CRPL-D27

UNITED STATES DEPARTMENT OF COMMERCE
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NATIONAL BUREAU OF STANDARDS
E. U. Condon, Director

BASIC RADIO PROPAGATION PREDICTIONS FOR FEBRUARY 1947 THREE MONTHS IN ADVANCE

ISSUED NOVEMBER 1946

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PREPARED BY CENTRAL RADIO PROPAGATION LABORATORY
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NATIONAL BUREAU OF STANDARDS

CENTRAL RADIO PROPAGATION LABORATORY

Basic Radio Propagation Predictions are prepared by the staff of the Central Radio Propagation Laboratory of the National Bureau of Standards under the direction of J. Howard Dellinger, Chief, and Newbern Smith, Assistant Chief.

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CENTRAL RADIO PROPAGATION LABORATORY
NATIONAL BUREAU OF STANDARDS
WASHINGTON 25, D. C.

Issued
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Comments are invited from users of this report as to the accuracy of predictions when applied to the solution of specific radio propagation problems. Such comments or queries concerning radio propagation should be addressed as follows:

For the Army:
Office of the Chief Signal Officer, War Dept.
Washington 25, D. C.
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For the Navy:
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For Others:
Central Radio Propagation Laboratory,
National Bureau of Standards,
Washington 25, D. C.

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I. TERMINOLOGY

The following symbols are used, as recommended by the International Radio Propagation Conference held in Washington, D. C., 17 April to 5 May 1944.

f^oF2 = ordinary-wave critical frequency for the $F2$ layer.

f^xF2 = extraordinary-wave critical frequency for the $F2$ layer.

Es = sporadic, or abnormal, E.

fEs = highest frequency of Es reflections.

muf or MUF = maximum usable frequency.

owf or OWF = optimum working frequency.

4000-muf chart = contour chart of muf for 4000-kilometer paths.

2000-muf chart = contour chart of muf for 2000-kilometer paths.

Zero-muf chart = contour chart of vertical-incidence critical frequency, extraordinary wave (f^xF2).

II. WORLD-WIDE PREDICTION CHARTS AND THEIR USES

The charts, figures 5 to 11, present world-wide predictions of monthly average maximum usable frequencies for February 1947. Conditions may be markedly different on disturbed days, expecially in or near the auroral zones, shown on the map of figure 1. The method of prediction is discussed in the IRPL Radio Propagation Handbook, Part 1, War Dept. TM 11–499, Navy Dept. DNC–13–1, p. 52, 53.

Although ionosphere characteristics are roughly similar for locations of equal latitude, there is also a considerable variation with longitude, especially in the case of the $F2$ layer. This "longitude effect" seems to be related to geomagnetic latitude. Attention was first called to this effect in the report "Radio Propagation Conditions" issued 10 Sept. 1943; it was brought into general operational use in the next issue (14 Oct. 1943).

The longitude effect in the $F2$ layer is taken care of by providing world charts for three zones, in each of which the ionosphere characteristics are considered independent of longitude, for practical purposes. These zones are indicated on the world map, figure 1.

Two $F2$ charts are provided for each zone, one of which, the "zero-muf chart," shows the vertical-incidence muf, or the critical frequency for the extraordinary wave, and the other, the "4000-muf chart," shows the muf for a transmission distance of 4000 km. Do not confuse the zero-muf charts with the f^oF2 charts appearing in the previous IRPL reports "Radio Propagation Conditions." (Values of $F2$-zero-muf exceed those of f^oF2 for the same location and local time by an amount approximately equal to half the gyro-frequency for the location. See IRPL Radio Propagation Handbook, Part 1 (War Dept. TM 11–499 and Navy Dept. DNC–13–1), p. 18, 19, 28, and fig. 9).

The longitude variation is operationally negligible in the case of the normal E layer and therefore only one E-layer chart is provided.

The variation of fEs with geomagnetic latitude seems to be well marked and important. Consequently, the fEs charts are constructed on the basis of geomagnetic latitude.

Since there are as yet insufficient correlated data, the fEs charts are much less precise than the other charts. Instructions for use of these charts appear in section IV, 3.

Attention is called to the fact that the 50-percent contour in figure 15, "Percentage of Time of Occurrence of Es-2000-muf in Excess of 15 Mc," does not necessarily coincide with the 3-Mc contour in figure 12, "Median fEs, in Mc," because the two charts are prepared independently.

III. DETERMINATION OF GREAT-CIRCLE DISTANCES, BEARINGS, AND LOCATION OF TRANSMISSION CONTROL POINTS

1. BY USE OF THE WORLD MAP AND GREAT-CIRCLE CHART

Figure 1 is a map of the world. Figure 2 is a chart to the same scale as figure 1, on which the solid-line curves crossing the equator at a single point represent great circles. The numbered dot-dash lines crossing the great circles indicate distances along them in thousands of kilometers. In using figures 1and 2, proceed as follows:

a. Place a piece of transparent paper over the map, figure 1, and draw the equatorial line (zero degrees). Place dots over the locations of the transmitting and receiving stations. Also mark the meridian whose local times are to be used as the times for calculation. Usually the Greenwich meridian is used.

b. Place this transparency over the chart, figure 2, and, keeping the equatorial line of the transparency always on the equatorial line of figure 2, slide the transparency horizontally until the terminal points marked on it fall either on the same great circle or the same proportional distance between adjacent great-circle curves. Draw in the path.

c. For paths shorter than 4000 km, locate the midpoint of the path, keeping the transparency in position on figure 2 and using as a distance scale the points at which the numbered lines in figure 2 cross the path as drawn on the transparency.

d. For paths longer than 4000 km, designating the ends as the *A*-end and *B*-end, respectively, locate on the path and mark with a dot the following "control points," scaling the distances as in *c* above:

For *F*2 layer, points *A* and *B*, 2000 km from each end.

For *E* layer, points *A'* and *B'*, 1000 km from each end.

2. BY USE OF THE NOMOGRAM OF FIGURE 4

Note.—Values near the ends of the nomogram scales of figure 4 are subject to error because the scales are compressed. If exact values are required in those regions, they should be calculated by means of the usual trigonometric formulas.

In figure 3, *Z* and *S* are the locations of the transmitting and receiving stations, where *Z* is the west and *S* the east end of the path. *If a point lies in the Southern Hemisphere, its angle of latitude is always taken as negative. Northern-Hemisphere latitudes are taken as positive.*

a. To obtain the great-circle distances ZS (*short route*):

(1) Draw a slant line from (lat. $Z-$lat. S) measured up from the bottom on the left-hand scale to (lat. $Z+$lat. S) measured down from the top of the right-hand scale. If (lat. $Z-$lat. S) or (lat. $Z+$lat. S) is negative, regard it as positive.

(2) Determine the separation in longitude of the stations. Regard as positive. If the angle so obtained is greather than 180°, then subtract from 360°. Measure this angle along the bottom scale, and erect a vertical line to the slant line obtained in (1).

(3) From the intersection of the lines draw a horizontal line to the left-hand scale. This gives *ZS* in degrees.

(4) Convert the distance *ZS* to kilometers, miles, or nautical miles, by using the scale at the bottom of figure 4.

Note.—The *long great-circle route* in degrees is simply $360°-ZS$. The value will always be greater than 180°. Therefore in order to obtain the distance in miles from the conversion scale, the value for the degrees in excess of 180° is added to the value for 180°.

b. To obtain the bearing angle PZS (*short route*):

(1) Subtract the short-route distance *ZS* in degrees obtained in *a* from 90° to get *h*. The value of *h* may be negative, and should be substituted in (2) below without change of sign.

(2) Draw a slant line from (lat. $Z-h$) measured up from the bottom on the left-hand scale to (lat. $Z+h$) measured down from the top on the right-hand scale. If (lat. $Z-h$) or (lat. $Z+h$) is negative, regard it as positive.

(3) From ($90°-$lat. S) measured up from the bottom on the left-hand scale, draw a horizontal line until it intersects the previous slant line.

(4) From the point of intersection draw a vertical line to the bottom scale. This gives the bearing angle *PZS*. The angle may be either east or west of north, and must be determined by inspection of a map.

c. To obtain the bearing angle PSZ:

(1) Repeat steps (1), (2), (3), and (4) in *b*, interchanging *Z* and *S* in all computations. The result obtained is the interior angle *PSZ* in degrees.

(2) The bearing angle *PSZ* is 360° minus the result obtained in (1) (as bearings are customarily given clockwise from due north).

Note.—The long-route bearing angle is simply obtained by adding 180° to the short-route value as determined in *b* or *c* above.

d. To obtain the latitude of Q (*mid- or other point of path*):

(This calculation is in principle the converse of *b*.)

(1) Obtain *ZQ* in degrees. If *Q* is the midpoint of the path, *ZQ* will be equal to one-half, *ZS*. If *Q* is one of the 2000-km "control points," *ZQ* will be approximately 18°, or $ZS-18°$.

(2) Subtract *ZQ* from 90° to get h'. The value of h' may be negative, and should be substituted in (3) below without change of sign.

(3) Draw a slant line from (lat. $Z-h'$) measured up from the bottom on the left-hand scale, to (lat. $Z+h'$) measured down from the top on the right-hand scale. If (lat. $Z-h'$) or (lat. $Z+h'$) is negative, regard it as positive.

(4) From the bearing angle *PZS* (taken always as less than 180°) measured to the right on the bottom scale, draw a vertical line to meet the above slant line.

(5) From this intersection draw a horizontal line to the left-hand scale.

(6) Subtract the reading given from 90° to give the latitude of *Q*. (If the answer is negative, then *Q* is in the Southern Hemisphere.)

e. To obtain the longitude difference t' between Z and Q:

(This calculation is in principle the converse of *a*.)

(1) Draw a straight line from (lat. $Z-$lat. Q) measured up from the bottom on the left-hand scale to (lat. $Z+$lat. Q) measured down from the top on the right-hand scale. If (lat. $Z-$lat. Q) or (lat. $Z+$lat. Q) is negative, regard it as positive.

(2) From the left-hand side, at *ZQ*, in degrees, draw a horizontal line to the above slant line.

(3) At the intersection drop a vertical line to the bottom scale, which gives t' in degrees.

muf, applying the *Es*-2000-muf on the left-hand scale and reading the answer on the middle scale. Enter in column *f*. Then modify the procedure in IV, 1 *c* (7), so that the highest of the *three* values, the *F*2-muf, the *E*-*F*1-muf, and the *Es*-muf, columns *h*, *g*, *f*, is the muf for the path.

(5) In the determination of owf under IV, 1 *d*, subtract 4 Mc from the *Es*-2000-muf found under (3) above to obtain the *Es*-2000-owf, entering in column *i*. Now find the *Es*-owf for the path, using the same nomogram, figure 14, as for the *E*-owf, applying the *Es*-2000-owf to the left-hand scale and reading the answer on the middle scale. Enter in column *j*. Then modify the procedure in section IV, 1 *d* (3) so that the highest of the *three* values, the *F*2-owf, the *E*-owf, and the *Es*-owf, columns *l*, *k*, *j*, is the owf for the path.

