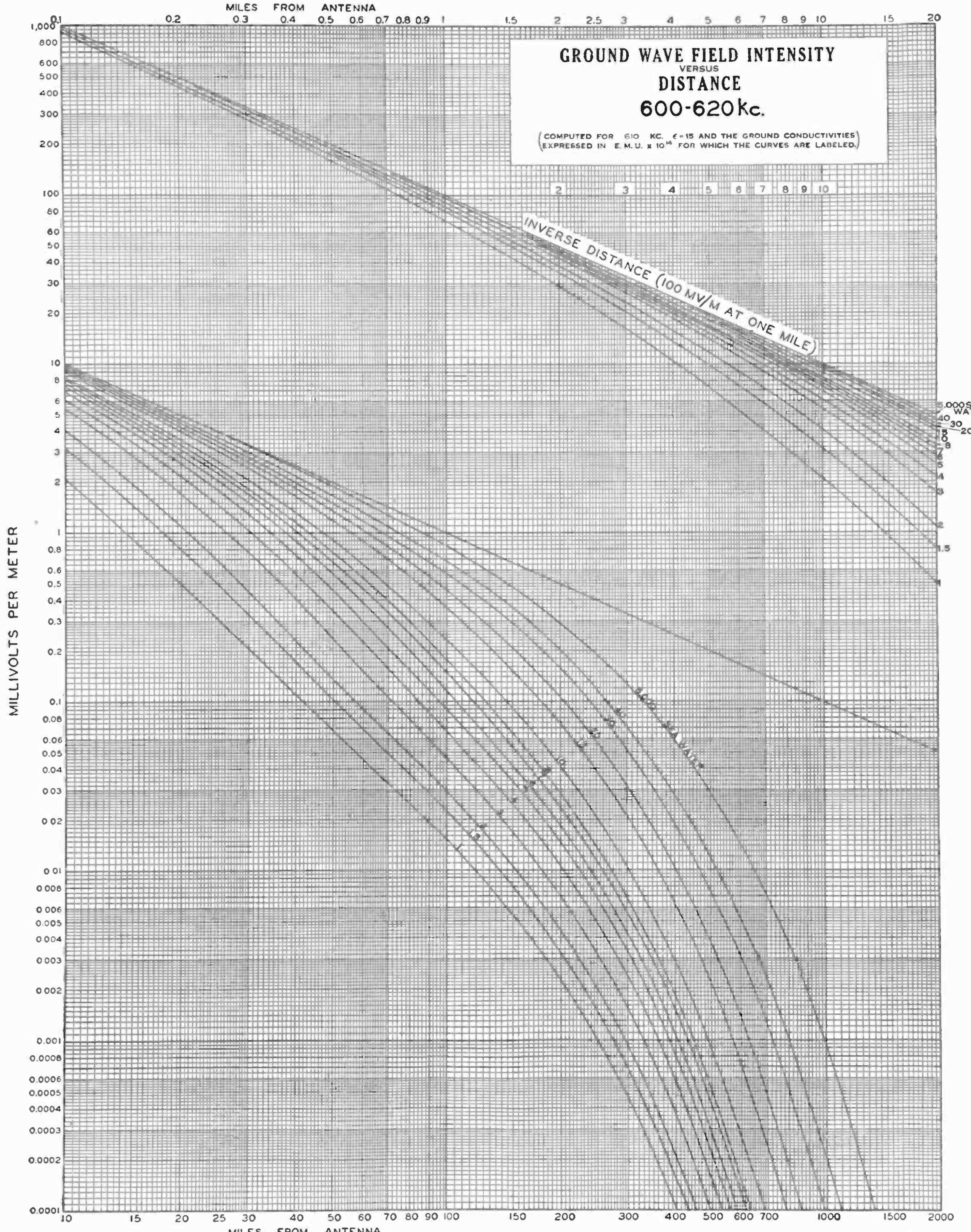


APPENDIX I - GRAPH 1

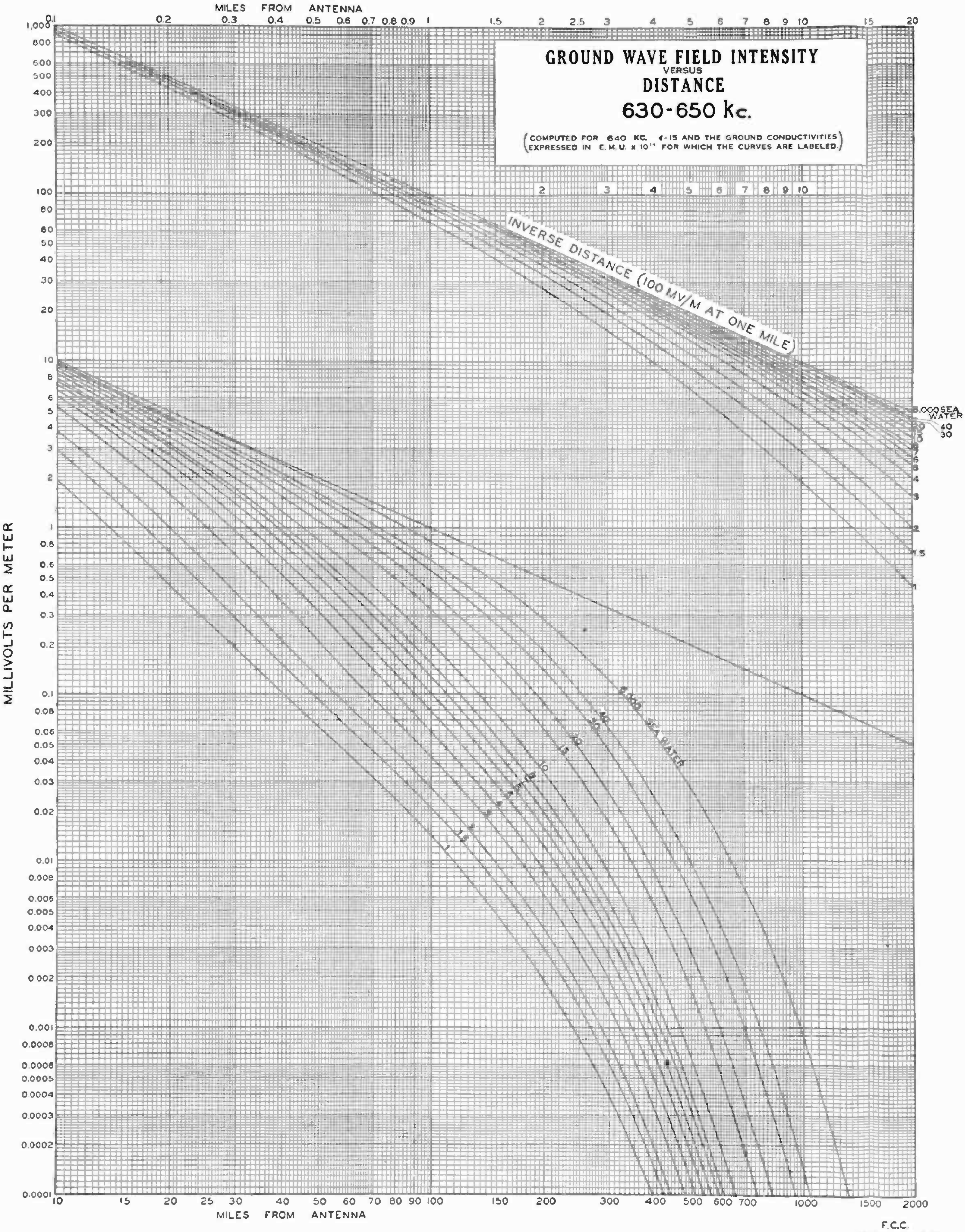


F.C.C.
JANUARY - 1940

APPENDIX I - GRAPH 2

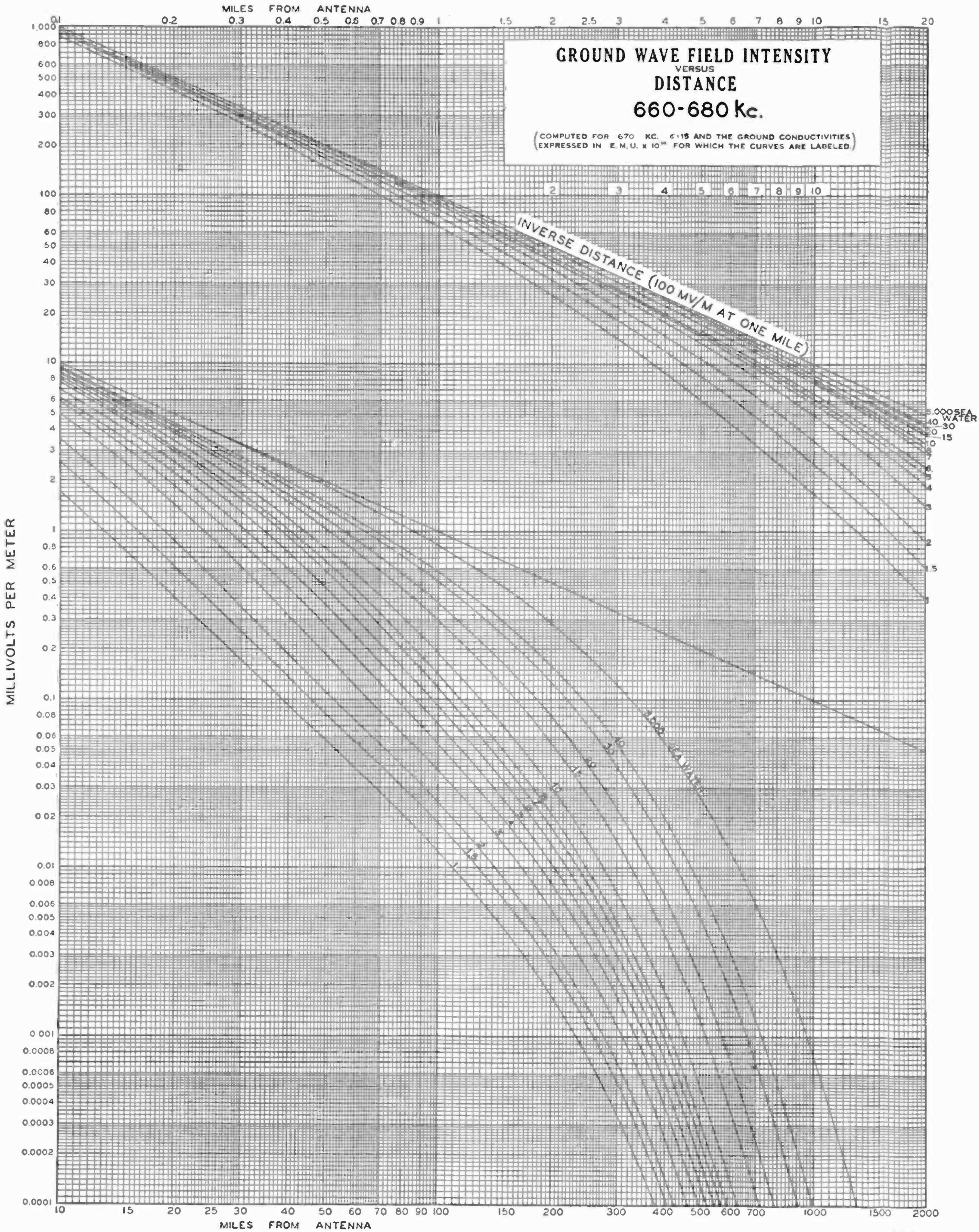


