IRPL-D 1

BASIC RADIO PROPAGATION PREDICTIONS

FOR DECEMBER, 1944

THREE MONTHS IN ADVANCE

ISSUED
SEPTEMBER, 1944

PREPARED BY INTERSERVICE RADIO PROPAGATION LABORATORY
National Bureau of Standards
Washington, D.C.

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This D-series report, issued monthly, serves as one of three current supplements to IRPL Radio Propagation Handbook, Part 1, (War Dept. TM11-499, Navy Dept. DNC-13-1). The other two supplements follow this one, later in the month. The supplements of the E series, "Radio Propagation Predictions One Month in Advance", include revisions two months later of certain of the predictions given in the D series, and nomograms giving predictions in a form for rapid operational use. The supplements of the F series, "Ionospheric Data", include basic data from which the predictions are derived, and a comparison between observed and predicted values. Before this month, most of the material was combined in the single report "Radio Propagation Conditions".

NOTE

All three supplements of this month's (September) issue are being furnished to the regular recipients of the discontinued single supplement, "Radio Propagation Conditions". Hereafter, only this D-series supplement will be furnished unless requests are received for the others. Requests should be sent in if future issues of the E and F supplements are desired.

This note does not apply to U.S.Army and Navy distribution.

CONTENTS

TERMINOLOGY

The following symbols are used, conforming to the recommendations of the International Wave Propagation Conference held in Washington, D.C., 17 April to 5 May, 1944.

f^oF2 - ordinary-wave critical frequency for the F2 layer. The term night F layer will no longer be used. The term F2 layer is now used for the night F layer as well as the daytime F2 layer.
f^xF2 - extraordinary-wave critical frequency for the F2 layer.
f_H - gyro-frequency.
Es - sporadic, or abnormal E.
fEs - highest frequency of Es reflections.
muf or MUF - maximum usable frequency.
owf or OWF - optimum working frequency.
luhf or LUHF - lowest useful high-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_o - unabsorbed field intensity (field intensity that would be received in absence of ionospheric absorption).
S_o - subsolar absorption constant (absorption per unit distance at the subsolar point).
K - absorption index (ratio of actual absorption to absorption at the subsolar point).

Note: The designation FF_2 has been replaced by F2.

WORLD-WIDE PREDICTION CHARTS AND THEIR USES

The charts, Fig. 1 through Fig. 8, present world-wide predictions of monthly average maximum usable frequencies for December, 1944. These represent the monthly average predictions essentially for ionospherically quiet days; conditions may be markedly different on disturbed days, especially in or near the auroral zones.

These charts are prepared by extrapolation of sunspot-cycle, seasonal, and diurnal trends shown by the analysis of vertical-incidence ionospheric data from about 30 stations. Description of the basic methods used for the predictions of these charts is given in the report IRPL-R4 issued 31 December 1943, available to authorized persons upon request. Devel pment of prediction methods is, however, in constant process, and parts of this report are now obsolete.

The ionization of the ionosphere is produced principally by two types of ionizing radiation, the chief one being ultra-violet light radiation from the sun, and the second being electrified particle radiation. The component of ionization caused by ultra-violet radiation is probably the same for all locations of equal latitude. The component caused by electrified particle radiation may be expected to be influenced by the earth's magnetic field. Consequently, although ionospheric 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 variation seems to vary with geomagnetic latitude, and was first mentioned in the report "Radio Propagation Conditions" issued 14 Oct. 1943.

The longitude variation seems to be least pronounced for the normal E layer. For this reason only one world-wide E-layer chart is provided. The variation of sporadic-E ionization with geomagnetic latitude seems to be well-marked and important, but there are, as yet, insufficient correlated data to permit an estimate of this variation; the Es charts furnished here are therefore of a far lower degree of precision than the other charts given. It is probable that the electrified particle radiation may be largely responsible for Es as well as for the pronounced low-level ionization which characterizes periods of ionospheric storminess, variations in Es, and in the earth's magnetic field being also associated with such periods.

In the case of the F2 layer the longitude variation is taken care of by providing world charts for three zones, throughout each of which the ionospheric characteristics are roughly similar, for practical purposes. These zones are indicated in the world map, Fig. 1.

Two 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. The zero-muf charts are not to be confused with the f^oF2 charts appearing in previous IRPL reports. 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, pp.18, 19, 28, and Fig. 9).

CALCULATION OF MAXIMUM USABLE FREQUENCIES AND OPTIMUM WORKING FREQUENCIES

Procedure for determination of muf or owf for transmission distances under 4000 km.

Radio propagation over distances up to 4000 km is generally dependent upon ionospheric conditions at the mid-point of the transmission path, which lies directly above the mid-point of the great circle between transmitting and receiving stations.

For a path 4000 km in length, the predicted monthly average F2 muf may be directly read off the 4000-muf charts furnished, at the latitude and local time of the mid-point of the path. For a path 2000 km in length the predicted monthly average E-layer muf may be directly read off the E-layer 2000-muf chart. The transmission distance is, in general, different from these values, and the following procedure may be followed:

1. Locate the mid-point of the transmission path. (Methods for doing this are given in the following section of this report).

2. Read the values of F2-zero-muf, F2-4000-muf, and E-layer 2000-muf for this location at the local time for the mid-point. In doing this, be sure to choose the F2 charts appropriate to the geographical zone for the mid-point.

3. By placing a straightedge between the values of F2-zero-muf and F2-4000-muf at the left- and right-hand sides, respectively, of the grid nomogram, Fig. 11, read the value of the muf for the actual path length at the intersection point of the straightedge with the appropriate vertical distance line. An auxiliary scale, at the right of this nomogram, enables rapid estimation of the owf, the optimum working frequency (85% of the muf, to allow an appropriate margin of safety for day-to-day variations).

4. By placing a straightedge between the value of the E-layer 2000-muf located on the left-hand scale of the nomogram, Fig. 12, and the value of the path length on the right-hand scale, read the muf or owf for that path length, by the combined effect of the E layer and the F1 layer, off the central scale. The characteristics of the E layer and of the F1 layer are sufficiently related that, for most practical purposes, they may be combined in this manner. The owf is here 97% of the muf, since the E layer is less variable from day to day than the F2 layer.

5. The values of muf or owf obtained by operations 3 and 4 are to be compared. The muf or owf for the transmission path is the higher of the two values thus determined.

Procedure for determination of muf or owf for transmission distances greater than 4000 km.

For distances over 4000 km, the vertical angle of departure is so small for reflection at E-layer heights that transmission solely by means of reflection from this layer is negligible, and E-layer muf usually need not be taken into consideration.

Over long paths the modes of reflection may be many, one of the most effective being that of a primary reflection at the F2 layer at the reflection point for maximum one-hop transmission (a point 2000 km from the transmitter, since 4000 km is the maximum distance for one-hop transmission), and subsequent reflections, at heights where absorption is negligible, between the F2 layer and the F1 layer, E layer or Es layer, until the ionization at these lower layers is no longer sufficient to enable such reflection, when the reflection must then proceed by means of F2 layer and the earth's surface to the receiver. The behavior of the wave in such an inter-layer reflection process may be much like that of the guided ultra-high-frequency waves in tropospheric ducts. Minimum attenuation is attained when both first and last reflection points correspond to the minimum practical take-off angle for single-hop transmission, that is, when both points are 2000 km distant from either end of the transmission path. Ionospheric characteristics at these "control points" thus determine the maximum-energy transmission over the path.

Because of the "wave guide" mode of transmission described briefly above, and treated at greater length in IRPL-R7, "Preliminary note on modes of long-path propagation," to be issued shortly, sometimes there is pronounced "non-great-circle path" propagation and bearing error when the muf for either reflecting layer fails with relative sharpness or when pronounced absorption, such as obtains in the auroral zones and at times of ionospheric storminess, causes bending of the wave front due to lateral energy loss. Procedures outlined here may not give correct values of muf in these cases, transmission in many such cases continuing beyond the limiting conditions indicated by predicted values.

In general, however, the value of muf for transmission paths greater than 4000 km may be obtained as follows:

1. Locate the two points 2000 km from the ends of the transmission path, that is, those points 2000 km from the ends of the great-circle distance between transmitting and receiving stations.

2. Read the value of the F2-4000-muf, at the local time for each point, at these points, being sure to choose the appropriate zone for each point.

3. Compare these two muf values. The lower of the two is the muf for the transmission path under consideration. 85% of this value, the owf for the path, may be rapidly obtained by means of the auxiliary muf-owf scale of Fig. 11

4. When one of the control points lies in a region where the E-2000-muf is greater than the F2-4000-muf, the former should be read at a control point 1000 km from the end of the path, instead of the latter as in step 2. This E-2000-muf, instead of the F2-4000-muf, should then be used in step 3.

DETERMINATION OF GREAT-CIRCLE DISTANCES, BEARINGS, LOCATION OF TRANSMISSION CONTROL POINTS, SOLAR ZENITH ANGLES.

The transmission path, which is the great-circle distance between transmitting and receiving stations, may be easily delineated by means of the world map, Fig. 1, and the great-circle chart, Fig. 13. A convenient procedure is as follows:

1. Place a transparent paper over the map, Fig. 1, and locate upon it at least a convenient reference latitude line (either pole, or the equator), the locations of the transmitting and receiving stations, and the meridian whose local times are to be used as the times for calculation.

2. Place this transparency over the chart, Fig. 11, and, keeping the reference line at the proper latitude, slide the transparency horizontally until the terminal points marked on it either fall on the same great-circle curve, or fall the same proportional distance between adjacent great-circle curves. Sketch in this path.

3. Using the small circles of Fig. 11 as reference, locate the mid-point of the path, for paths under 4000 km, or locate points 2000 km from either end of the path, for paths greater than 4000 km. These are the "control points" discussed in the previous section of this report. The transparency may then be placed over the prediction chart at the proper latitude and local time, and the values of muf conveniently read off the chart.