Because of the variable nature of *Es*, and the relative uncertainty with which *Es* is known, caution should be used in the application of *Es*-owf, particularly for short paths. While transmission should take place most of the time on *Es*-owf, fluctuations in *Es* may at times interrupt service. It is thus often desirable to operate near the owf for the regular layers (*E*, *F*1, *F*2) only, without the inclusion of *Es*, although transmission may take place more than 80 percent of the time near the *Es*-owf.

V. ABSORPTION, DISTANCE RANGE, AND LOWEST USEFUL HIGH FREQUENCY

The procedures outlined in the text of this report will give an adequate solution to most of the high-frequency propagation problems that will normally be encountered in the field. If operating frequencies are chosen near the calculated owf prediction in any given case, best possible results should be had, at least in communications work.

The use of frequencies too far below the owf will result in weak reception because of increasing ionospheric absorption as the frequency decreases. The factor that limits the usefulness of low field intensities is usually atmospheric noise at the receiving location.

The determination of lowest useful high frequencies is more difficult than the determination of muf and the techniques for their prediction are less far advanced.

The subject of absorption, distance range, and lowest useful high frequency is discussed at length in IRPL Radio Propagation Handbook, Part 1, p. 69–97 (War Dept. TM 11–499, Navy Dept. DNC–13–1), and formulas, graphs, and nomograms for calculation are given there.

Simpler and more accurate techniques are being developed and will be released as soon as the work is completed.

VI. SAMPLE MUF AND OWF CALCULATIONS

1. FOR SHORT PATHS

Required: The muf and owf for transmission between Washington, D. C. (39.0° N, 77.5° W) and Miami, Fla. (25.7° N, 80.5° W) for average conditions during the month of February 1947.

Solution:

Let the local time used for this problem be GCT (*Z* time or that of 0° longitude).

The midpoint of the path is at approximately 32.5° N, 79.0° W, and the transmission path length is approximately 1500 km, all in *W* zone.

The values of *E*- and *F2*-layer muf and owf, and also *Es*-muf and owf for even hours, GCT, as determined by using the procedure given in section IV, are given in table 1. The final values are presented graphically in figure 16.

Values of owf for the path obtained by the procedure of section IV, 1 *c* for the regular layers only are given in columns *k* and *l* of table 1. The higher of these two values for each even hour is underscored and plotted in figure 16. The resulting graph of owf, for the regular layers only, is shown as a solid-line curve.

Values of *Es*-owf are controlling for hours for which the value in column *j* exceeds the corresponding underlined value in columns *k* or *l*. For the month of February, *Es*-owf is not the controlling frequency over this path at any time. Accordingly, no values of *Es*-owf are plotted in figure 16.

Figure 16 shows that skip will occur, on the average, during the night hours, if a frequency as high as 10.0 Mc is used. A frequency as high as 8.0 Mc will not skip, on the average, at any time of day, but its use is not advisable because of (*a*) the day-to-day variability, causing some probability of skip during the night hours, and (*b*) ionospheric absorption during the daytime, which is more pronounced at low frequencies.

A satisfactory plan to insure continuous transmission at all times, over a path like this, involves the use of two frequencies, one for night and one for day. Figure 16 shows that a night frequency of 6.7 Mc, to be used from 0000 to 1250 GCT, and a day frequency of 14.3 Mc, to be used from 1250 to 0000 GCT, would be satisfactory. The periods of usefulness of these frequencies are shown by the heavy dashed line on figure 16.

2. FOR LONG PATHS

Required: The muf and owf for transmission between Washington, D. C. (39.0° N, 77.5° W) and Trieste, Italy (45.7° N, 13.8° E) for average conditions during the month of February 1947.

Solution:

Let the local time for this problem be GCT (*Z* time or that of 0° longitude).

The path length is approximately 7100 km, and the two *F*2-layer control points, *A* and *B*, respectively, are at approximately 49° N, 56.5° W, and 52° N, 12.5° W. These are, respectively, in the *W* zone and the *I* zone, as shown on the map, figure 1. The two *E*-layer and *Es* control points, A' and B', respectively, are located at approximately 44° N, 68.5° W, and 49.5° N, 1.5° E. These are in the *W* and *I* zones, respectively.

The values of muf and owf over this transmission path, as determined by the procedure in section IV, are given in table 2 for even hours, GCT. Provision has been made in the computation of this table for the inclusion of the effects of *Es*. The final figures are shown graphically in figure 17.

Figure 17 shows that skip will occur, on the average, during the night hours if a frequency as high as 11.0 Mc is used, although higher frequencies may be used during a limited portion of the day.

A good, practical arrangement to insure continuous transmission at all times is to select three frequencies in a manner similar to that suggested in the preceding problem. A frequency of 8.4 Mc may be used from 2040 to 1055 GCT, a frequency of 21.0 Mc may be used from 1150 to 1850 GCT, and a transition frequency of 14.0 Mc may be used from 1055 to 1150 GCT, and from 1850 to 2040 GCT.

By inspection of the absorption chart and the noise map (figs. 81 and 120 of the IRPL Radio Propagation Handbook, Part 1, War Dept. TM 11–499, Navy Dept. DNC–13–1), it may be seen that considerations of the lowest useful high frequency over this path may be of considerable importance in selecting frequencies for use. Consequently, in cases of transmission failure on the frequencies here recommended, particularly in the case of the transition frequency, changing the frequency to a value slightly under the muf for the path may be advisable.

The bearing of Trieste from Washington is approximately 51°, and that of Washington from Trieste is approximately 299°, both determined by the nomogram of figure 4.

VII. ERRATUM

Contours 32 to 38, located between hours 00 and 04, and latitudes 10° N to 30° S, were erroneously numbered in figure 10 of CRPL–D24. Substitute numbers 38 for 22, 36 for 24, 34 for 26, and 32 for 28, respectively, for correct numbering.

CRPL—FORM AF

TABLE I.—Solution of short-path transmission problem.

DATE 2 October 1946

MUF-OWF WORK SHEET FOR PATHS 4000 KM OR LESS

From Washington, D. C. To Miami, Fla. Distance, 1500 km Zone W Predicted for Feb 1947

Note: All frequencies are in megacycles.

GCT	f_{E_s}	E_s 2000-muf	E-layer 2000-muf	F_2 zero-muf	F_2 4000-muf	E_s-muf for Path	E-F_1-muf for Path	F_2-muf for Path	E_s 2000-owf	E_s-owf for Path	E-owf for Path	F_2-owf for Path	MUF for Path	OWF for Path
	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Procedure	Scale	5 X a	Scale	Scale	Scale				b-4.0		Same as g	.85 h	Highest of f, g, h	Highest of j, k, l
00				8.9	28.8			16.8				14.3	16.8	14.3
01														
02				5.9	17.3			10.4				8.8	10.4	8.8
03														
04	2.1	10.5		5.5	15.0	9.2		9.3	6.0	5.6		7.9	9.3	7.9
05														
06	2.1	10.5		5.3	14.2	9.7		8.8	6.5	6.0		7.4	9.7	7.4
07														
08	2.1	10.5		5.2	15.1	9.7		9.2	6.5	6.0		7.8	9.7	7.8
09														
10	2.2	11.0		4.9	13.9	10.1		8.5	7.0	6.4		7.2	10.1	7.2
11														
12	2.3	11.5	7.3	6.9	21.0	10.6	6.7	12.5	7.5	6.9	6.7	10.6	12.5	10.6
13														
14	2.9	14.5	14.2	10.4	35.4	13.4	13.0	20.4	10.5	9.7	13.0	17.3	20.4	17.3
15														
16	3.2	16.0	16.8	11.5	37.4	14.8	15.5	21.9	12.0	11.0	15.5	18.6	21.9	18.6
17														
18	3.5	17.5	17.2	11.7	37.4	16.2	15.9	22.1	13.5	12.4	15.9	18.8	22.1	18.8
19														
20	3.1	15.5	16.0	11.7	39.0	14.3	14.8	22.7	11.5	10.6	14.8	19.3	22.7	19.3
21														
22	2.2	11.0	11.8	11.3	37.7	10.1	10.9	22.0	7.0	6.4	10.9	18.7	22.0	18.7
23														
Done by														
Checked														

CRPL—FORM AH

TABLE 2.—Solution of long-path transmission problem.

DATE 2 October 1946

MUF-OWF WORK SHEET FOR PATHS OVER 4000 KM.

From Washington, D. C. To Trieste, Italy Distance, 7100 km Predicted for Feb., 1947

Note: All frequencies are in megacycles.

	A-end						B-end											
	Pt. A in W Zone			Pt. A' in W Zone			Pt. B in I Zone			Pt. B' in I Zone								
GCT	f_{E_S}	E_S 2000-muf	F_2 4000-muf	E-layer 2000-muf	E_S 2000-owf	F_2 4000-owf	f_{E_S}	E_S 2000-muf	F_2 4000-muf	E-layer 2000-muf	E_S 2000-owf	F_2 4000-owf	MUF A-end	MUF B-end	OWF A-end	OWF B-end	MUF for PATH	OWF for PATH
	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r
Procedure	Scale pt. A'	5 X a	Scale pt. A	Scale pt. A'	b-4.0	.85 c	Scale pt. B'	5 X g	Scale pt. B	Scale pt. B'	h-4.0	.85 i	Highest of b,c,d	Highest of h,i,j	Highest of d,e,f	Highest of j,k,l	Lower of m,n	Lower of o,p
00			20.5			17.4	2.0	10.0	11.0		6.0	9.4	20.5	11.0	17.4	9.4	11.0	9.4
01																		
02			15.8			13.4	2.0	10.0	10.6		6.0	9.0	15.8	10.6	13.4	9.0	10.6	9.0
03																		
04			13.5			11.5	2.1	10.5	10.8		6.5	9.2	13.5	10.8	11.5	9.2	10.8	9.2
05																		
06	2.0	10.0	12.0		6.0	10.2	2.1	10.5	9.9		6.5	8.4	12.0	10.5	10.2	8.4	10.5	8.4
07																		
08			11.4			9.7	2.3	11.5	14.4	10.7	7.5	12.2	11.4	14.4	9.7	12.2	11.4	9.7
09																		
10			10.8			9.2	3.2	16.0	28.8	14.2	12.0	24.5	10.8	28.8	9.2	24.5	10.8	9.2
11																		
12			25.5	9.2		21.7	3.3	16.5	33.5	15.1	12.5	28.5	25.5	33.5	21.7	28.5	25.5	21.7
13																		
14	3.1	15.5	32.2	14.1	11.5	27.4	3.2	16.0	33.8	14.4	12.0	28.7	32.2	33.8	27.4	28.7	32.2	27.4
15																		
16	3.1	15.5	36.1	15.7	11.5	30.7	2.5	12.5	33.4	11.2	8.5	28.4	36.1	33.4	30.7	28.4	33.4	28.4
17																		
18	3.1	15.5	37.3	15.6	11.5	31.7	2.0	10.0	27.5		6.0	23.4	37.3	27.5	31.7	23.4	27.5	23.4
19																		
20	2.5	12.5	36.5	13.4	8.5	31.0			18.5			15.7	36.5	18.5	31.0	15.7	18.5	15.7
21																		
22			28.6	7.5		24.3			14.2			12.1	28.6	14.2	24.3	12.1	14.2	12.1
23																		
Done by																		
Checked																		