APPENDIX I - GRAPH 3



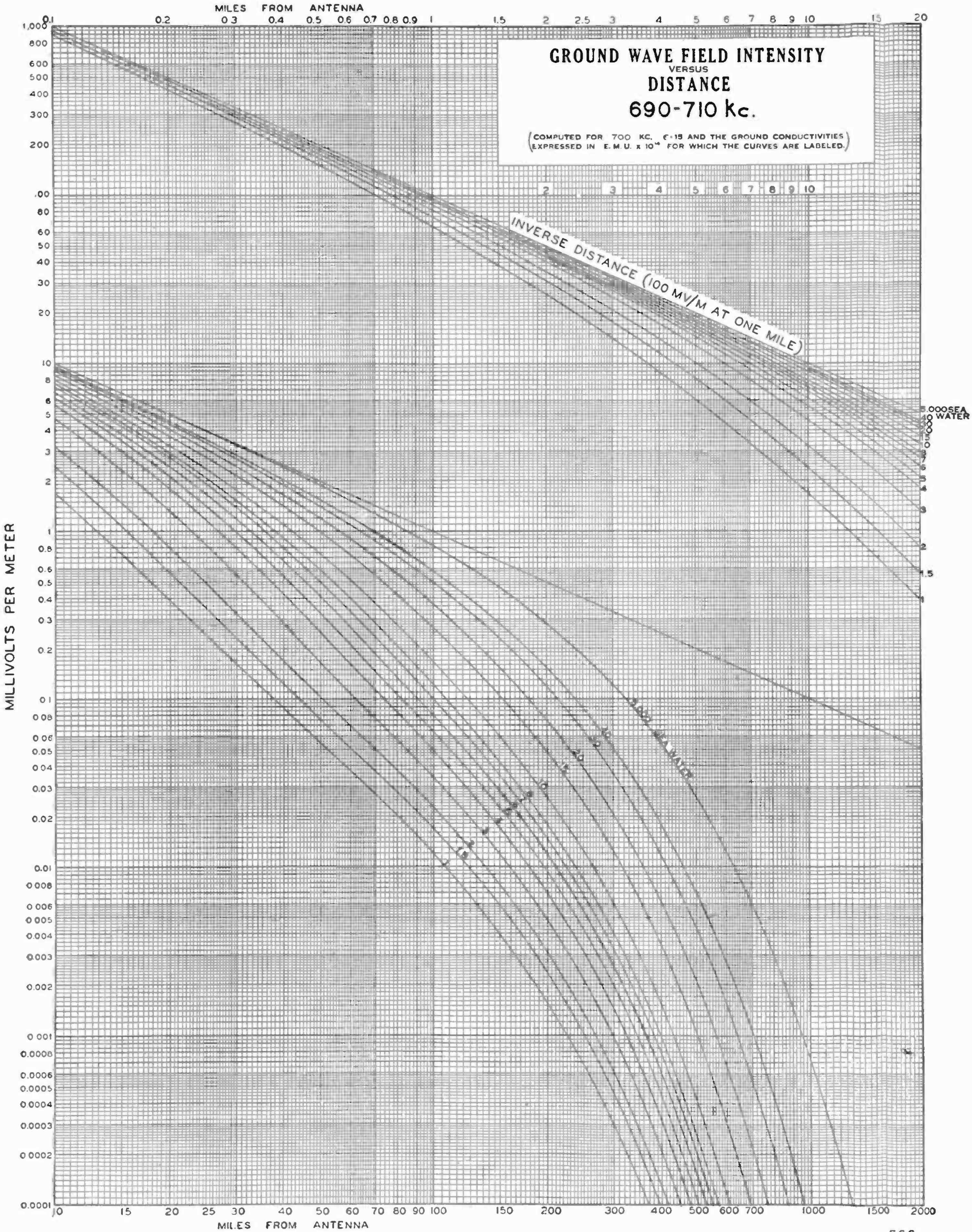
APPENDIX I - GRAPH 4

760684°—47 (Face p. 50) No. 13

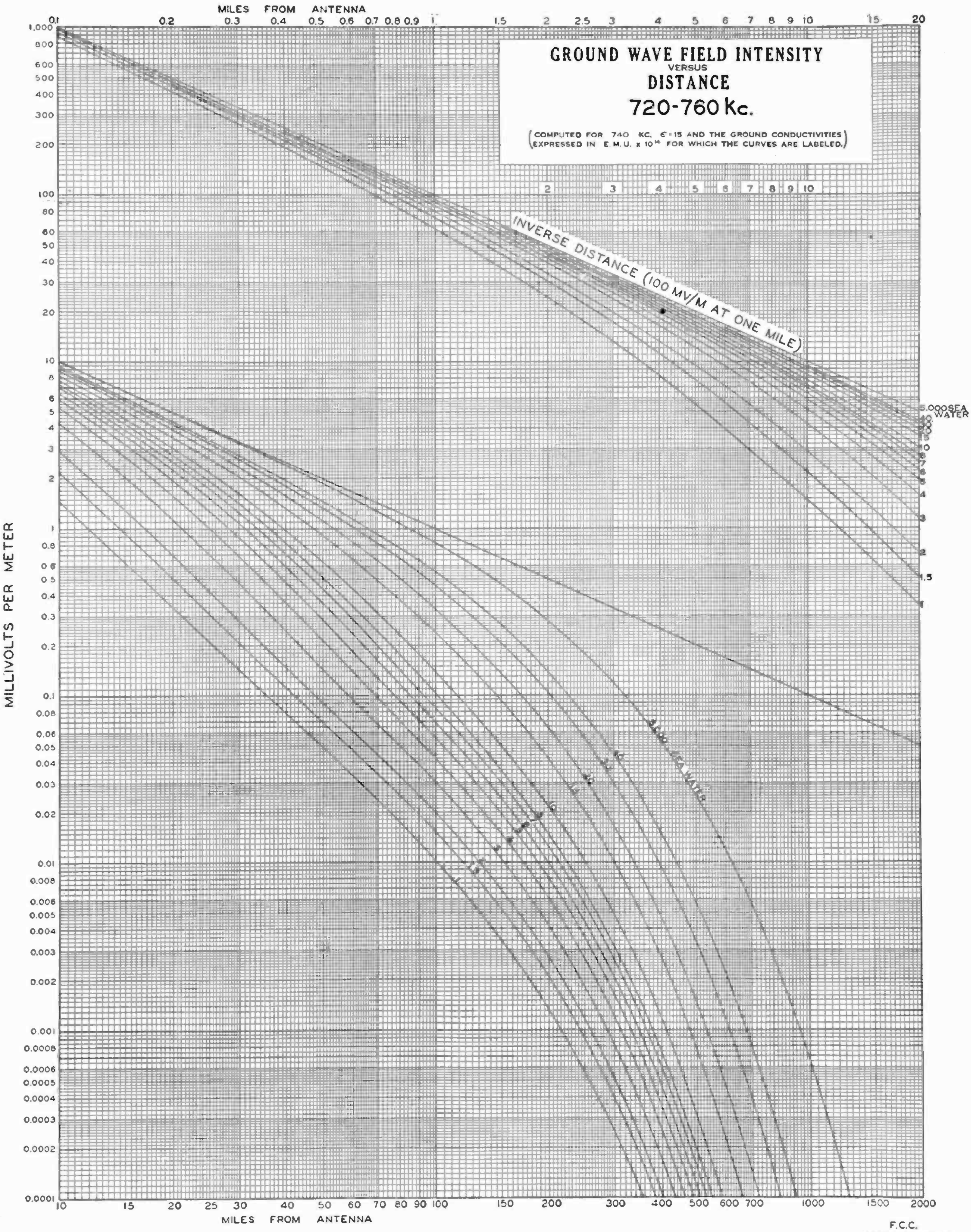


APPENDIX I - GRAPH 5

760684°—47 (Face p. 50) No. 14