Great-circle distances, bearings, location of mid-points or other "control points" 2000 km in from the ends of the transmission path, as well as solar zenith angles, may be readily obtained from the nomogram, Fig. 15.

This nomogram, originally devised by M. d'Ocagne (Nomographic. Les Calculs Usuels Effectués au Moyen des Abaques. Essai d'une Théorie Générale. /Gauthier-Villans/, p.84) is based upon the cosine-haversine formulas for solution of a spherical triangle, and consists simply of a square or rectangle along the sides of which are scaled natural haversines of the designated angles, where the length of each rectangle side is taken as unity.

Referring to the auxiliary diagram, Fig. 14, let Z and S be the locations of transmitting and receiving stations; then, by using the nomogram, Fig. 15,

A. <u>To obtain the great-circle distance ZS:</u>

1. Draw slant line from (Lat. of Z - lat. of S), measured up from bottom on left scale, to (Lat. of Z + lat. of S), measured down from top of right scale.

2. From (Long. of S - Long. of Z) on bottom scale, measured from left to right, draw vertical line to the slant line obtained in (1).

3. From the intersection, draw a horizontal line to the left scale. This gives ZS in degrees.

4. Using the conversion scale, ZS may be read off in kilometers, statute miles, or nautical miles.

B. <u>To obtain the bearing angle PZS:</u>

1. Subtract the distance ZS (in degrees) from 90° to get h.

2. Draw slant line from (Lat. Z - h) measured up from bottom on left scale, to (Lat. Z + h), measured down from top on right scale.

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

4. From the intersection, draw a vertical line to the bottom scale, which gives the bearing angle PZS.

C. <u>To obtain the bearing angle PSZ</u>:

1. Repeat the process of B, interchanging Z and S in all computations. The result obtained is the interior angle PSZ.

2. Bearings being customarily given clockwise from due north, the bearing angle PSZ is 360° minus the result obtained in (1).

D. <u>To obtain latitude of Q (mid, or other, point of path)</u>:

1. Obtain ZQ in degrees. If Q is the mid-point of the path, ZQ will be equal to ZS/2. 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'.

3. Draw slant line from (Lat. Z - h'), measured up from bottom of left scale, to (Lat. Z + h'), measured down from top on right scale.

4. From bearing angle PZS, measured to right on bottom scale, draw vertical line to the above slant line. From this intersection, draw horizontal line to left scale. Subtract the reading given from 90° to give latitude of Q.

E. <u>To obtain longitude difference, t', between Z and Q</u>:

1. Draw straight line (Lat. Z - Lat. Q), measured up from bottom on left-hand scale, to (Lat. Z + Lat. Q), measured down from top on right-hand scale.

2. From the left side, at ZQ, in degrees, draw a horizontal line to the above slant line.

3. At intersection, drop a vertical line to bottom scale to get t'.

F. <u>To obtain solar zenith angle, ψ, at a given place</u>:

1. Let the declination of the sun be d, and let Z be the place under consideration.

2. Draw straight line from (Lat. Z - d), measured up from bottom on left scale, to (Lat. Z + d), measured down on right scale.

3. From [(12 - local time of Z, in hours) x 15]$^{\circ}$, on bottom scale, measured from left to right, draw a vertical line to the slant line above.

4. From this intersection, draw a horizontal line to the left scale. This gives ψ, in degrees.

ABSORPTION, DISTANCE RANGE, AND LOWEST USEFUL HIGH FREQUENCY

The determination of absorption, distance range, and lowest useful high frequency is discussed at length in IRPL Radio Propagation Handbook, Part 1, pp. 69-97.

If F = the field intensity expressed as the logarithm to the base 10 of the microvolts per meter,

F_o = the unabsorbed field intensity, in like units, at distance d, for a radiated power of 1 kw.
S_o = subsolar absorption constant, twice the $\log_{10}$ of the ratio of incident to reflected sky-wave field intensity for a wave traveling 1000 km at or near the subsolar point.
$\overline{K}$ = average value of the absorption index K over the path.
(If ψ = solar zenith angle,
$K = 0.142 + 0.858 \cos \psi$ where $\psi \leqslant 99.5^\circ$,
$K = 0$ where $\psi \geqslant 99.5^\circ$).
d = length of transmission path, thousands of km.
P = average effective radiated power, in kilowatts.

$$F = F_o - 1/2\ (S_o\ \overline{K}\ d) + 1/2 \log P$$

F must be such as to equal or exceed the radio noise intensity at the receiver.

Graphs showing values of atmospheric radio noise intensity, variations of F_o with distance and frequency, and of S_o with frequency, as well as nomograms and charts for obtaining $\overline{K}d$, are presented in the IRPL Radio Propagation Handbook, Part 1.

If the appropriate values for all other quantities are substituted in the above equation, d is the maximum distance range for the path and frequency under consideration. Conversely, if d is given, the frequency determined from the equation is the lowest useful high frequency for the path.

For convenience in estimating absorption (exclusive of auroral absorption) over a path, the chart, Fig. 16, is presented.

SAMPLE SOLUTIONS OF TRANSMISSION PROBLEMS

For short paths:

Required: The muf and owf for transmission between Washington, D.C. (39.0°N, 77.5°W) and Miami, Florida (25.7°N, 80.5°W) for average conditions during the month of December 1944.

Solution: Let the local time used for this problem be GCT, or that of 0°.

By locating both stations on a transparency placed over the map, Fig. 1, and locating the line indicating 0° longitude, then transferring the transparency to the great-circle chart, Fig. 13, and drawing in the transmission path, measuring its distance, and locating the midpoint, the location of the midpoint is at approximately 32.5°N, 79.0°W, and the transmission path length is approximately 1500 km.

This distance and location of the midpoint of the transmission path may likewise be determined by means of the nomogram, Fig. 15.

The values of muf and owf over this transmission path, following the various processes previously outlined, determined for each hour, GCT, are given in Table 1, the final values being graphically presented in Fig. 17.

By inspection of Fig. 17, it may be seen that skip will occur, on the average, during night hours if a frequency as high as 6.5 Mc is used. A frequency as high as 5.1 Mc will not skip, on the average, at any time of day, but 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 good arrangement to insure continuous transmission at all times might be to select three frequencies for use, one for night, one for daytime, the other for a transition period.

By inspection of Fig. 17, it may be seen that a frequency of 4 Mc used between the hours of 2300 and 1200 GCT, a transition frequency of 6 Mc used between the hours of 1200 to 1330 and 2100 to 2300 GCT, and a daytime frequency of 10 Mc to be used from 1330 to 2100 GCT, might be advisable.

Referring to the Es chart, Fig. 9, showing median values of Es, it may be seen that median values of Es in excess of 2 Mc are predicted for nearly all times of day at the latitude of the control point. Roughly, the value of the factor to be applied to vertical-incidence values of Es, to obtain equivalent transmission frequencies at distances of 1500 km and more, is 5. Therefore, about half the time, transmission is likely to be possible, even during night hours, by means of Es reflection on frequencies as high as 10 Mc. This is corroborated by the values shown on Fig. 10 giving percentages of time occurrence when Es-propagation is possible at frequencies above 15 Mc. (The logarithm to the base 10 of the ratio of percentages of time occurrences of vertical-incidence sporadic-E reflections above any two selected frequencies is approximately proportional to the difference of the two frequencies, the constant of proportionality varying from about -0.3 for months near both summer and winter solstices to about -0.7 for months near equinoctial periods).

For long paths:

Required: The muf and owf for transmission between New York City (40.5°N, 74.0°W) and Moscow (56.0°N, 37.0°E), for average conditions during the month of December 1944.

Solution: Let the local time used for this problem be GCT, or that of 0°.

By locating both stations on a transparency placed over the map, Fig. 1, and locating the line indicating 0° longitude, then transferring the transparency to the great-circle chart, Fig. 13, and drawing in the transmission path, measuring its distance, and locating control points 2000 km along the path from each terminal, the distance may be seen to be approximately 7500 km and the two control points approximately at 54.0°N, 56.0°W and at 64.0°N, 4.0°E. These are respectively in zone W and zone I as shown on the map, Fig. 1.

This distance and the locations of the two control points may likewise be determined by means of the nomogram, Fig. 15. The bearing of Moscow from New York City, determined by means of this nomogram, is approximately 35°.

The values of muf and owf over this transmission path, following the various processes previously outlined, determined for each hour, GCT, are given in Table 2, the final values being graphically presented in Fig. 18.

By inspection of Fig. 18, it may be seen that skip will occur, on the average, during night hours if a frequency as high as 5 Mc is used, although much 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 for the preceding problem.

In this case a frequency of 3.9 Mc may be used from 1715 to 1130 GCT, a transition frequency of 6 Mc used between 1130 and 1215 GCT and again between 1545 and 1715 GCT, and a daytime frequency 10 Mc which may be used between 1215 and 1545 GCT.

Inspection of the median Es chart, Fig. 9, indicates that Es in excess of 2 Mc will occur at both control points on the average, from 1630 until 0900 GCT. Since the approximate value of the factor giving the equivalent frequency for long-path transmission is 5, transmission on a frequency of 10 Mc may be expected to be possible during these hours on approximately half the days of the month.

Table 1
Solution of Short-Path Transmission Problem

Path: Washington, D.C. (39.0°N, 77.5°W) to
Miami, Florida (25.7°N, 80.5°W).
Midpoint of path: 32.5°N, 79.0°W.
Transmission distance: 1500 km.