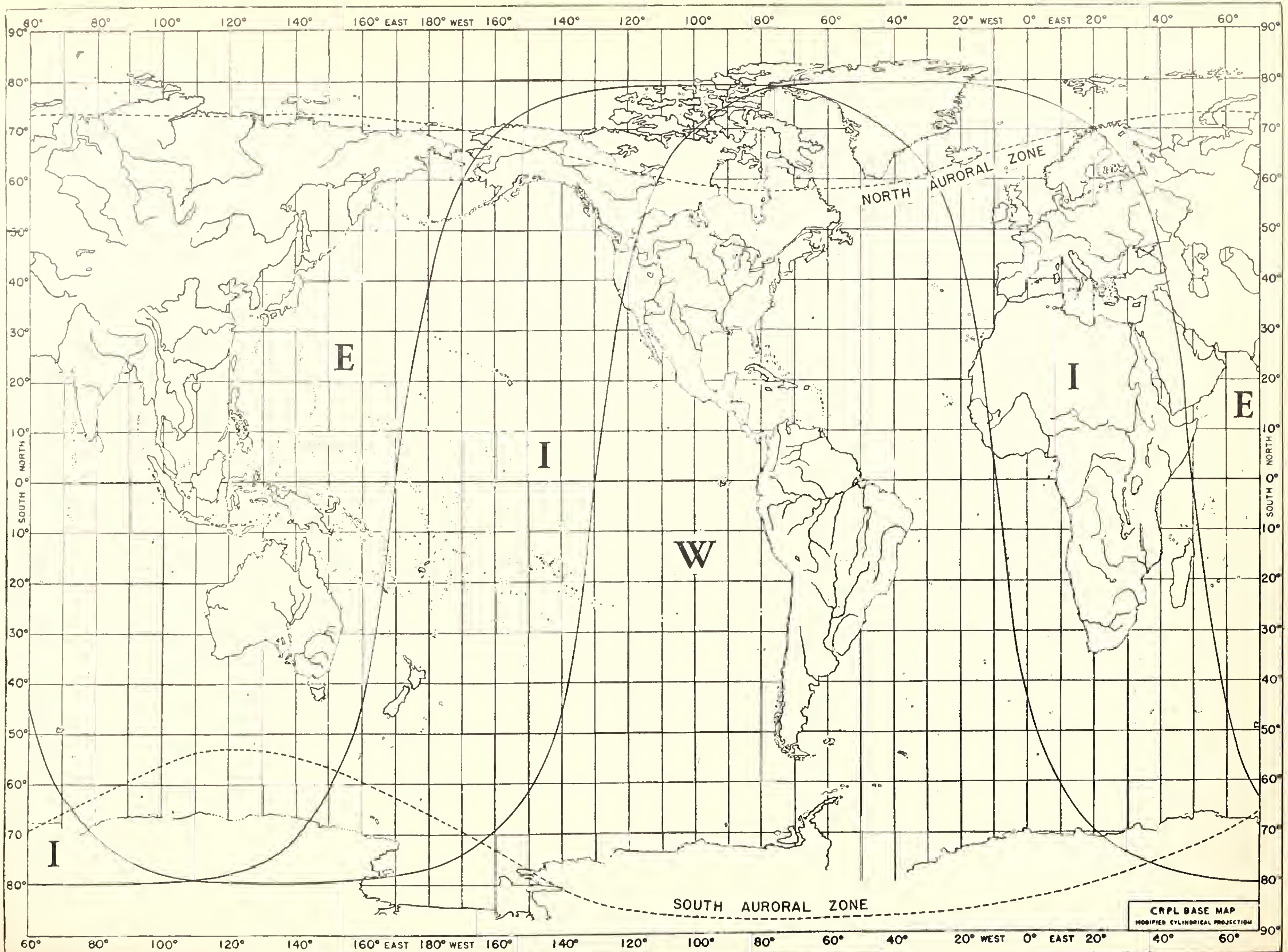

Fig. I. WORLD MAP SHOWING ZONES COVERED BY PREDICTED CHARTS, AND AURORAL ZONES.

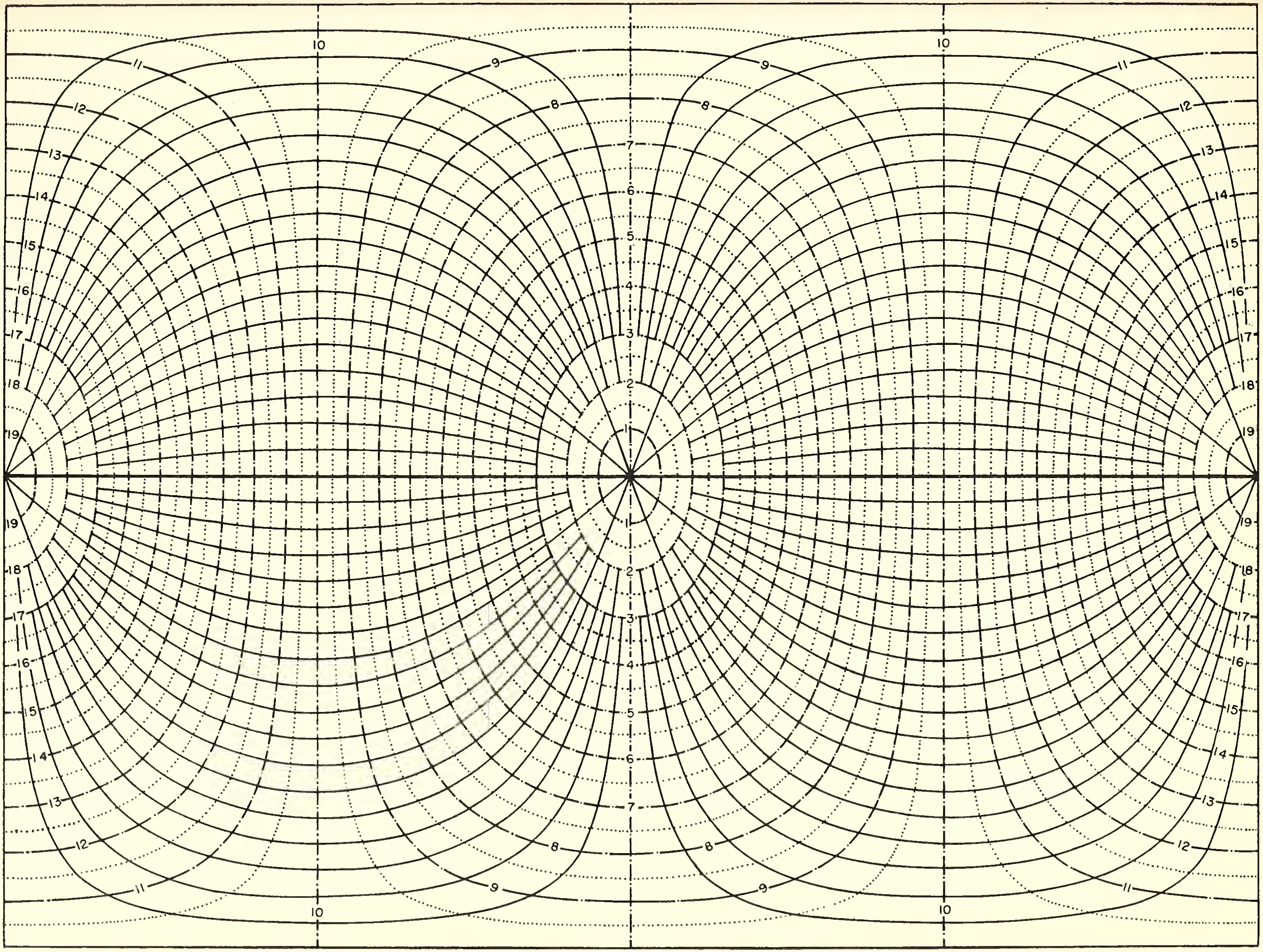

Fig. 2. GREAT CIRCLE CHART CENTERED ON EQUATOR. SOLID LINES REPRESENT GREAT CIRCLES. NUMBERED DOT-DASH LINES INDICATE DISTANCES IN THOUSANDS OF KILOMETERS.

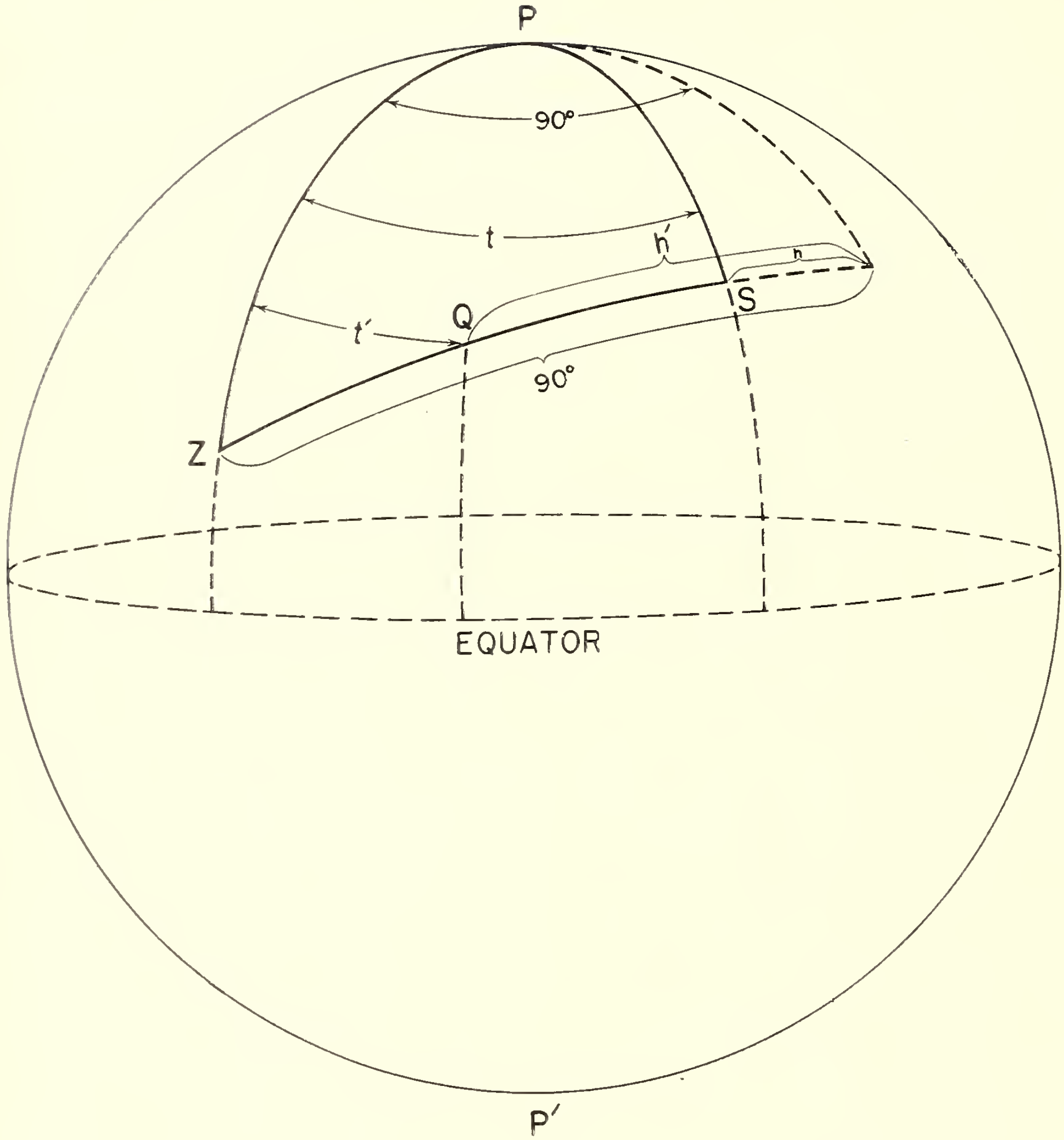

Fig. 3. DIAGRAM OF TRANSMISSION PATH AUXILIARY TO EXPLANATION OF USE OF DISTANCE — BEARING NOMOGRAM, FIG. 4.