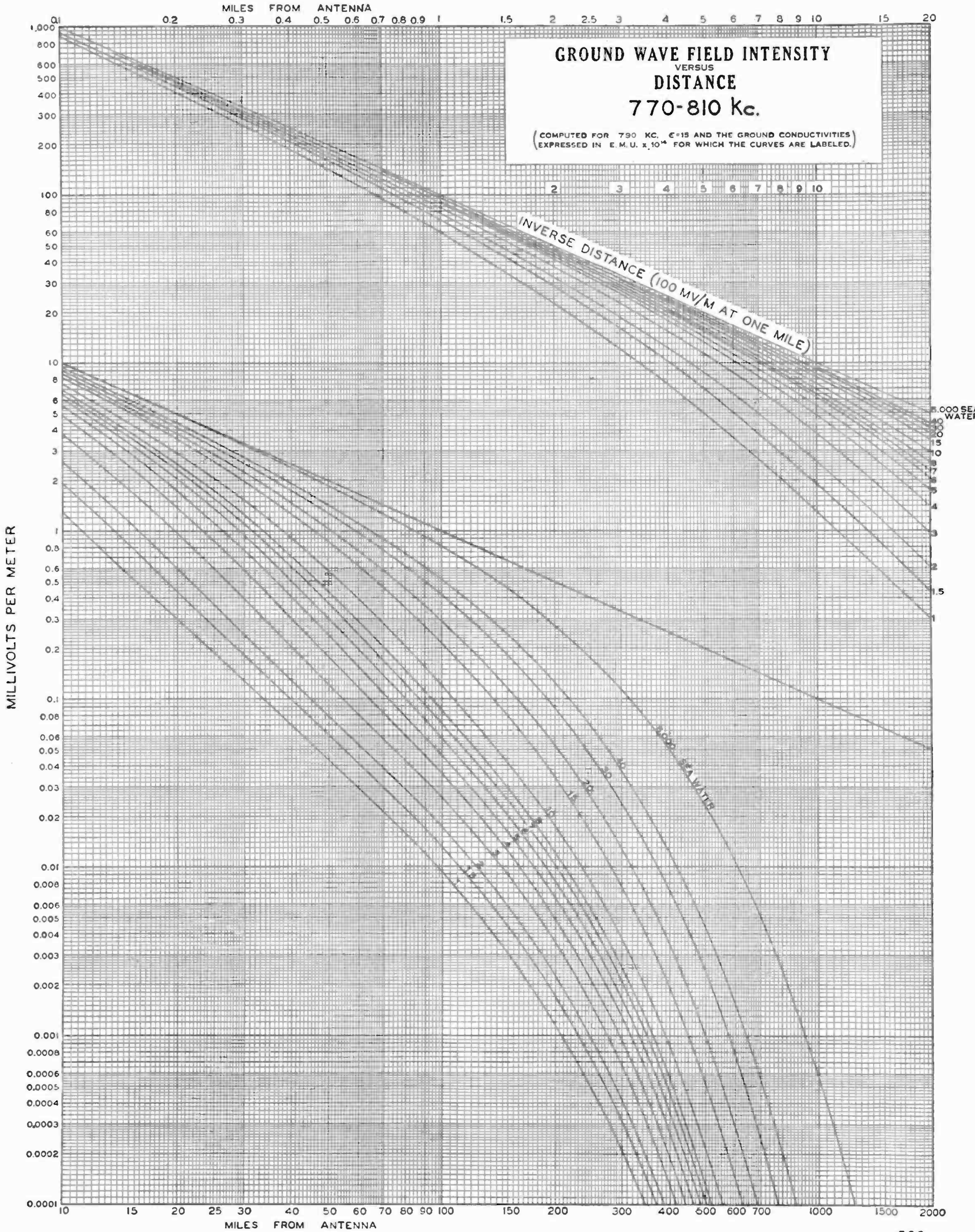


APPENDIX I - GRAPH 6



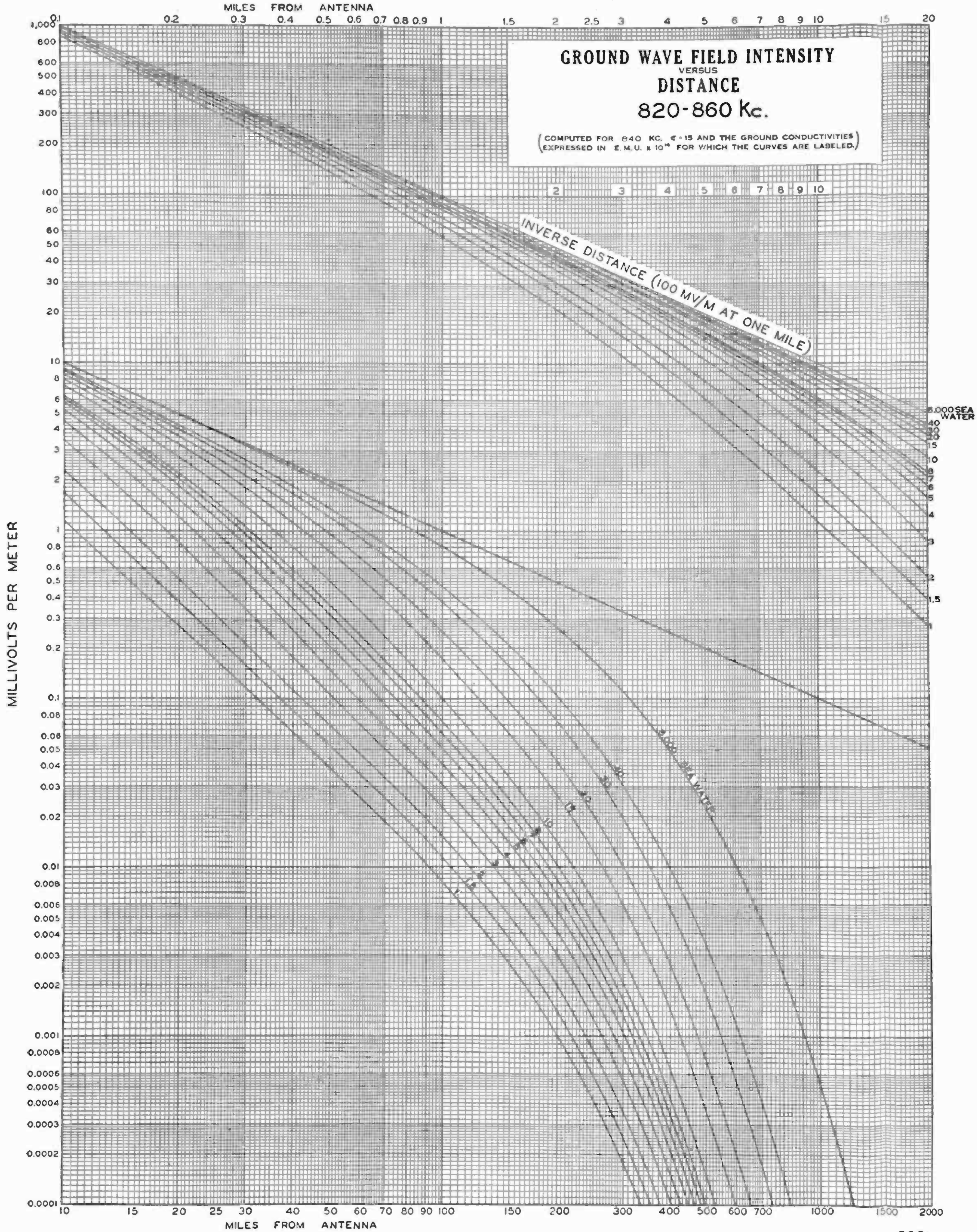
APPENDIX I - GRAPH 7

760684°—47 (Face p. 50) No. 16



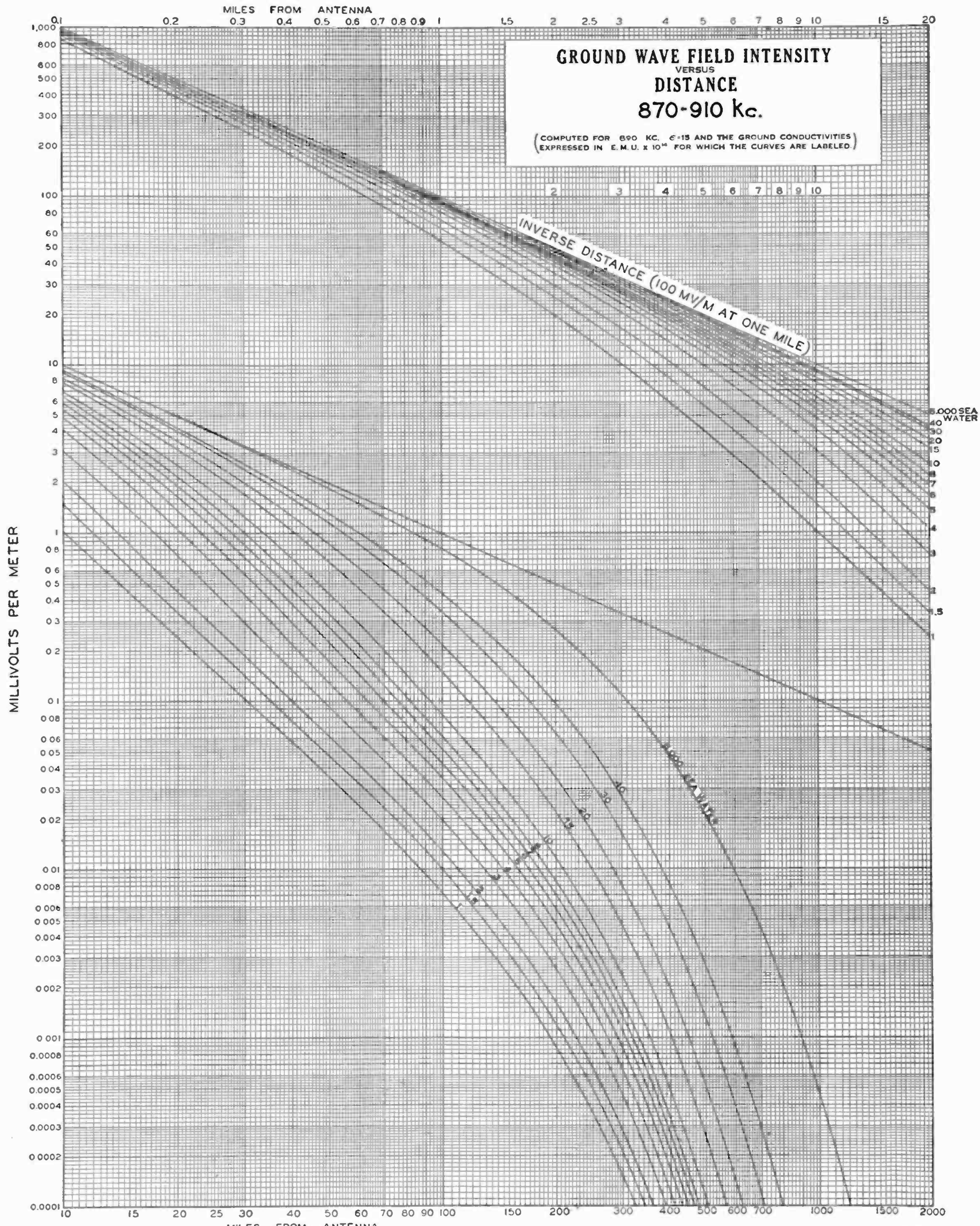