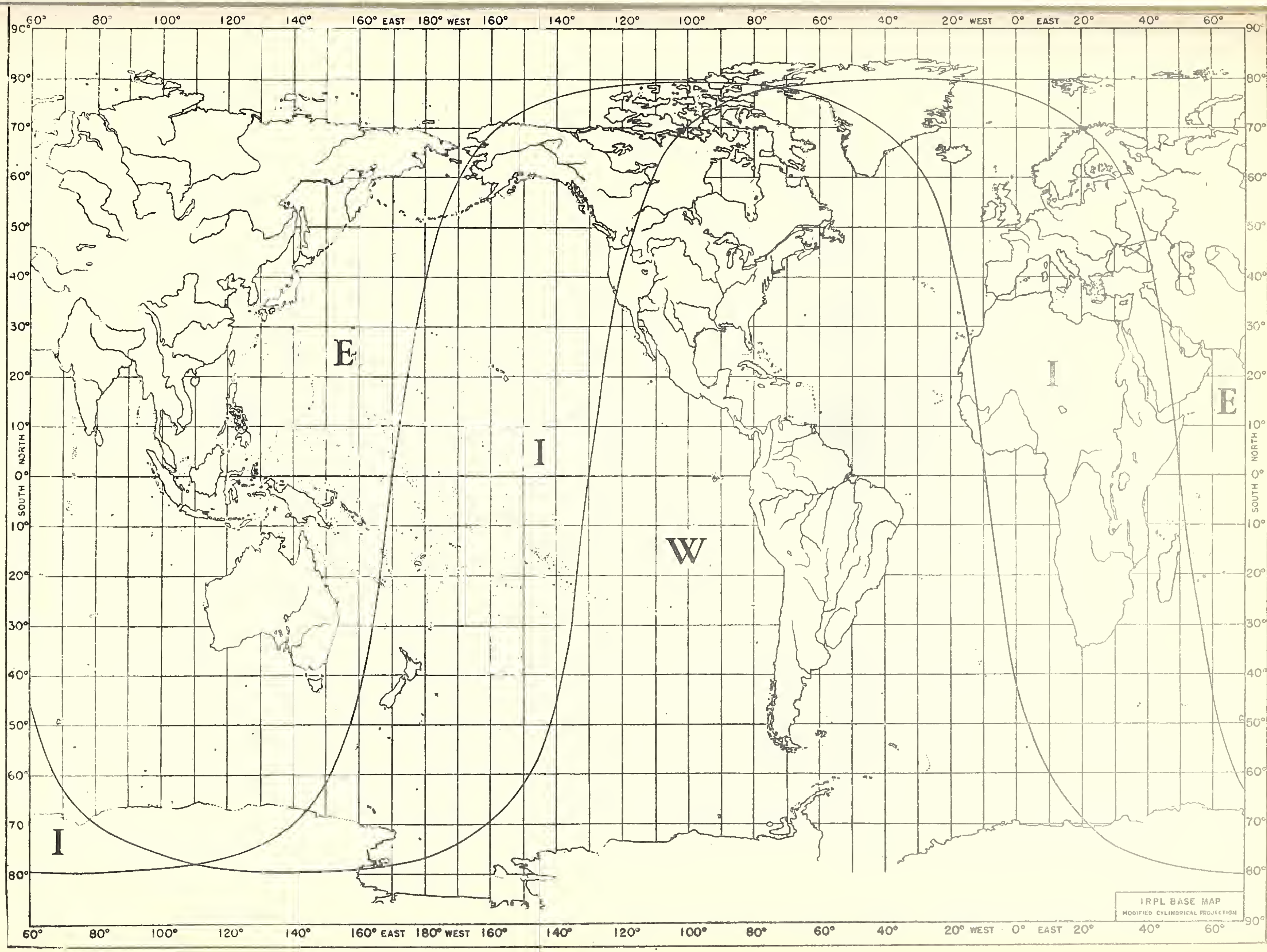
[illegible]	E-layer 2000-km muf, Mc	Combined E- and F1-layer 1500-km muf, Mc	Combined E- and F1-layer 1500-km owf, Mc	F2-layer zero-muf, Mc 75°W	F2-layer 4000-muf, Mc 75°W	F2-layer 1500-muf Mc 75°W	F2-layer 1500-km owf, Mc	Combined muf, Mc, all layers	Combined owf, Mc, all layers
00				3.5	9.7	[illegible]	5.0	5.9	5.0
01				3.2	8.4	[illegible]	4.4	5.2	4.4
02				3.0	8.3	5.1	4.3	5.1	4.3
03				3.2	8.6	5.4	4.6	5.4	4.6
04				3.4	9.1	5.7	4.8	5.7	4.8
05				3.4	9.3	5.8	4.9	5.8	4.9
06				3.5	9.4	5.8	5.0	5.8	5.0
07				3.7	9.7	6.0	5.2	6.0	5.2
08				3.8	9.9	6.2	5.3	6.2	5.3
09				3.7	9.9	6.2	5.2	6.2	5.2
10				3.4	9.5	5.8	4.9	5.8	4.9
11	0.0	0.0	0.0	3.2	8.7	5.4	4.6	5.4	4.6
12	7.3	6.7	6.5	3.8	10.8	6.6	5.6	6.7	6.5
13	10.1	9.3	9.0	5.2	16.5	9.7	8.2	9.7	9.0
14	12.1	11.1	10.8	6.3	19.6	11.6	9.8	11.6	10.8
15	13.4	12.2	11.8	6.8	[illegible]	12.3	10.4	12.3	11.8
16	14.0	12.9	12.5	7.0	21.6	12.8	10.8	12.9	12.5
17	14.4	13.2	12.9	7.2	22.0	13.0	11.1	13.2	12.9
18	14.2	13.1	12.7	7.2	22.8	13.4	11.4	13.4	12.7
19	13.7	12.5	12.1	7.1	21.9	13.0	11.0	13.0	12.1
20	12.4	11.4	11.0	6.8	21.0	12.5	[illegible]	12.5	11.1
21	10.6	9.8	9.4	6.4	20.0	11.8	10.1	11.8	10.1
22	[illegible]	7.5	7.2	5.9	17.4	10.5	8.9	10.5	8.9
23	0.0	0.0	0.0	4.5	13.0	7.8	6.7	7.8	6.7

Table 2.

Solution of Long-Path Transmission Problem

Path: New York City (40.5°N, 74.0°W) to
Moscow (56.0°N, 37.0°E).
Control point A at 54.0°N, 56.0°W;
Control point B at 64.0°N, 4.0°E.
Transmission distance: 7500 km.

Time, GCT	F2-4000-muf, in Mc, W zone Control point A	F2-4000-muf, in Mc, I zone Control point B	Muf, in Mc, for transmission path	Owf, in Mc, for transmission path
00	8.2	4.8	4.8	4.1
01	6.9	4.8	4.8	4.1
02	6.1	4.8	4.8	4.1
03	5.7	4.9	4.9	4.2
04	5.7	5.0	5.0	4.2
05	5.5	5.1	5.1	4.4
06	5.4	5.3	5.3	4.5
07	5.2	5.9	5.2	4.4
08	5.0	7.2	5.0	4.2
09	4.9	10.1	4.9	4.2
10	4.8	13.5	4.8	4.1
11	5.9	15.3	5.9	5.0
12	10.0	16.1	10.0	8.5
13	15.2	16.1	15.2	12.9
14	17.5	15.3	15.3	13.0
15	20.2	13.7	13.7	11.6
16	20.8	11.4	11.4	9.7
17	21.0	8.3	8.3	7.0
18	20.0	5.8	5.8	4.9
19	18.6	4.8	4.8	4.1
20	16.4	4.7	4.7	4.0
21	13.9	4.6	4.6	3.9
22	11.1	4.6	4.6	3.9
23	9.1	4.7	4.7	4.0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IRPL BASE MAP
MODIFIED CYLINDRICAL PROJECTION

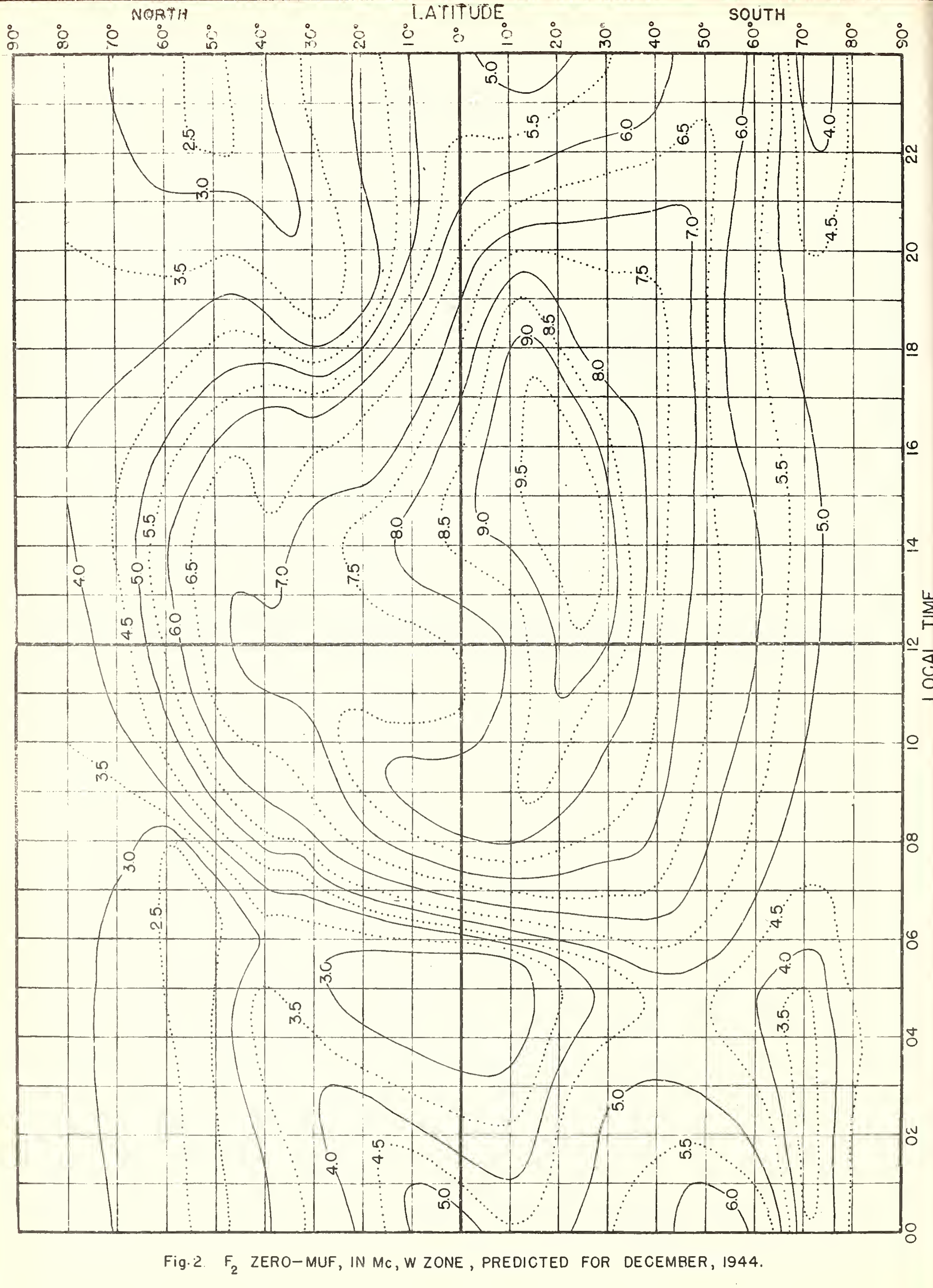

Fig. 2. F_2 ZERO-MUF, IN Mc, W ZONE, PREDICTED FOR DECEMBER, 1944.