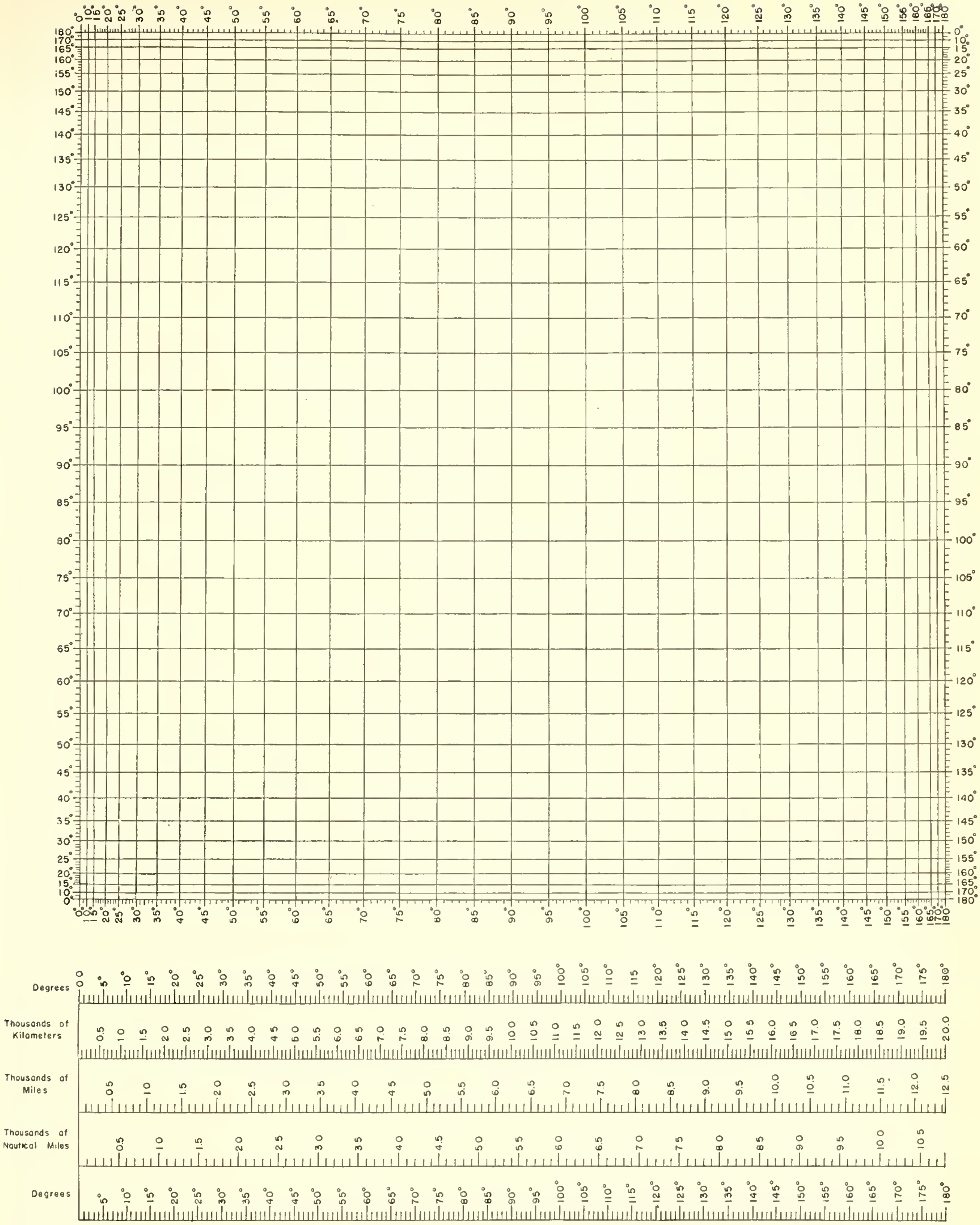

Fig. 4. NOMOGRAM (AFTER D'OCAGNE) FOR OBTAINING GREAT-CIRCLE DISTANCES, BEARINGS, LATITUDE AND LONGITUDE OF TRANSMISSION CONTROL POINTS, SOLAR ZENITH ANGLES.
CONVERSION SCALE FOR VARIOUS DISTANCE UNITS.