F.C.C.
JANUARY-1940

APPENDIX I - GRAPH 8



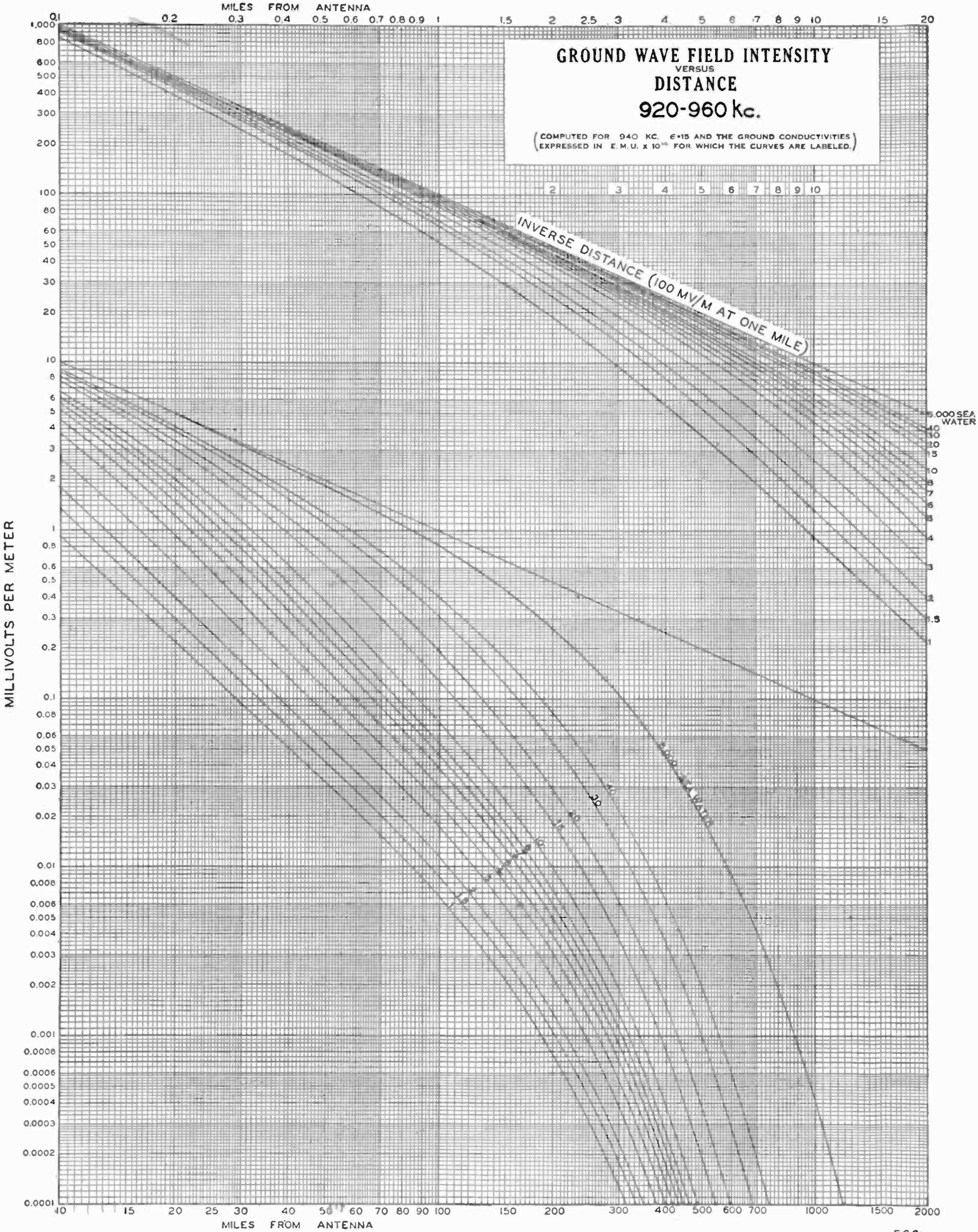
APPENDIX I - GRAPH 9

760684°—47 (Face p. 50) No. 18



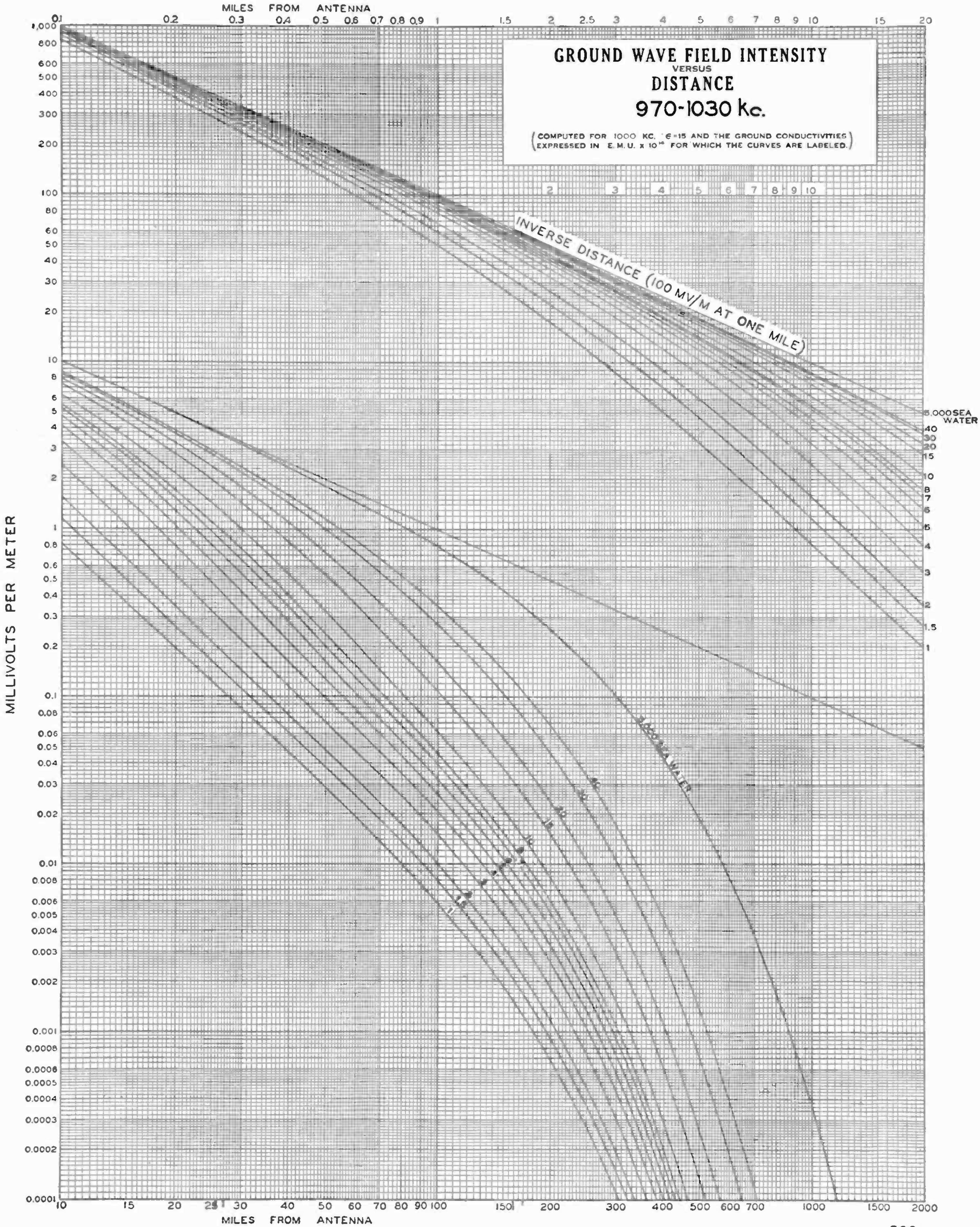
F.C.C.