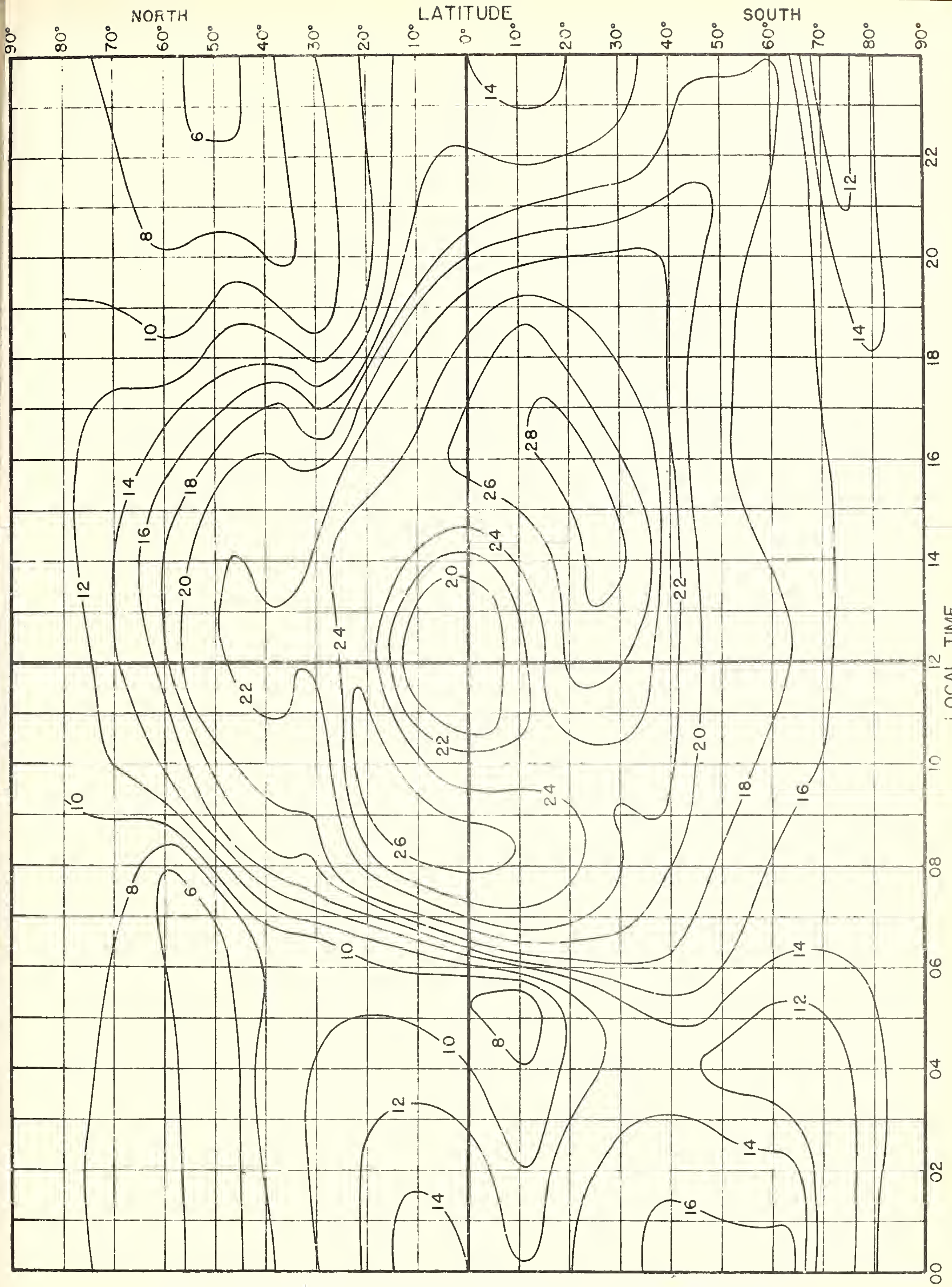

Fig. 3. F_2 4000—MUF, IN Mc, W ZONE, PREDICTED FOR DECEMBER, 1944.

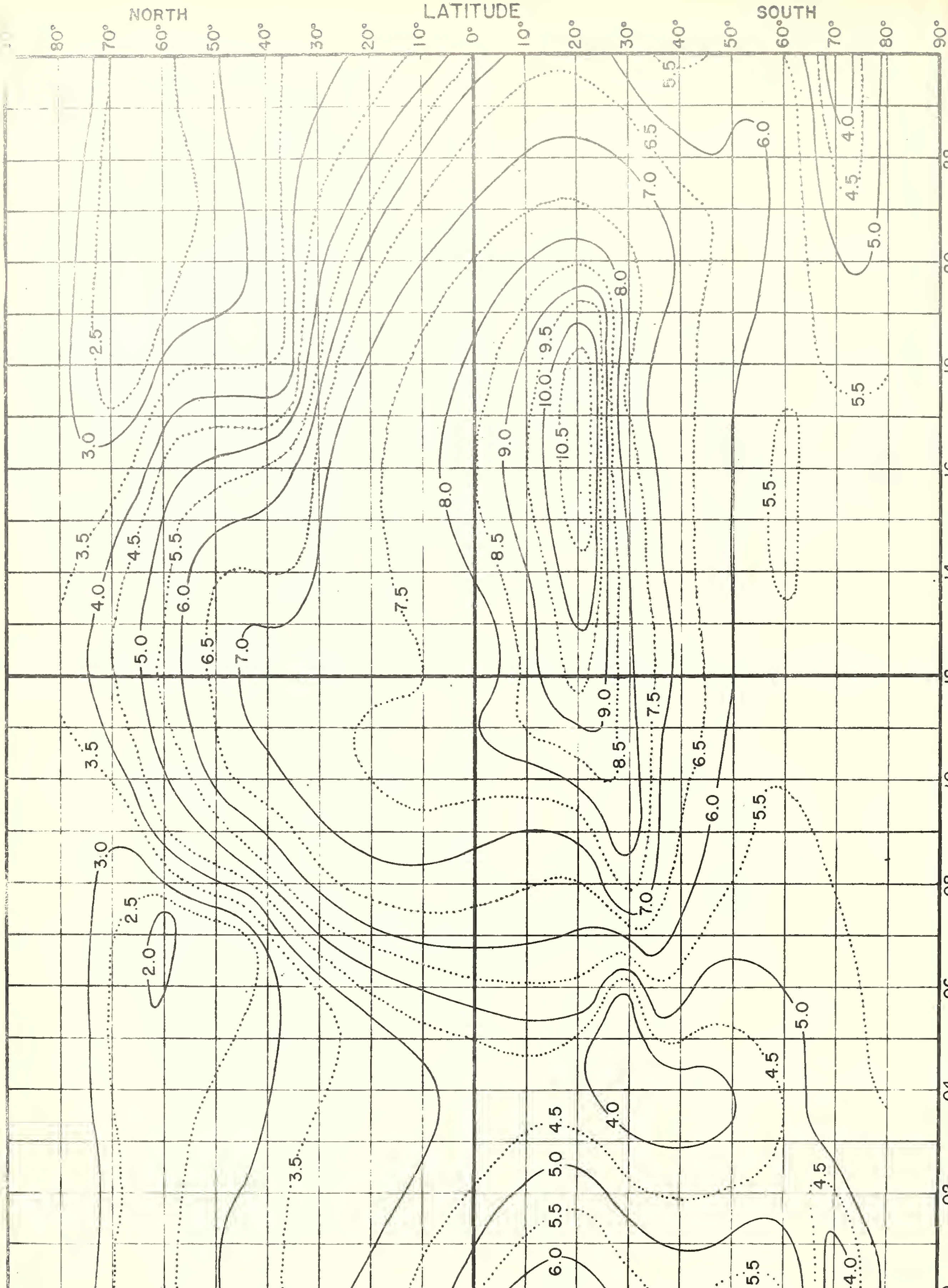

Fig. 4. F_2 ZERO—MUF, IN Mc, I ZONE, PREDICTED FOR DECEMBER, 1944.