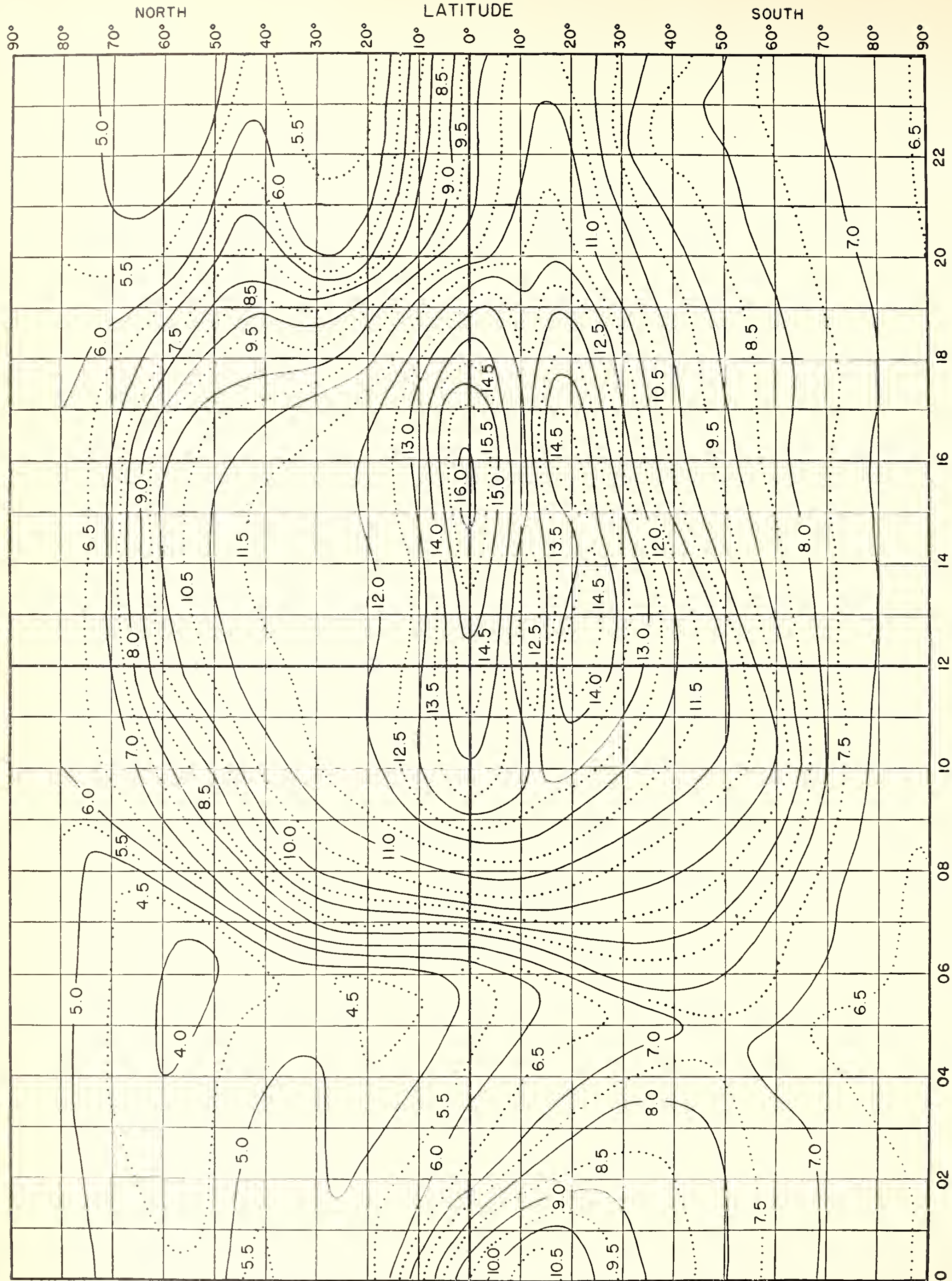

Fig. 5. F_2 ZERO—MUF, IN Mc, W ZONE, PREDICTED FOR FEBRUARY, 1947

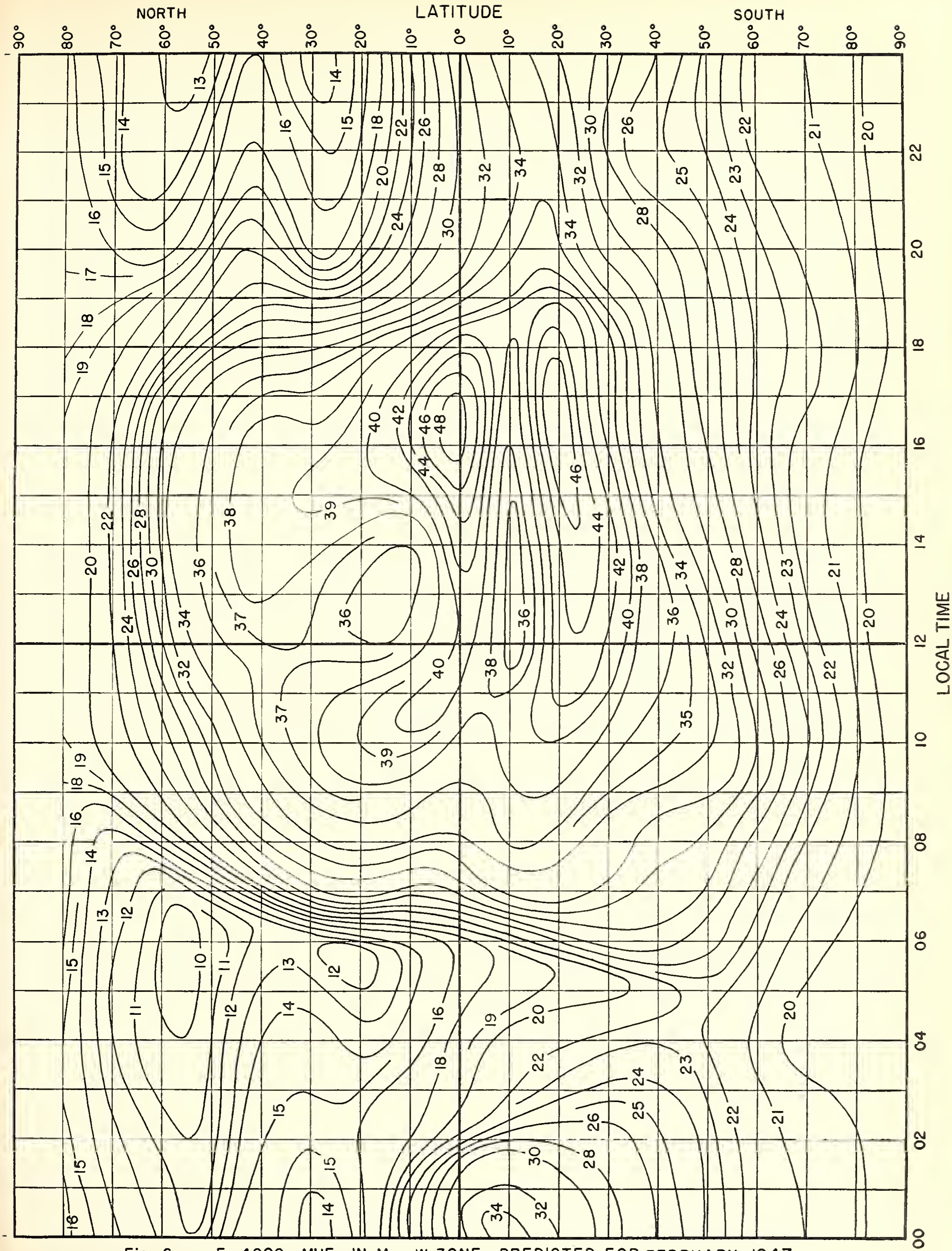

Fig. 6. F_2 4000—MUF, IN Mc, W ZONE, PREDICTED FOR FEBRUARY, 1947

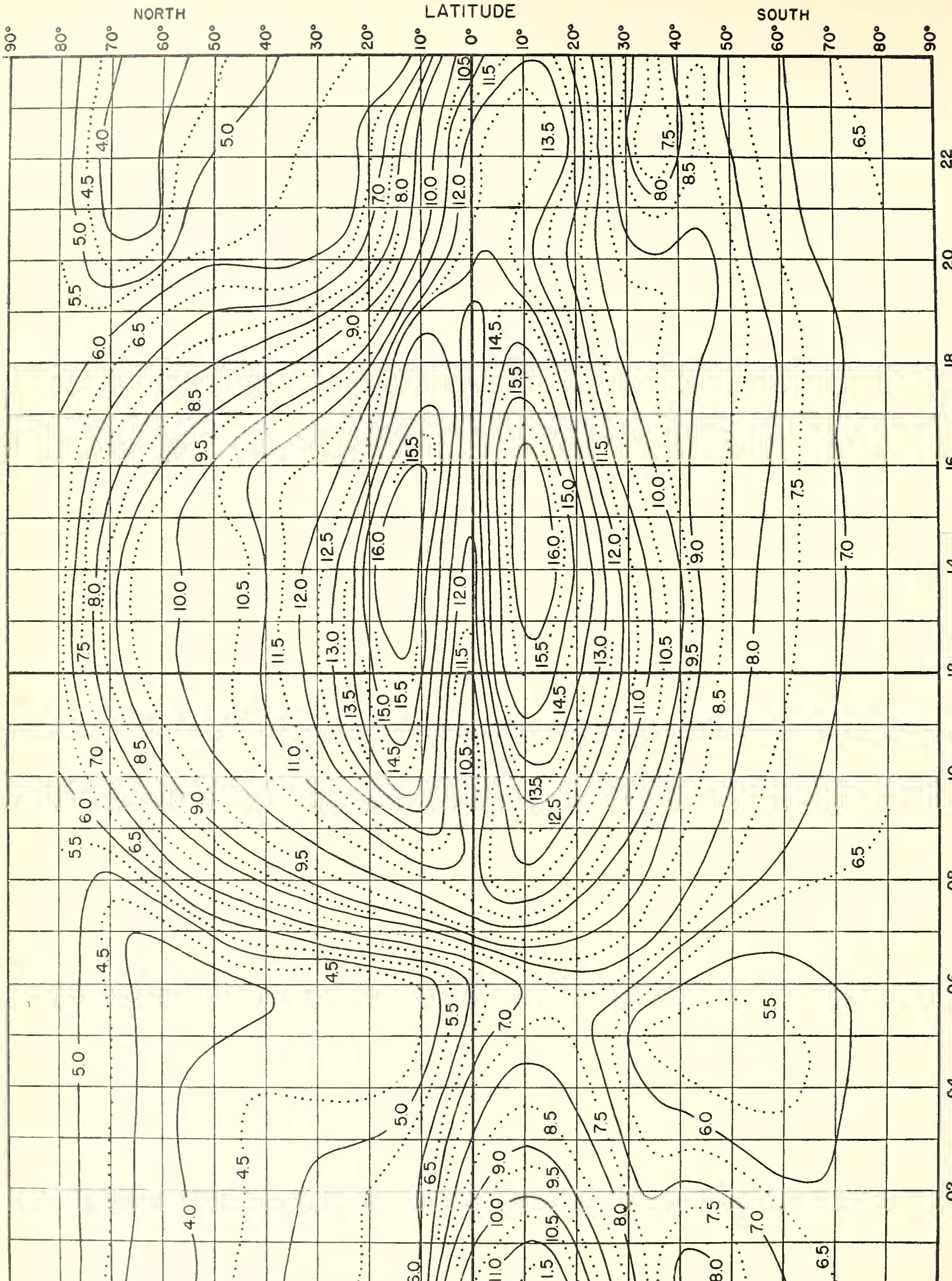

Fig. 7. F_2 ZERO—MUF, IN Mc, 1 ZONE, PREDICTED FOR FEBRUARY, 1947

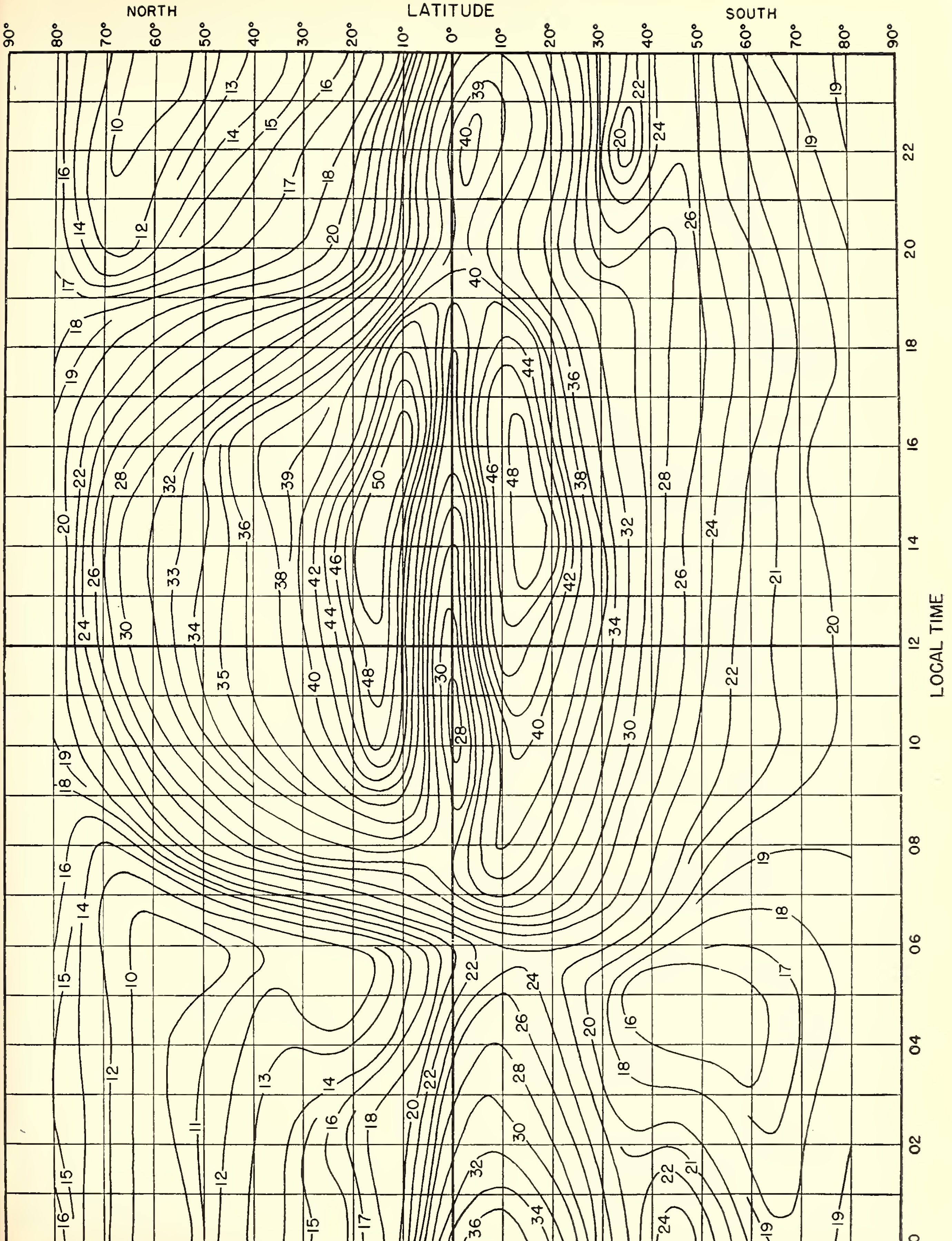