JANUARY-1940

APPENDIX I - GRAPH 10



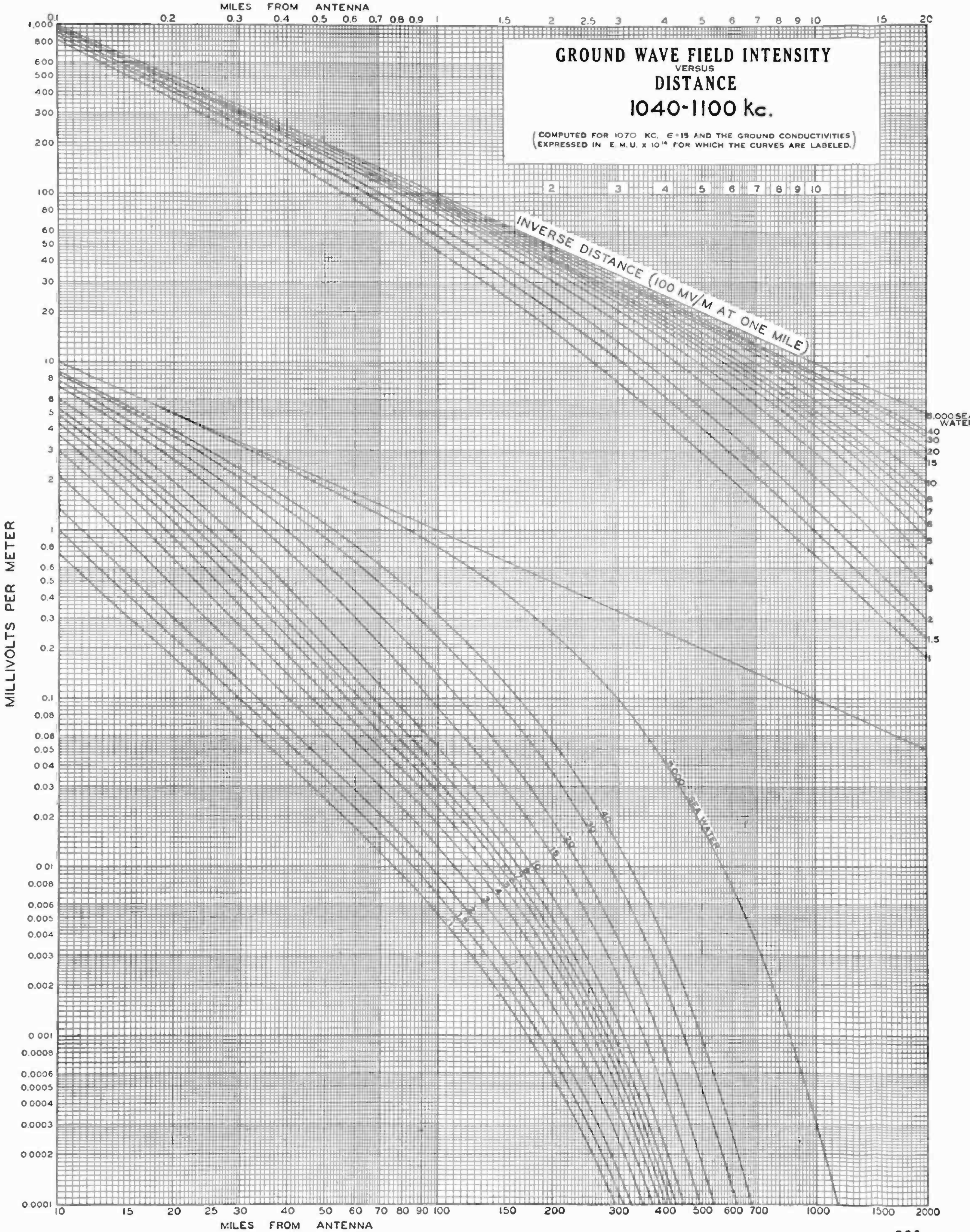
APPENDIX I - GRAPH 11

700684°—47 (Face p. 50) No. 20

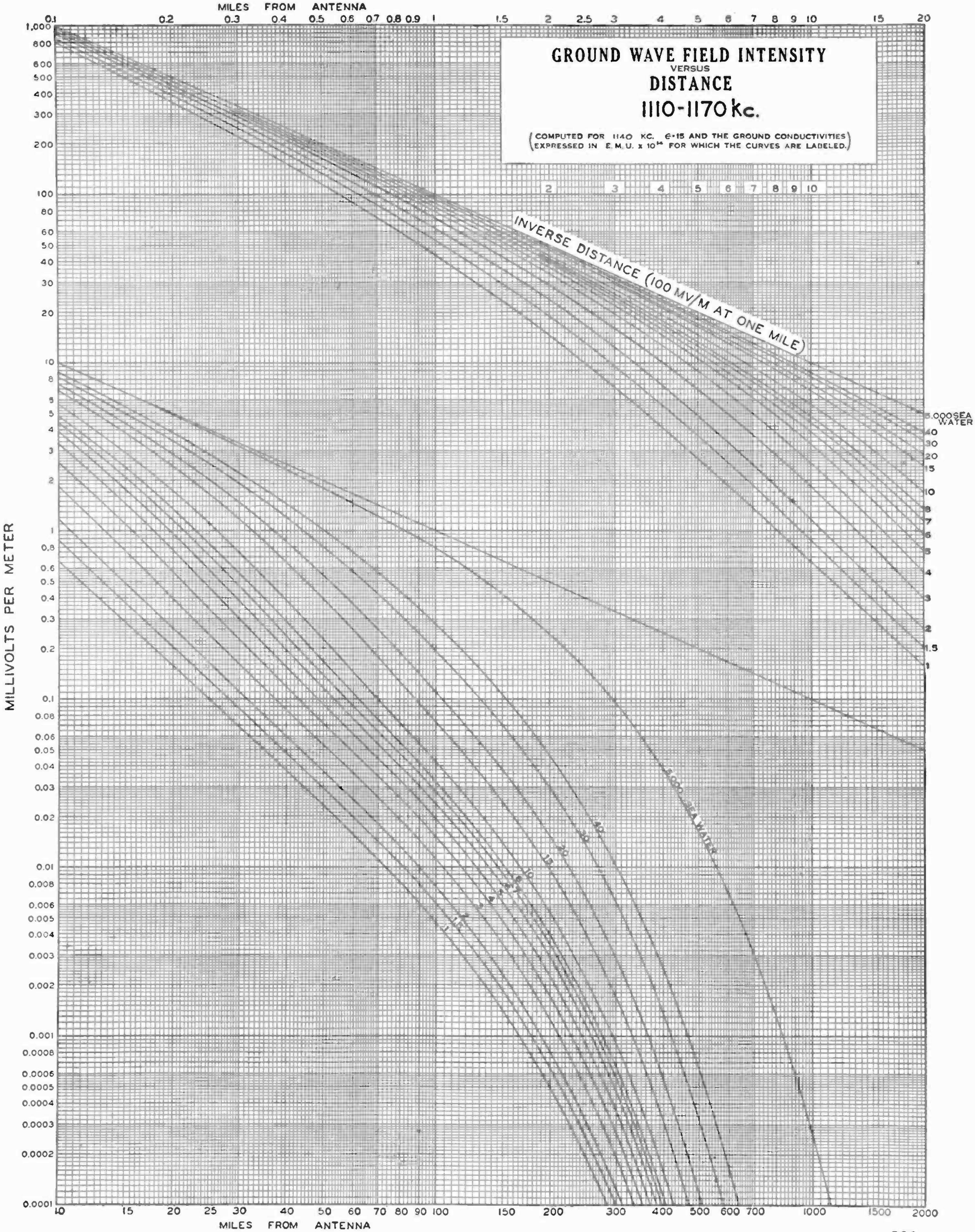


APPENDIX I - GRAPH 12