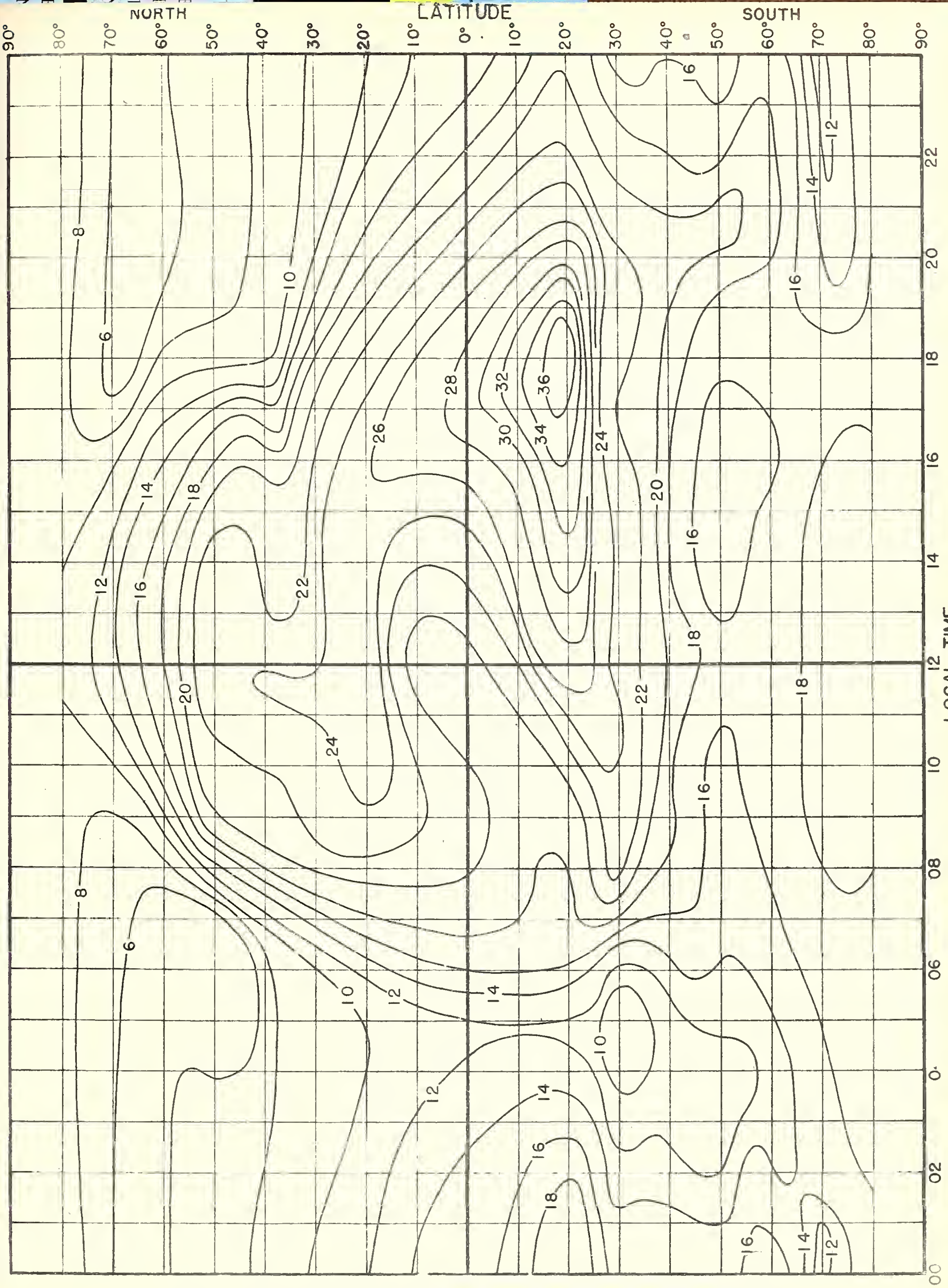

Fig. 5. F_2 4000—MUF, IN Mc, I ZONE, PREDICTED FOR DECEMBER, 1944.