Fig. 8. F_2 4000—MUF, IN Mc, I ZONE, PREDICTED FOR FEBRUARY, 1947

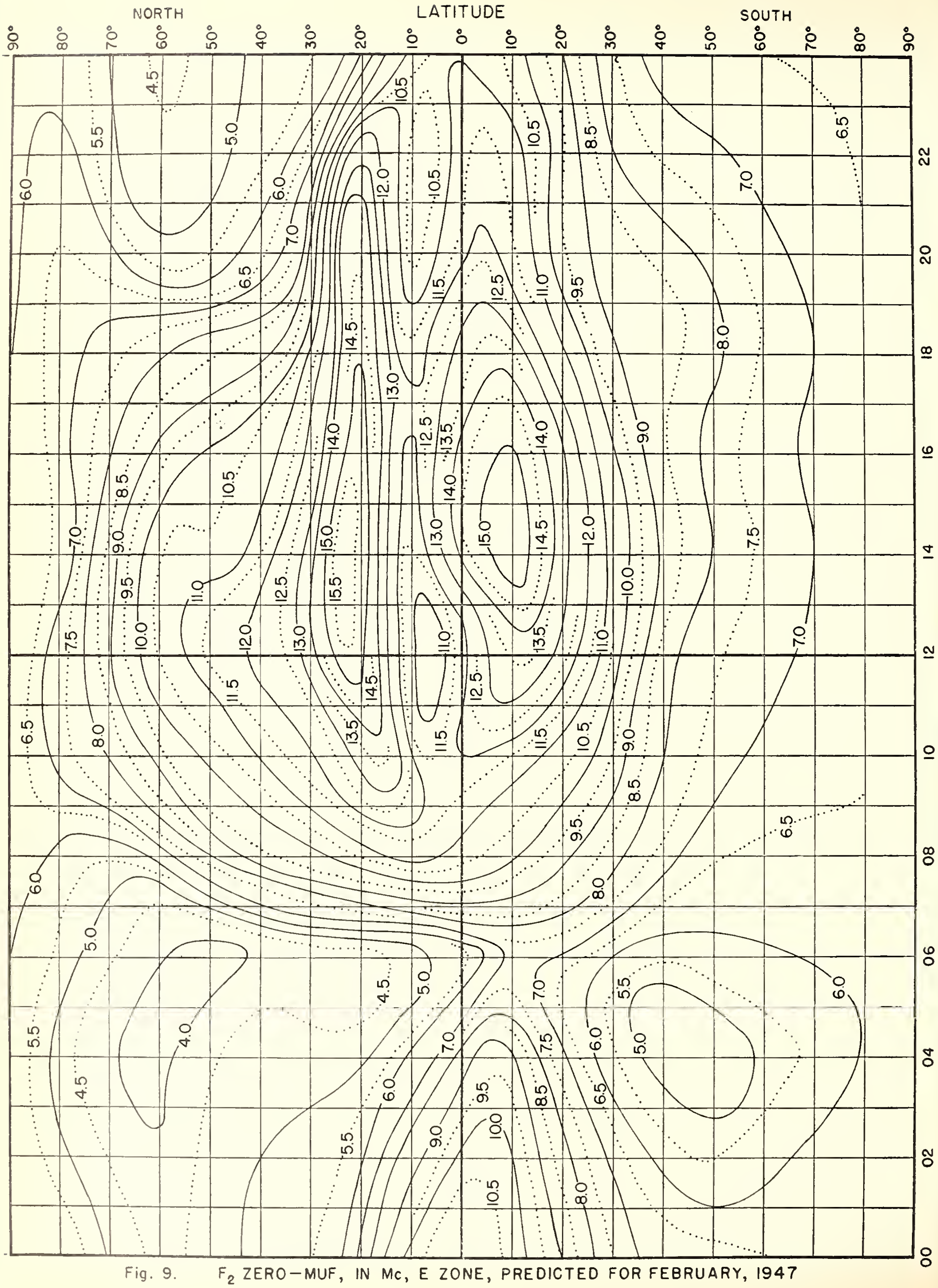

Fig. 9. F_2 ZERO—MUF, IN Mc, E ZONE, PREDICTED FOR FEBRUARY, 1947

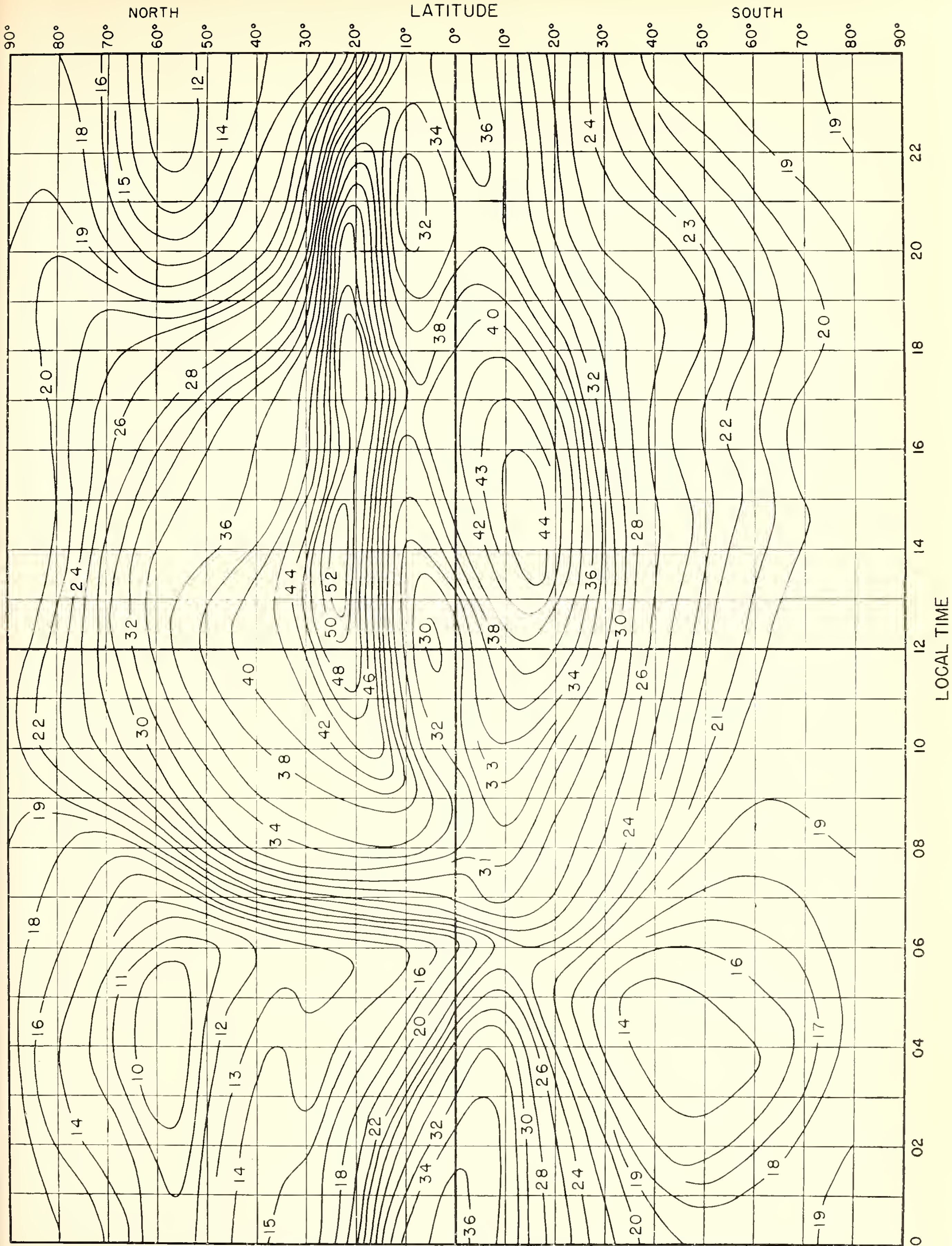

Fig. 10. F_2 4000–MUF, IN Mc, E ZONE, PREDICTED FOR FEBRUARY, 1947

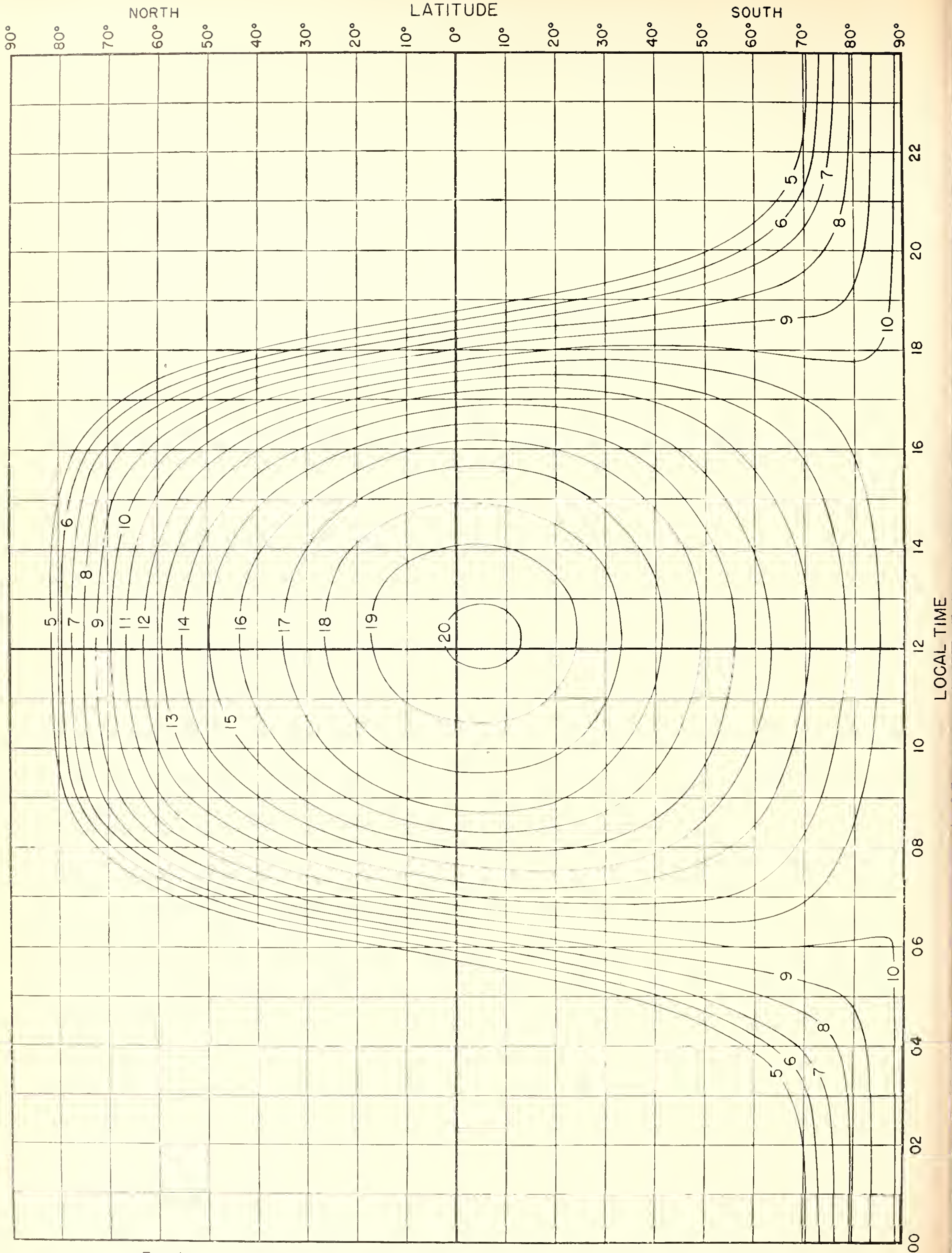

Fig. 11 E-LAYER 2000-MUF, IN Mc, PREDICTED FOR FEBRUARY, 1947