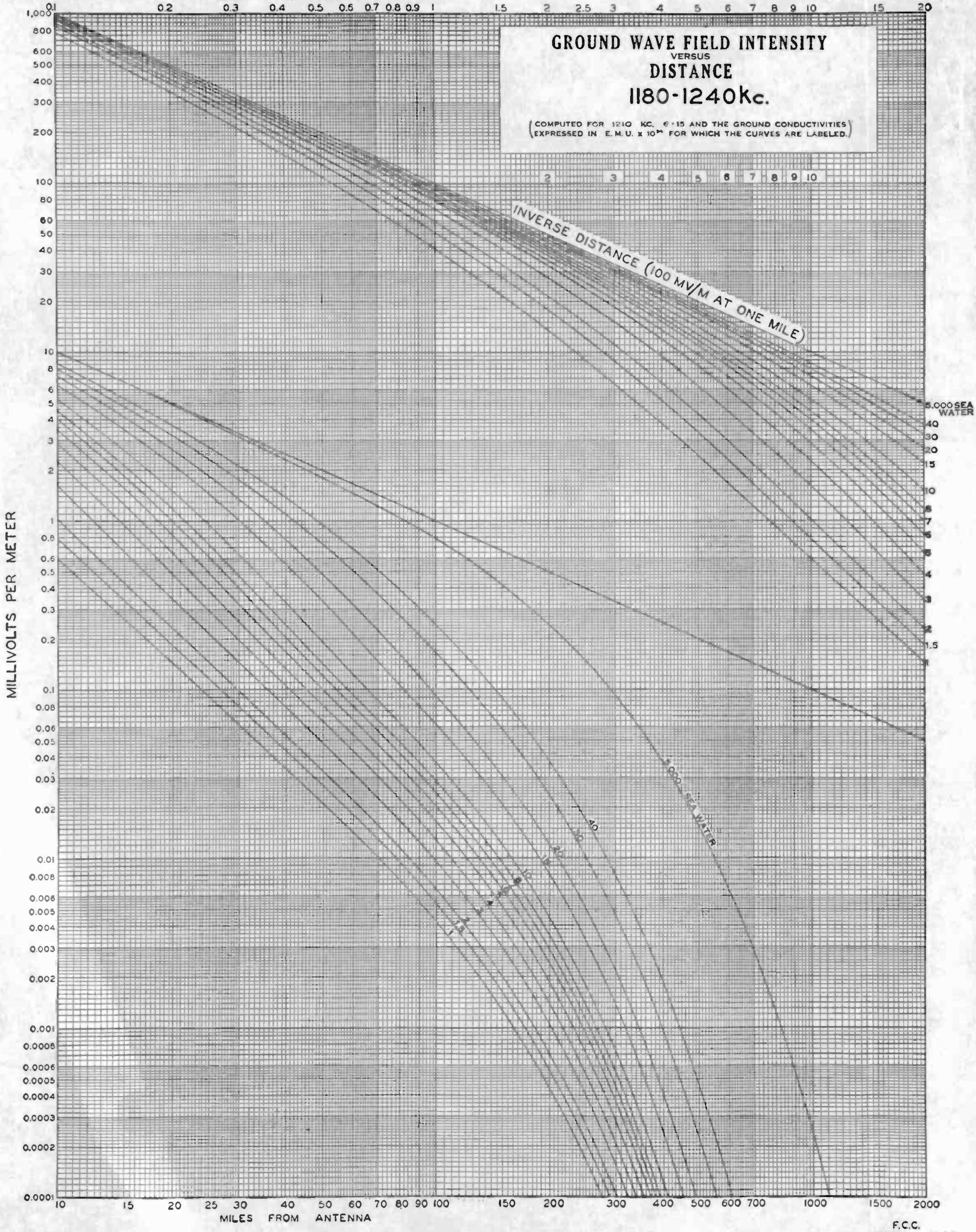
760684°—47 (Face p. 50) No. 21



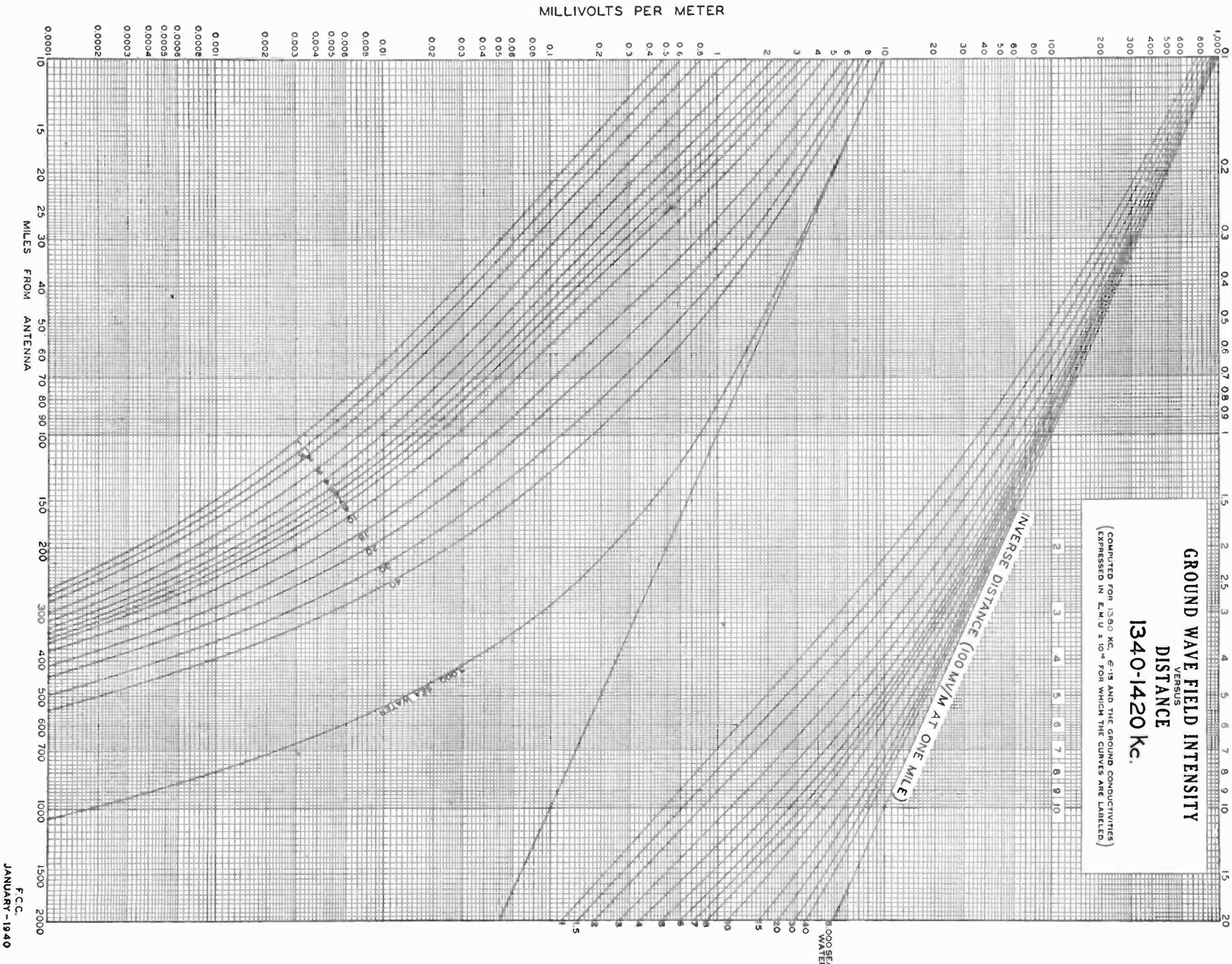
APPENDIX I - GRAPH 13



APPENDIX I - GRAPH 14

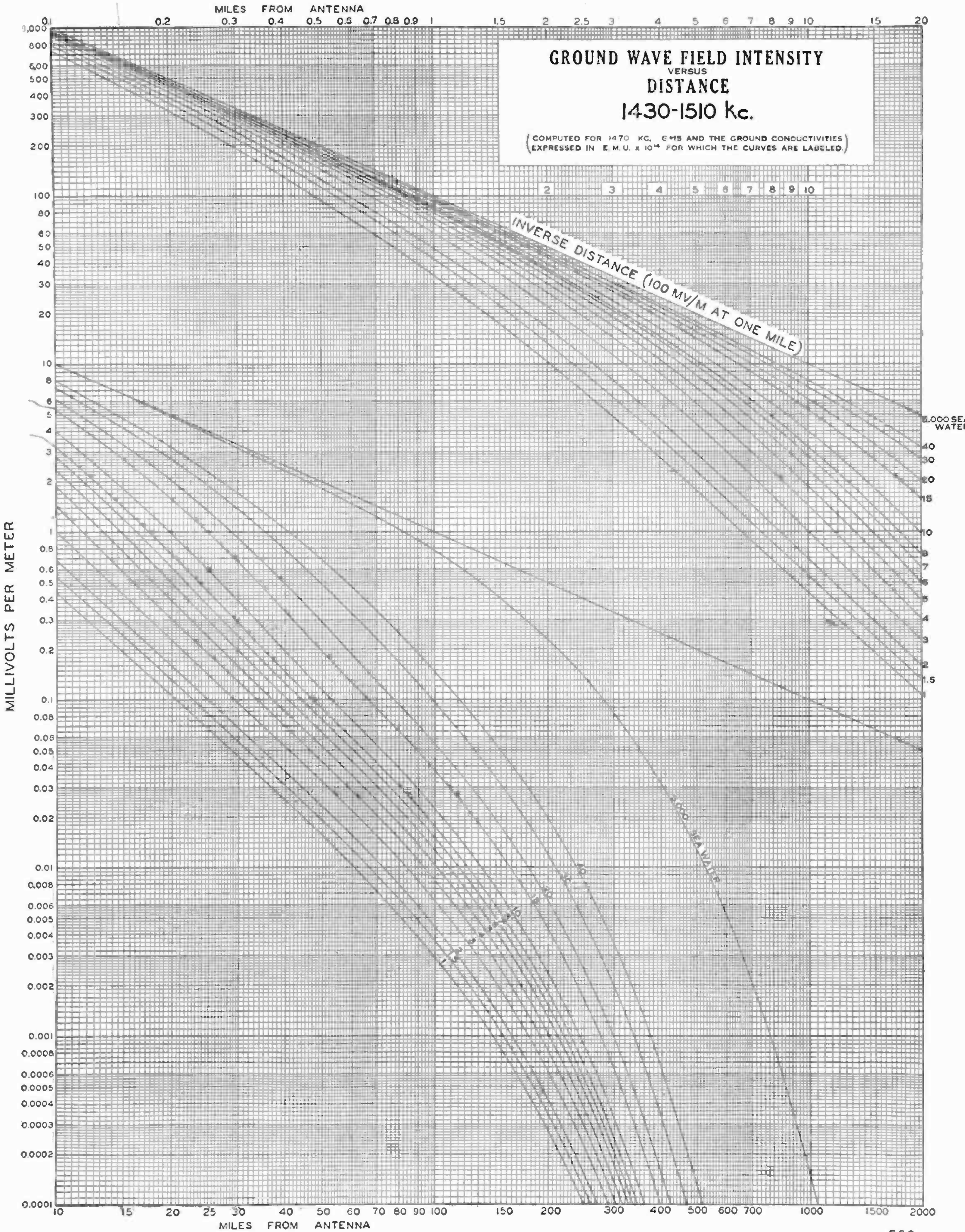