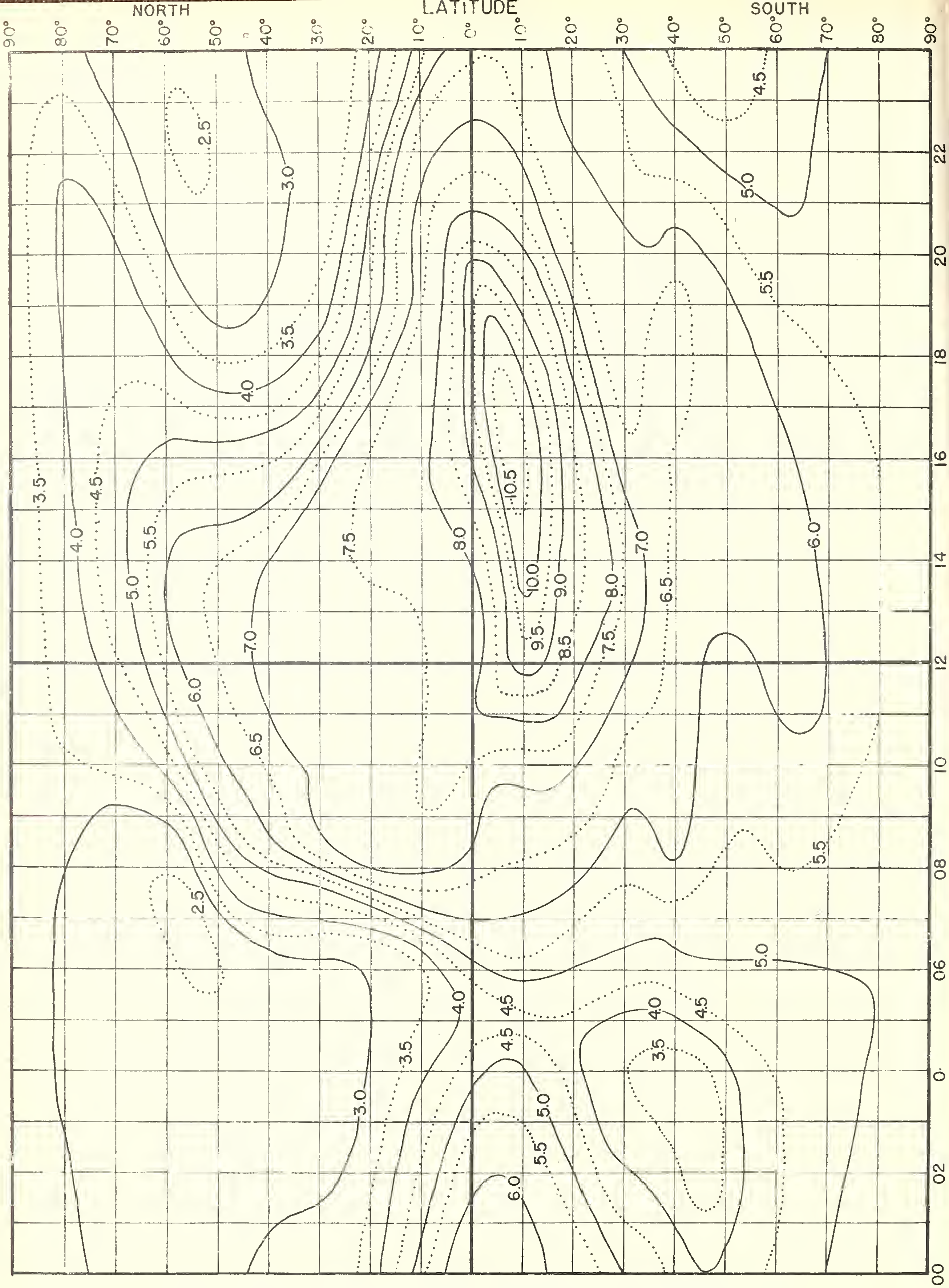

Fig. 6. F_2 ZERO—MUF, IN Mc, E ZONE, PREDICTED FOR DECEMBER, 1944

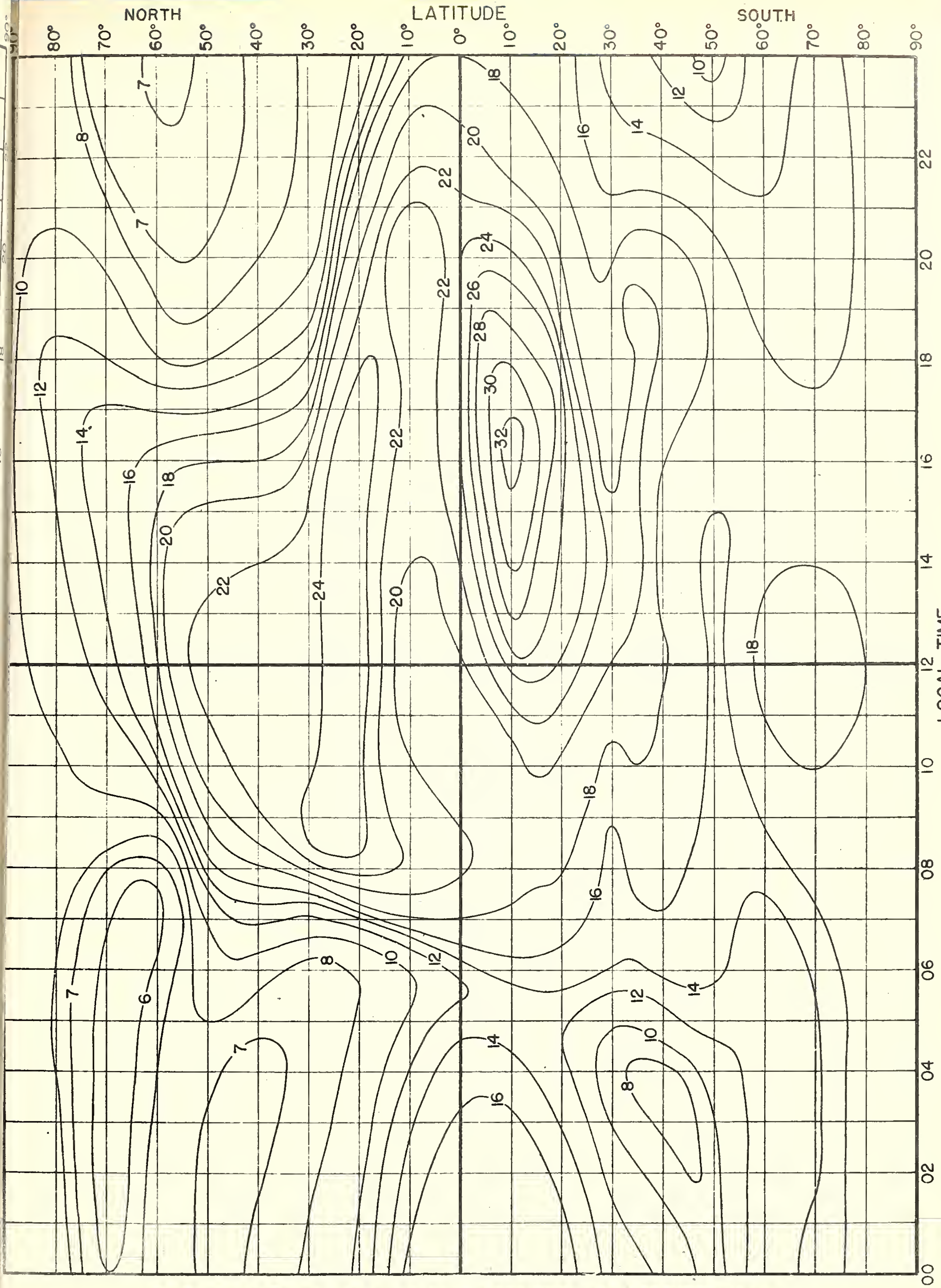

Fig. 7. F_2 4000—MUF, IN Mc, E ZONE, PREDICTED FOR DECEMBER, 1944.

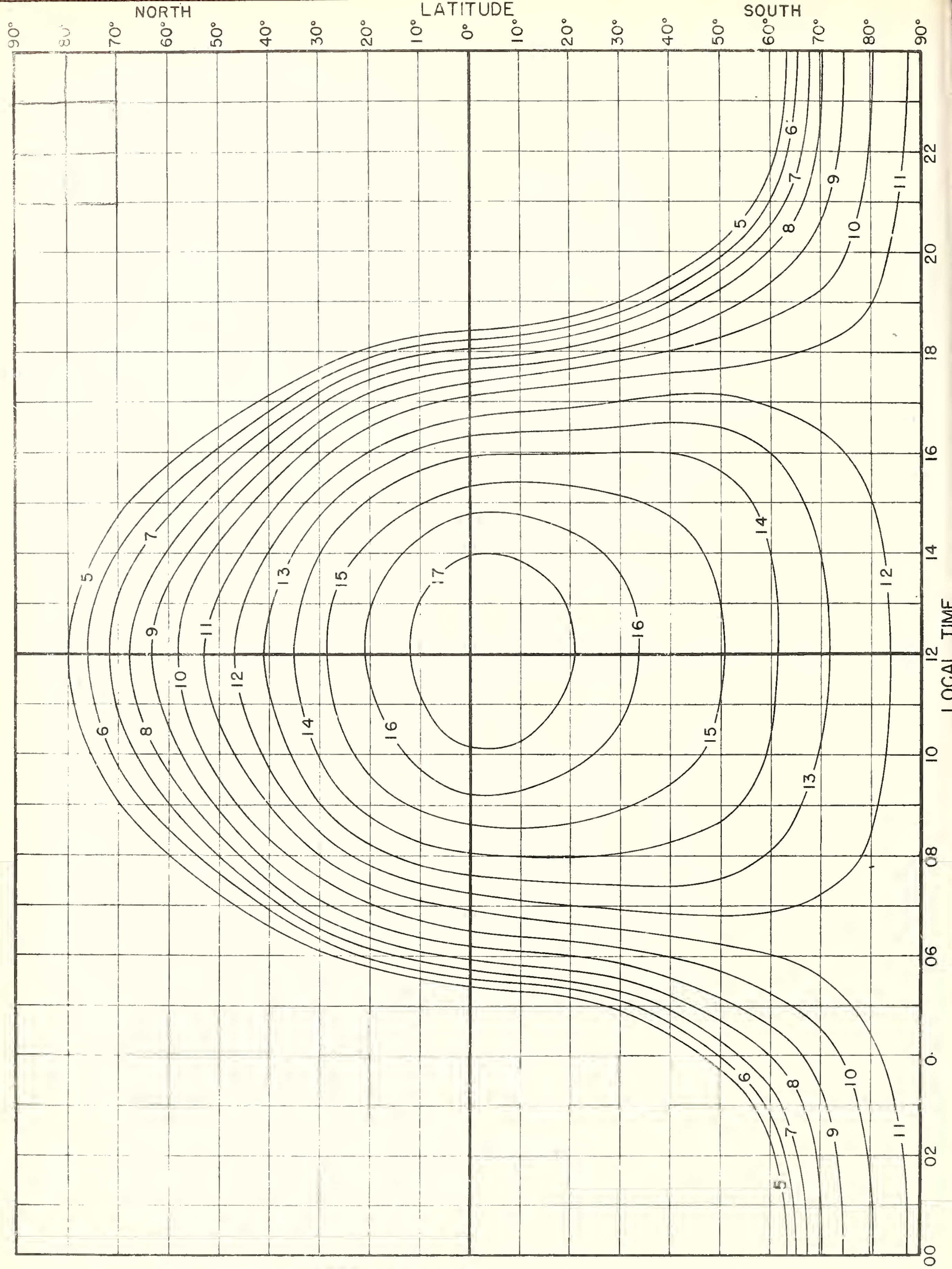

Fig.8. E-LAYER 2000-MUF, IN Mc, PREDICTED FOR DECEMBER, 1944

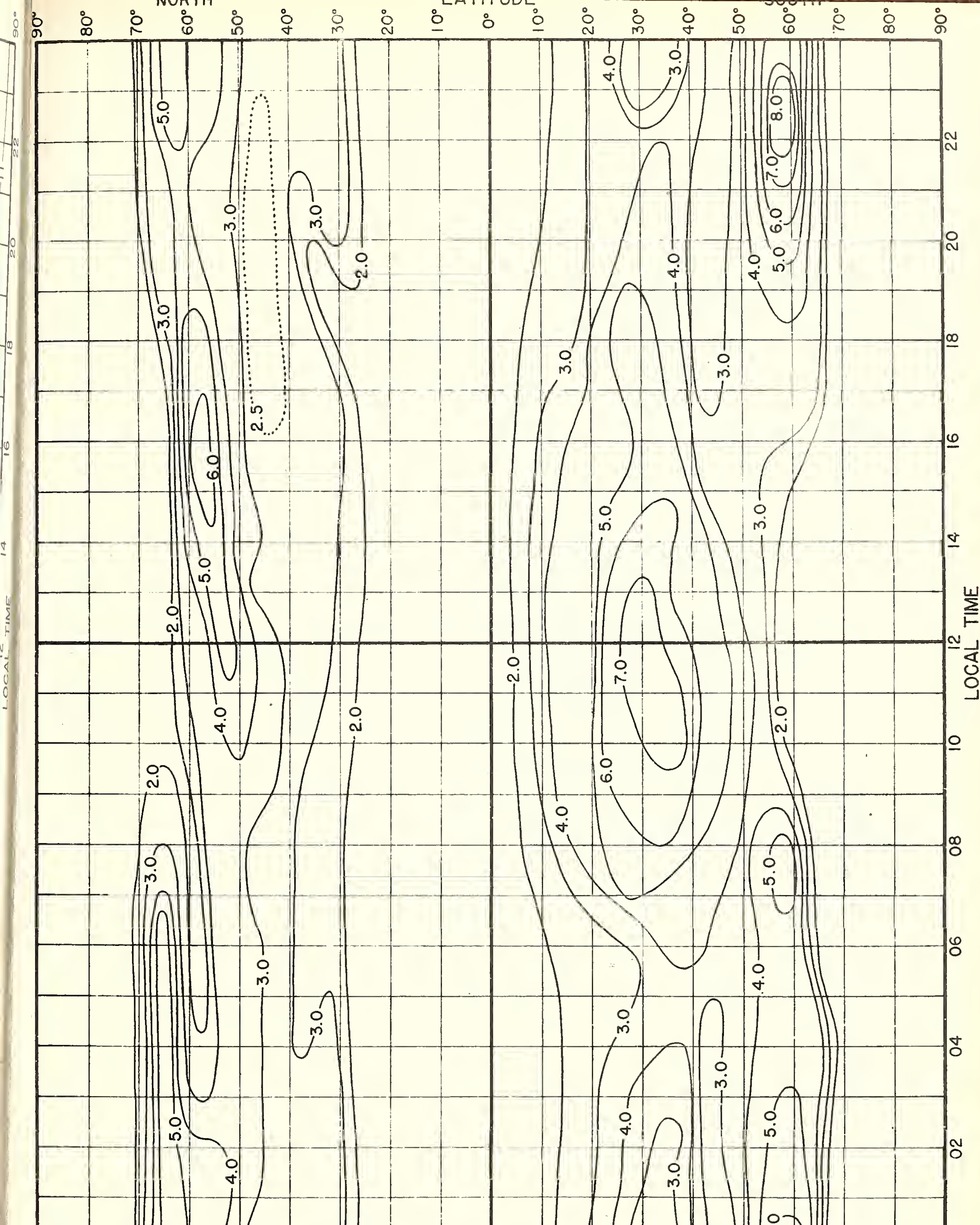

Fig. 9. MEDIAN E_s, IN Mc, PREDICTED FOR DECEMBER, 1944.