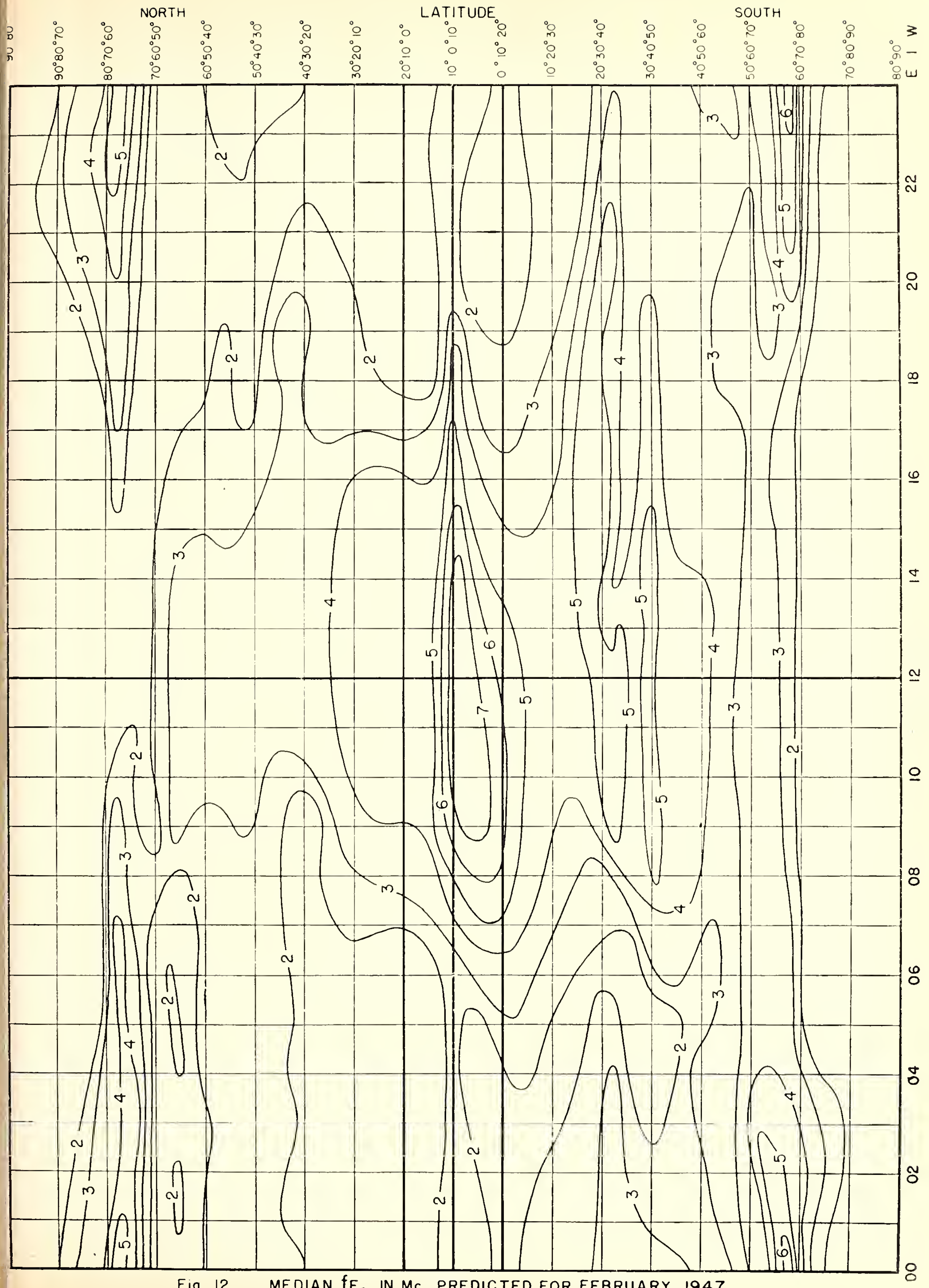

Fig. 12. MEDIAN f_{E_s}, IN Mc, PREDICTED FOR FEBRUARY, 1947

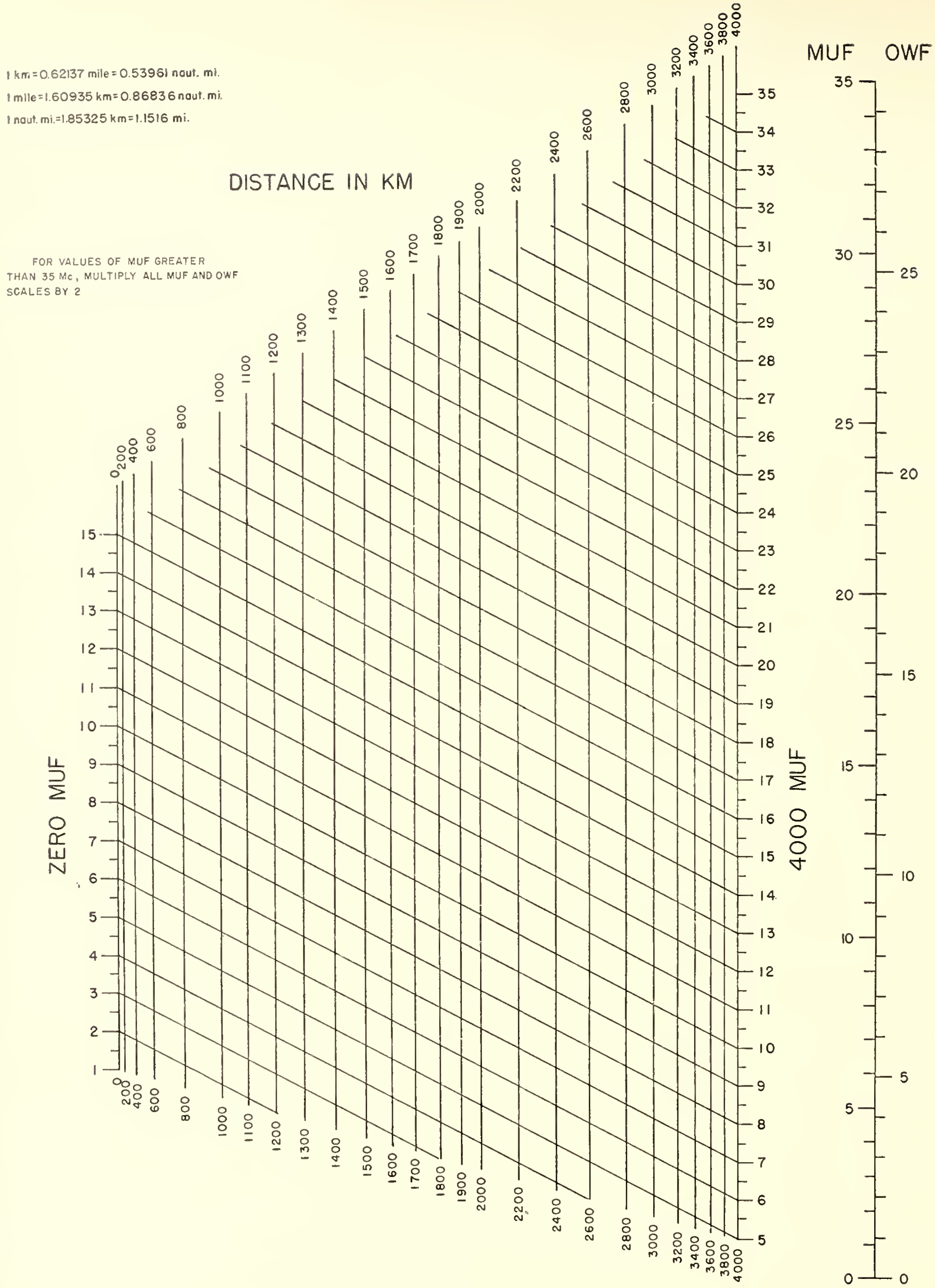

FIG. 13. NOMOGRAM FOR TRANSFORMING F_2-ZERO-MUF AND F_2-4000-MUF TO EQUIVALENT MAXIMUM USABLE FREQUENCIES AT INTERMEDIATE TRANSMISSION DISTANCES; CONVERSION SCALE FOR OBTAINING OPTIMUM WORKING FREQUENCIES.