APPENDIX I - GRAPH 15

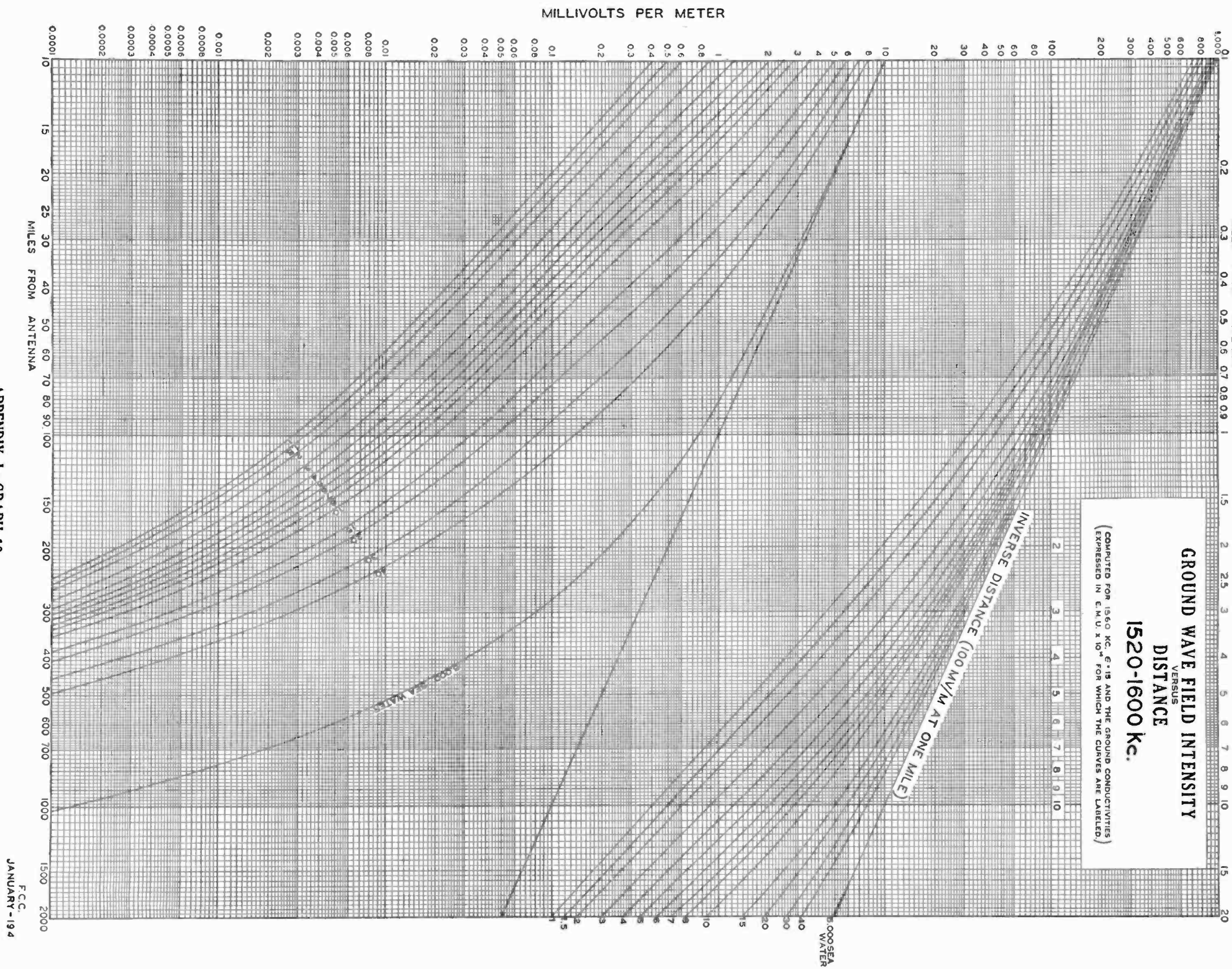


APPENDIX I - GRAPH 17

700884°—47 (Face p. 50) No. 26

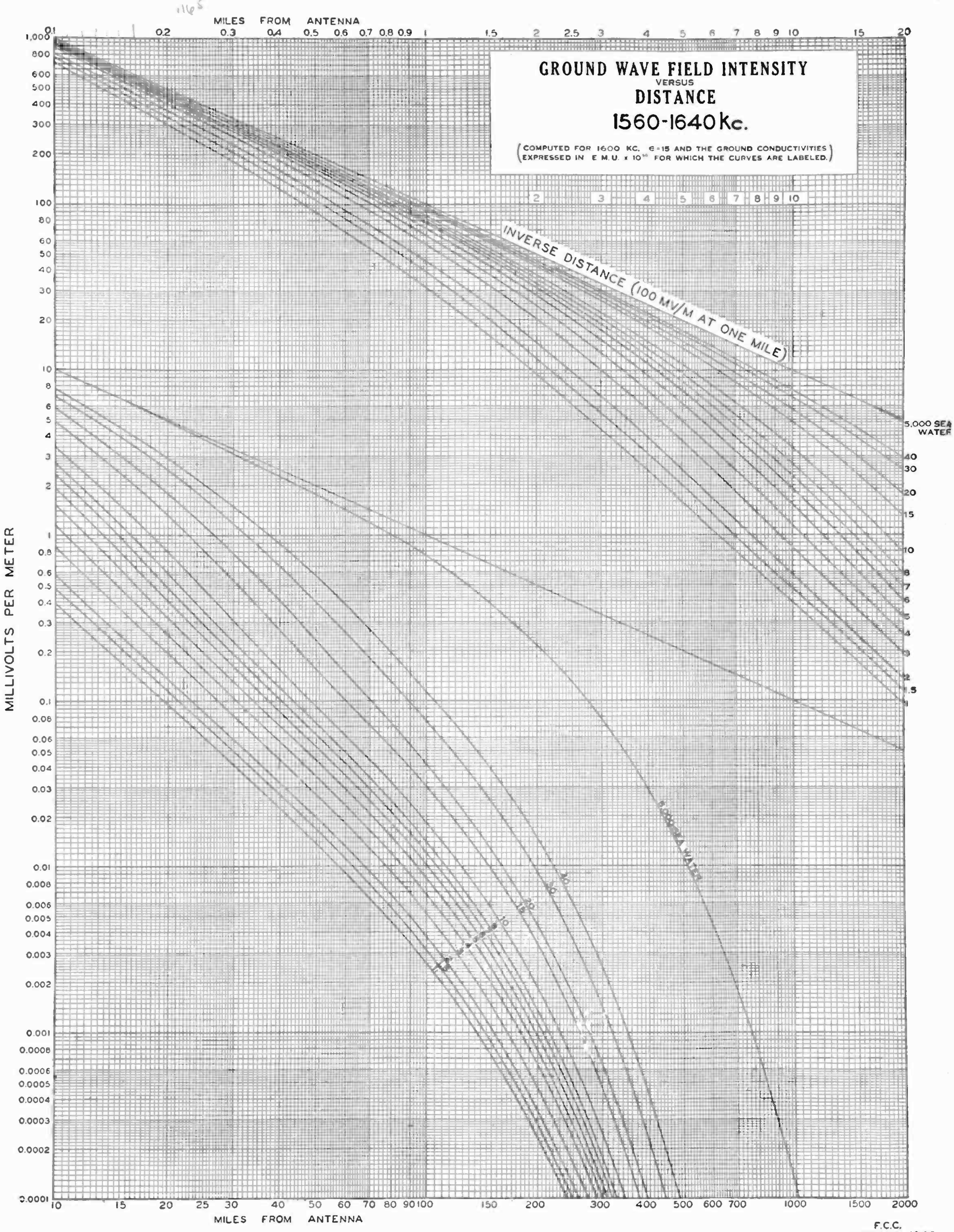


APPENDIX I - GRAPH 18