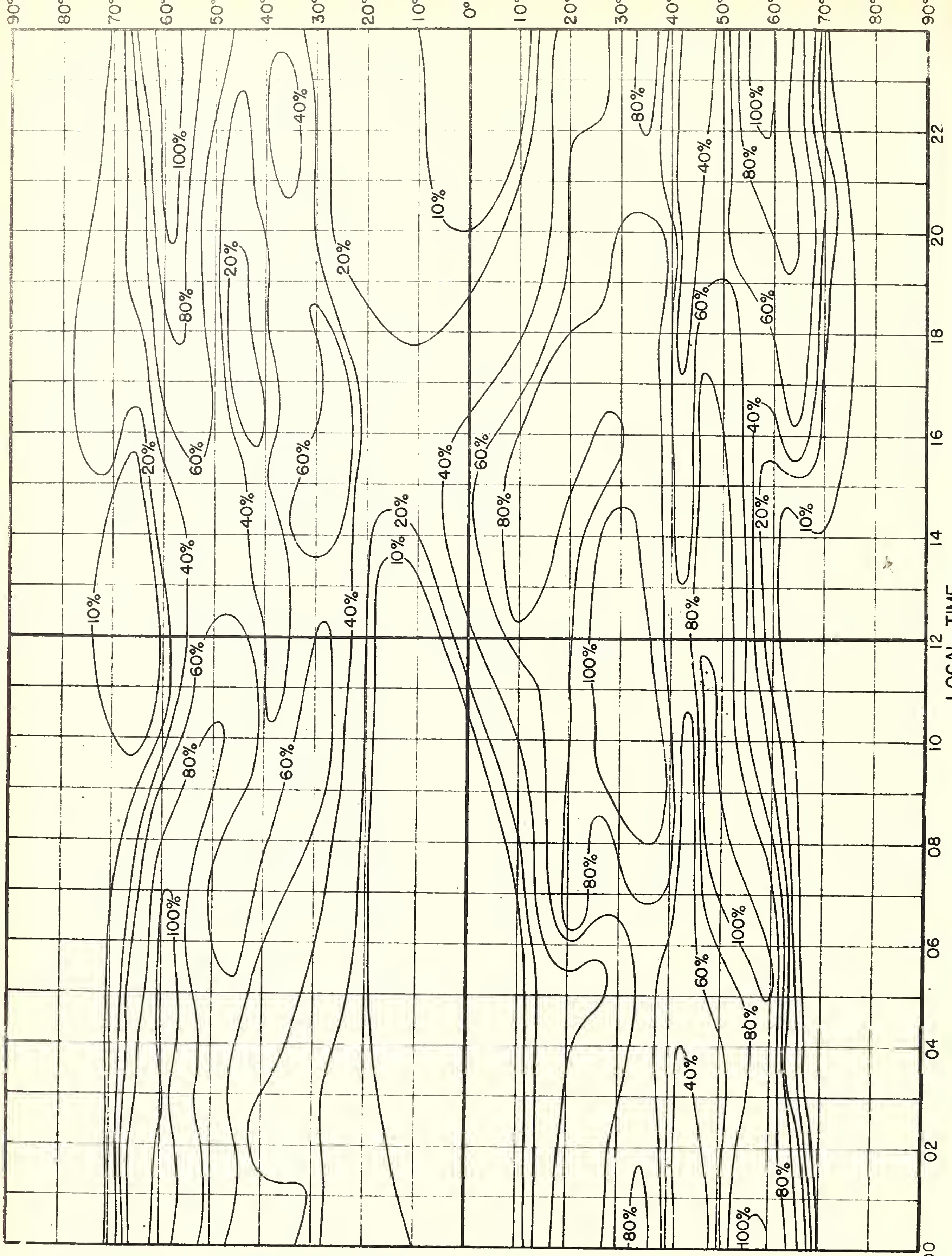

Fig. 10. PERCENTAGE OF TIME OCCURENCE FOR E_s IN EXCESS OF 15 Mc, PREDICTED FOR DECEMBER, 1944.

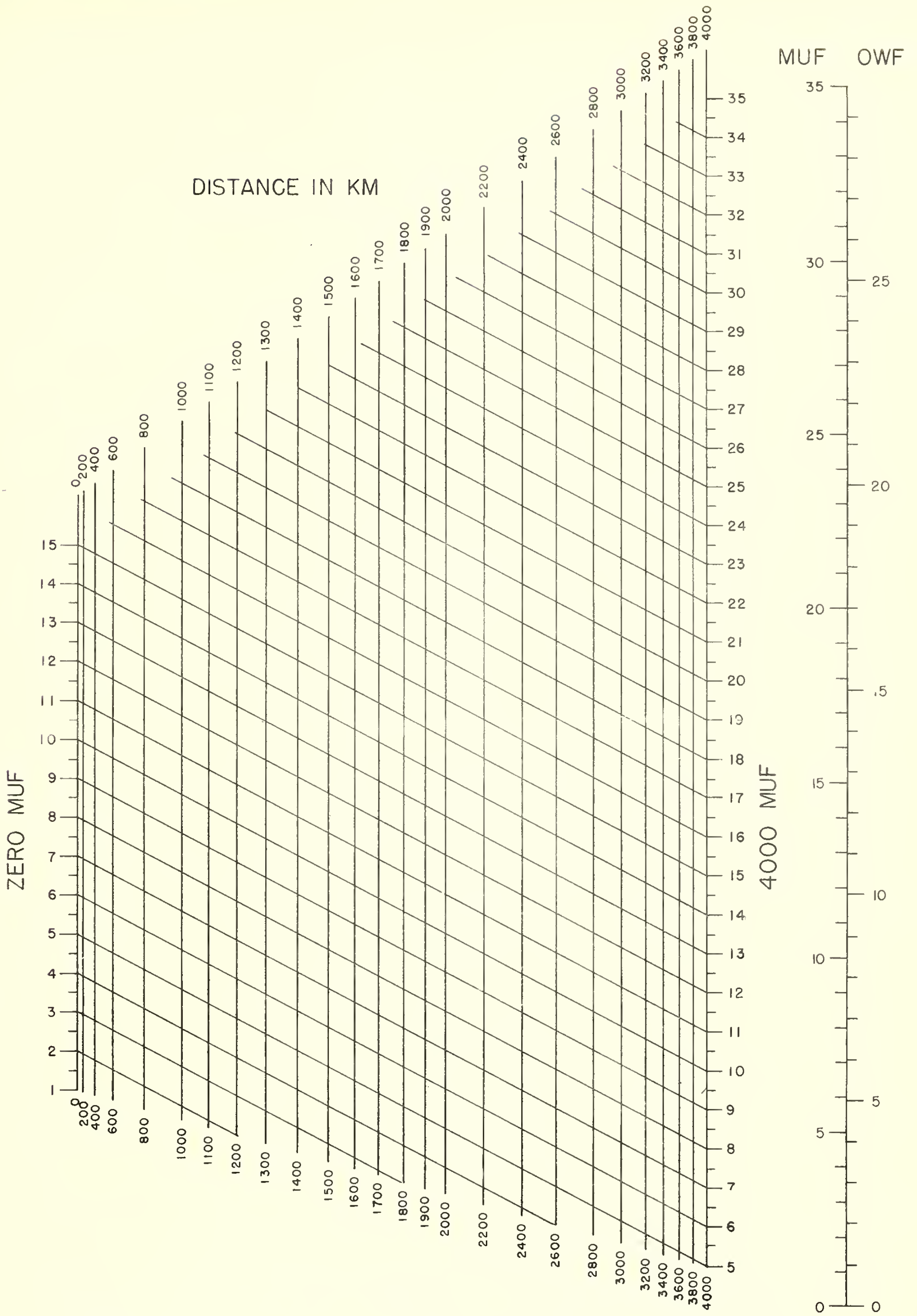

FIG.11 NOMOGRAM FOR TRANSFORMING F_2-ZERO-MUF AND F_2-4000-MUF TO EQUIVALENT MAXIMUM USABLE FREQUENCIES AT INTERMEDIATE TRANSMISSION DISTANCES; CONVERSION SCALE FOR OBTAINING OPTIMUM WORKING FREQUENCIES.