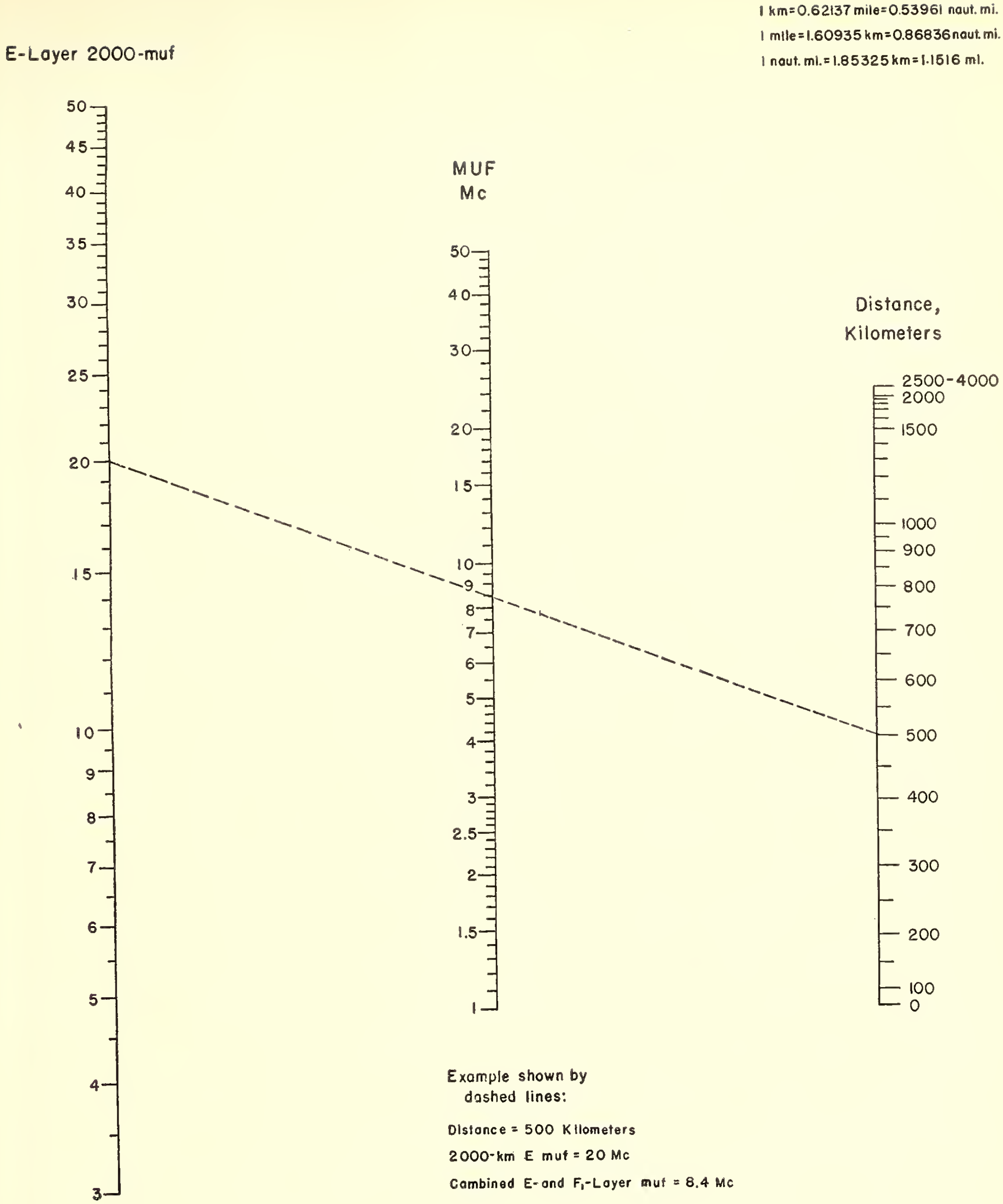

FIG. 14, NOMOGRAM FOR TRANSFORMING E—LAYER 2000—MUF TO EQUIVALENT MAXIMUM USABLE FREQUENCIES AND OPTIMUM WORKING FREQUENCIES DUE TO COMBINED EFFECT OF E LAYER AND F_1 LAYER AT OTHER TRANSMISSION DISTANCES.

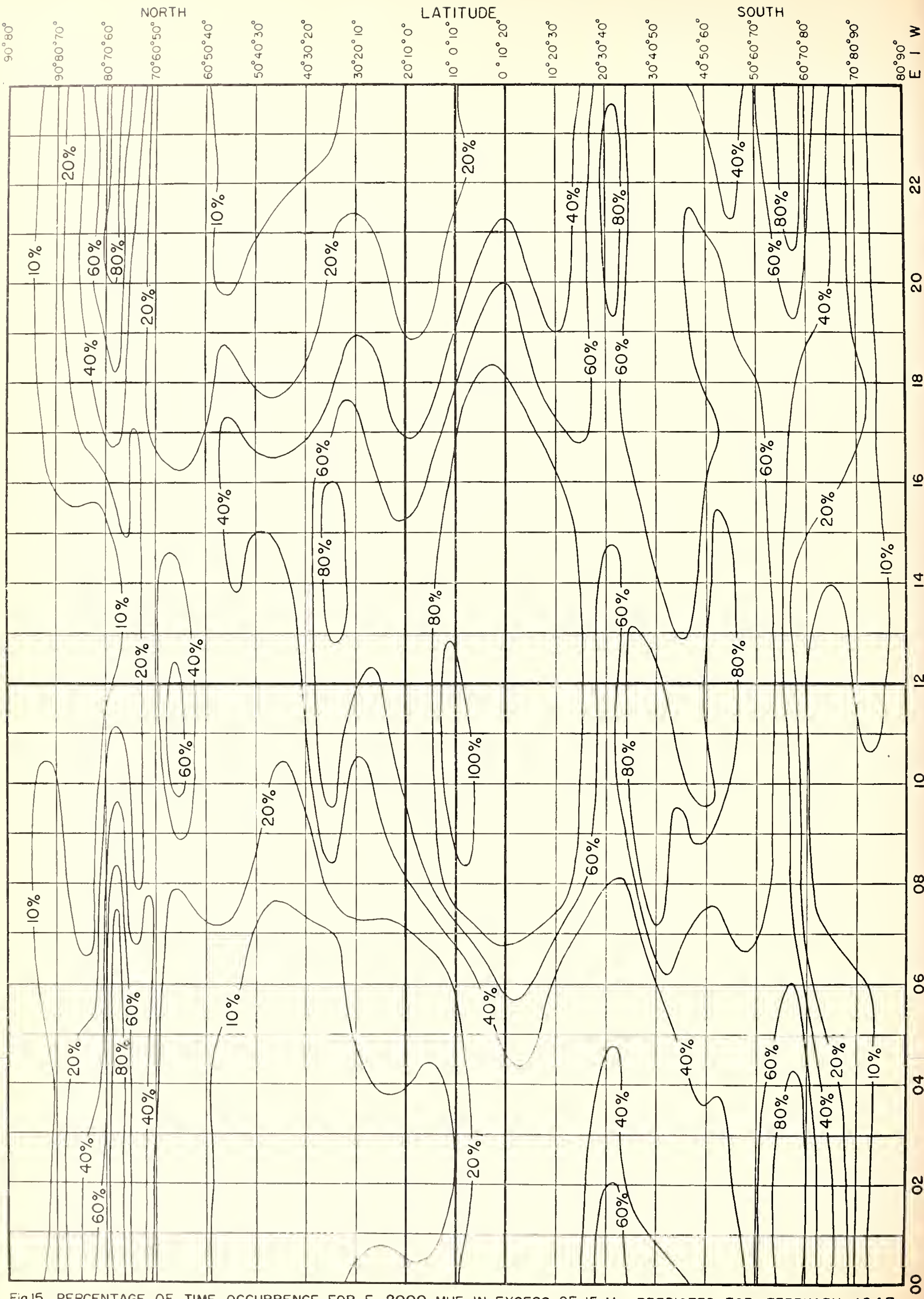

Fig.15 PERCENTAGE OF TIME OCCURRENCE FOR E_s 2000-MUF IN EXCESS OF 15 Mc, PREDICTED FOR FEBRUARY, 1947.

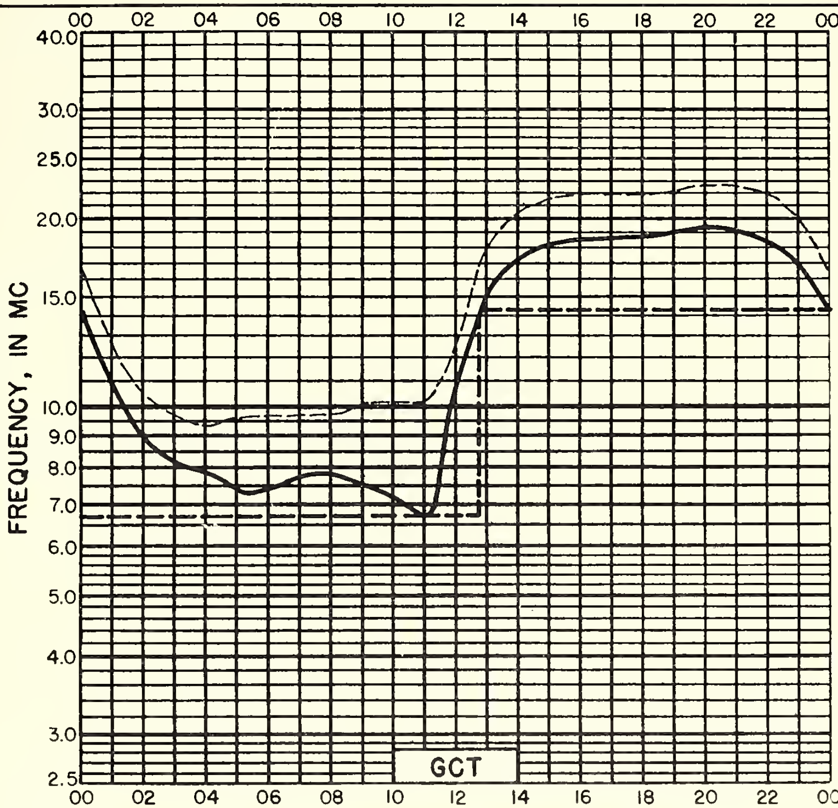

Fig. 16. SAMPLE SOLUTION OF TRANSMISSION PROBLEM FOR SHORT PATH, FEBRUARY, 1947

TRANSMISSION PATH: WASHINGTON, D.C. (39.0°N, 77.5°W) TO MIAMI, FLORIDA (25.7°N, 80.5°W)

---- MUF —— OWF — — — SUGGESTED FREQUENCY USAGE

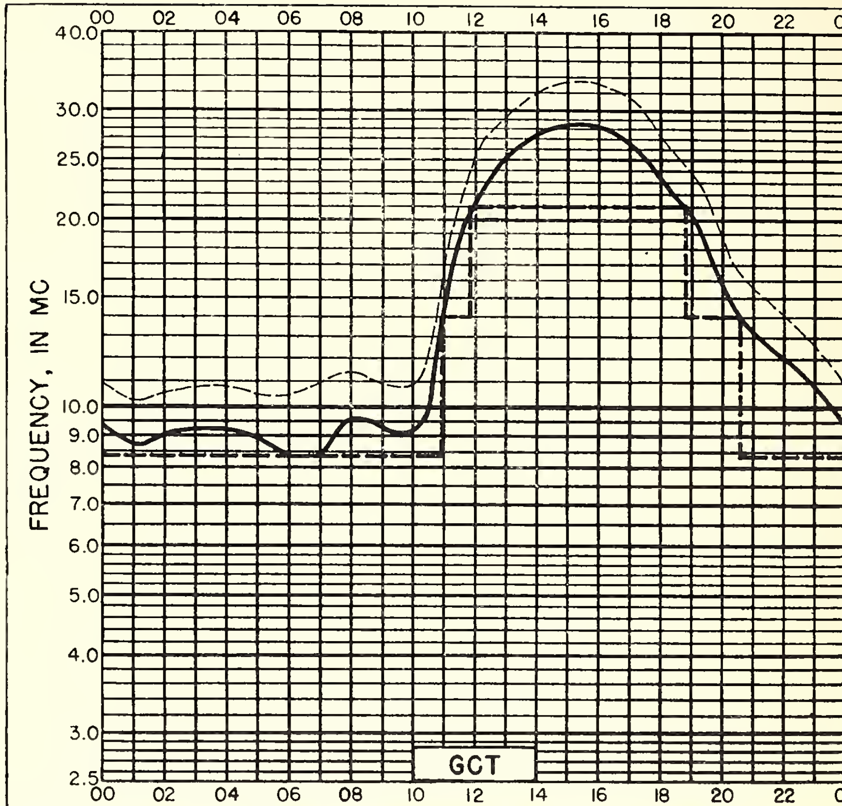

Fig. 17. SAMPLE SOLUTION OF TRANSMISSION PROBLEM FOR LONG PATH, FEBRUARY, 1947

TRANSMISSION PATH: WASHINGTON, D.C. (39.0°N, 77.5°W) TO TRIESTE, ITALY (45.7°N, 13.8°E)

---- MUF —— OWF — — — SUGGESTED FREQUENCY USAGE

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