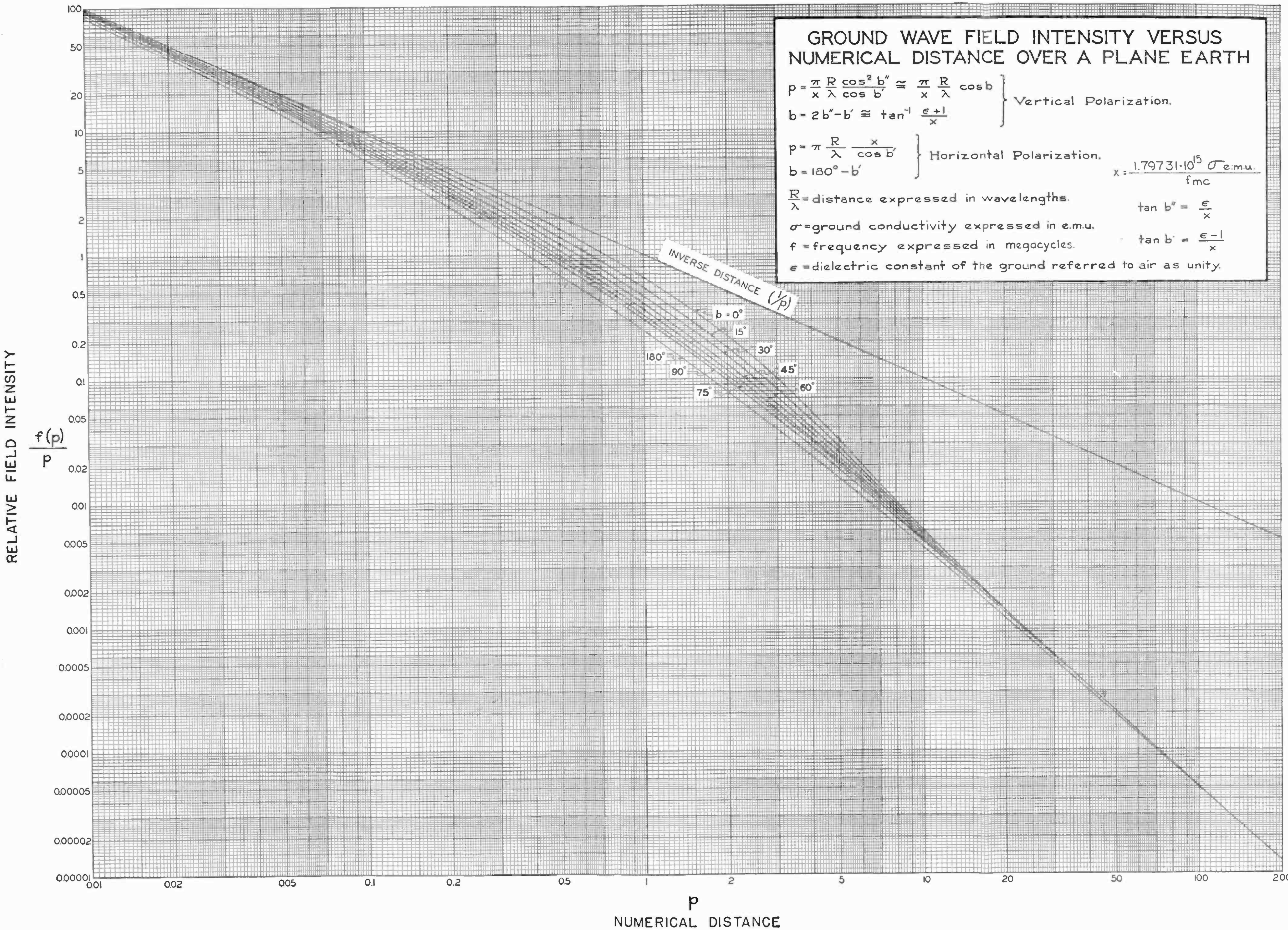
APPENDIX I - GRAPH 19

76084°—47 (Face p. 50) No. 28



APPENDIX I - GRAPH 20

760684°—47 (Face p. 50) No. 29



APPENDIX I - GRAPH 21

760684°—47 (Face p. 50) No. 30