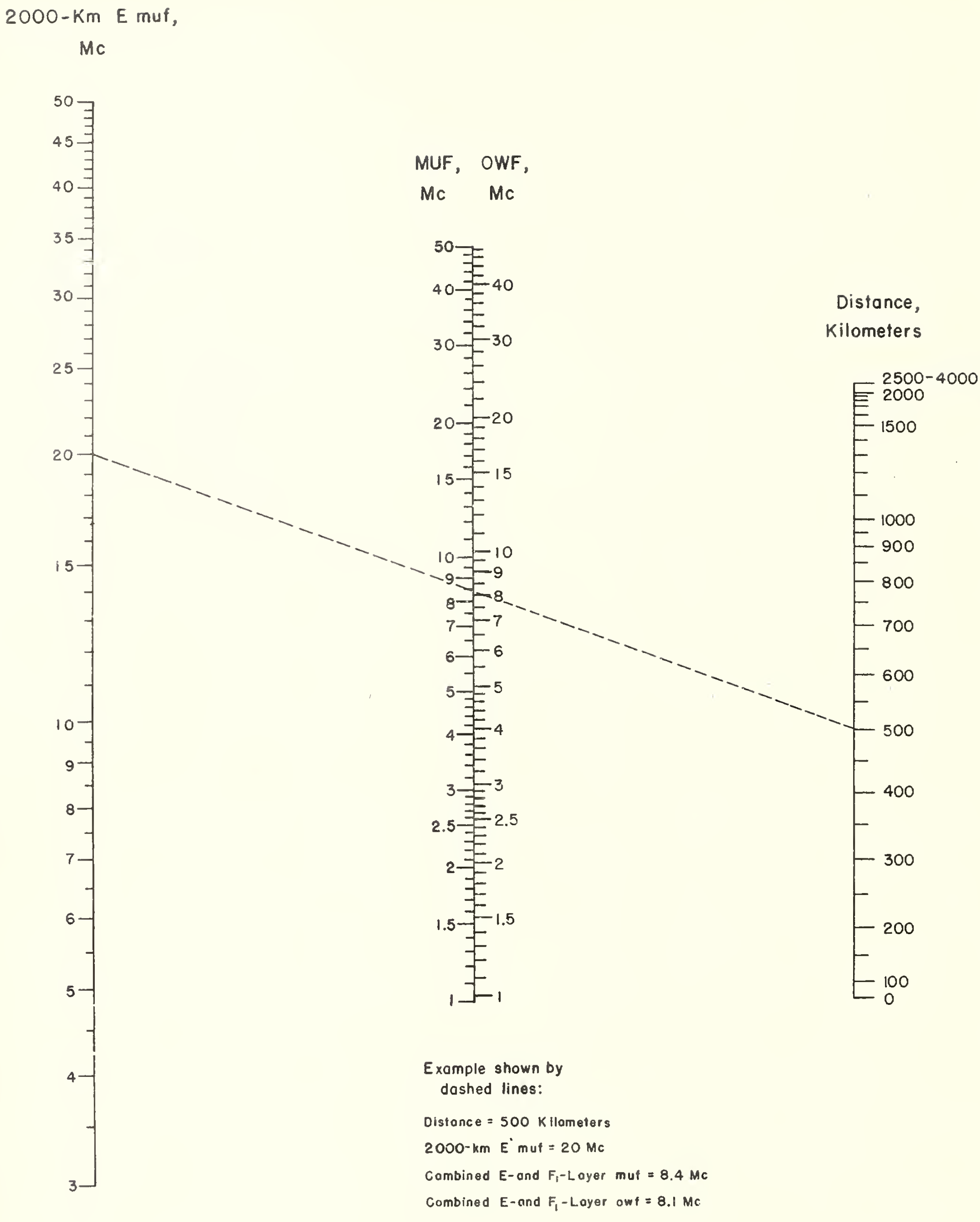

FIG. 12. NOMOGRAM FOR TRANSFORMING E—LAYER 2000—MUF TO EQUIVALENT MAXIMUM USABLE FREQUENCIES AND OPTIMUM WORKING FREQUENCIES DUE TO COMBINED EFFECT OF E LAYER AND F_1 LAYER AT OTHER TRANSMISSION DISTANCES.

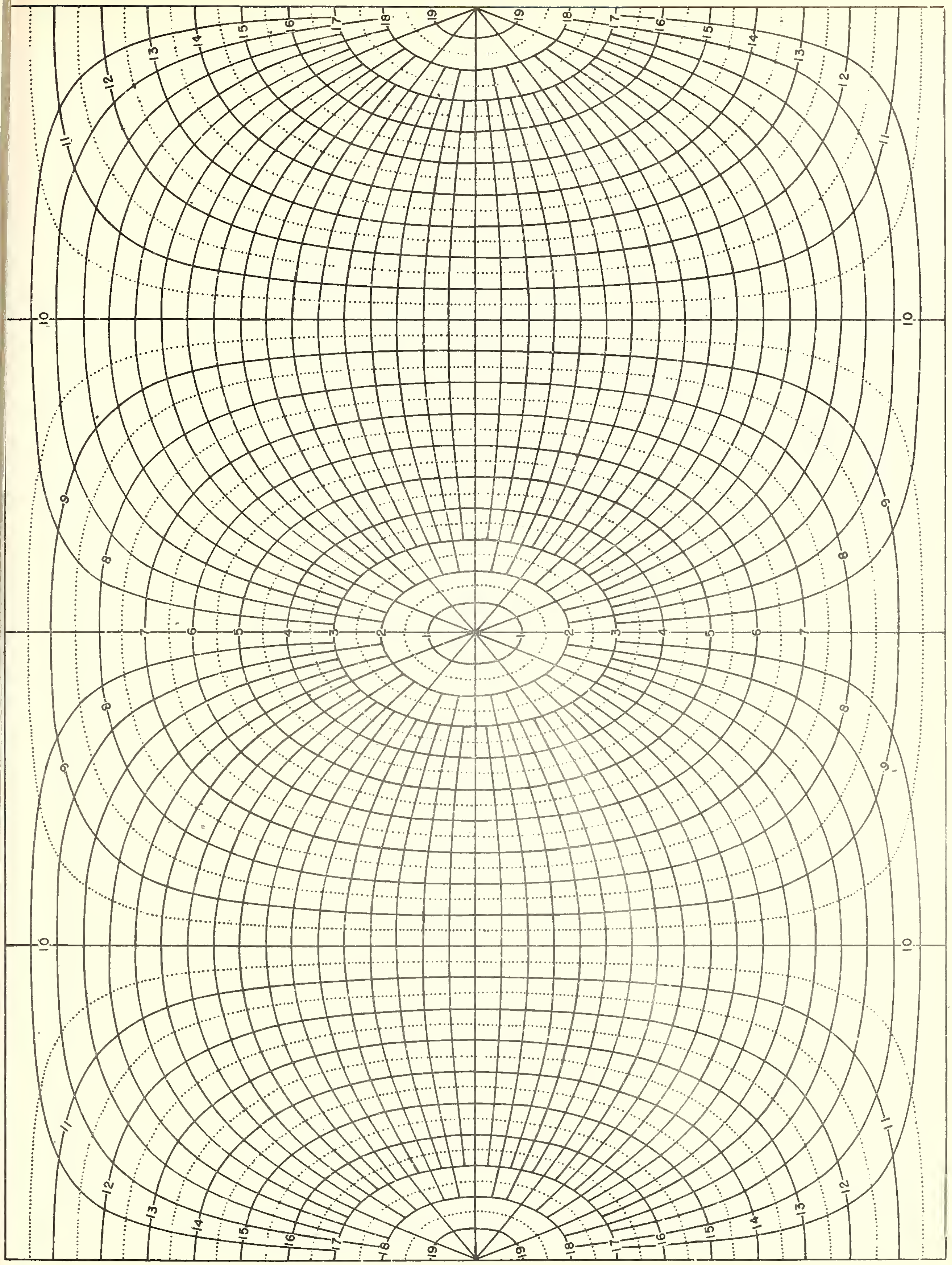

FIG. 13. GREAT CIRCLE CHART, CENTERED ON EQUATOR, WITH SMALL CIRCLES INDICATING DISTANCES IN KILOMETERS.

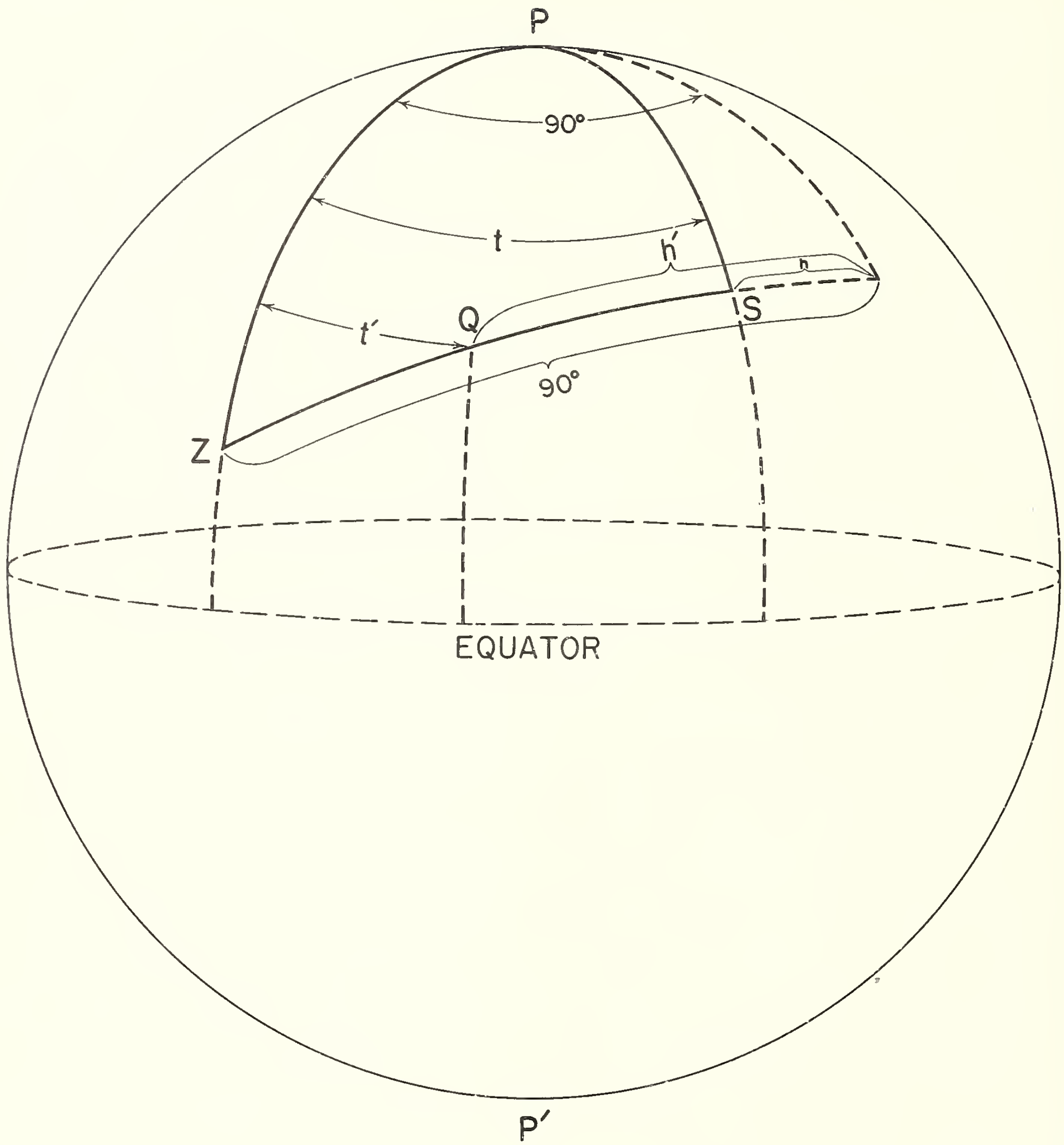

Fig. 14. DIAGRAM OF TRANSMISSION PATH AUXILIARY TO EXPLANATION OF USE OF DISTANCE — BEARI NOMOGRAM, FIG. 15.

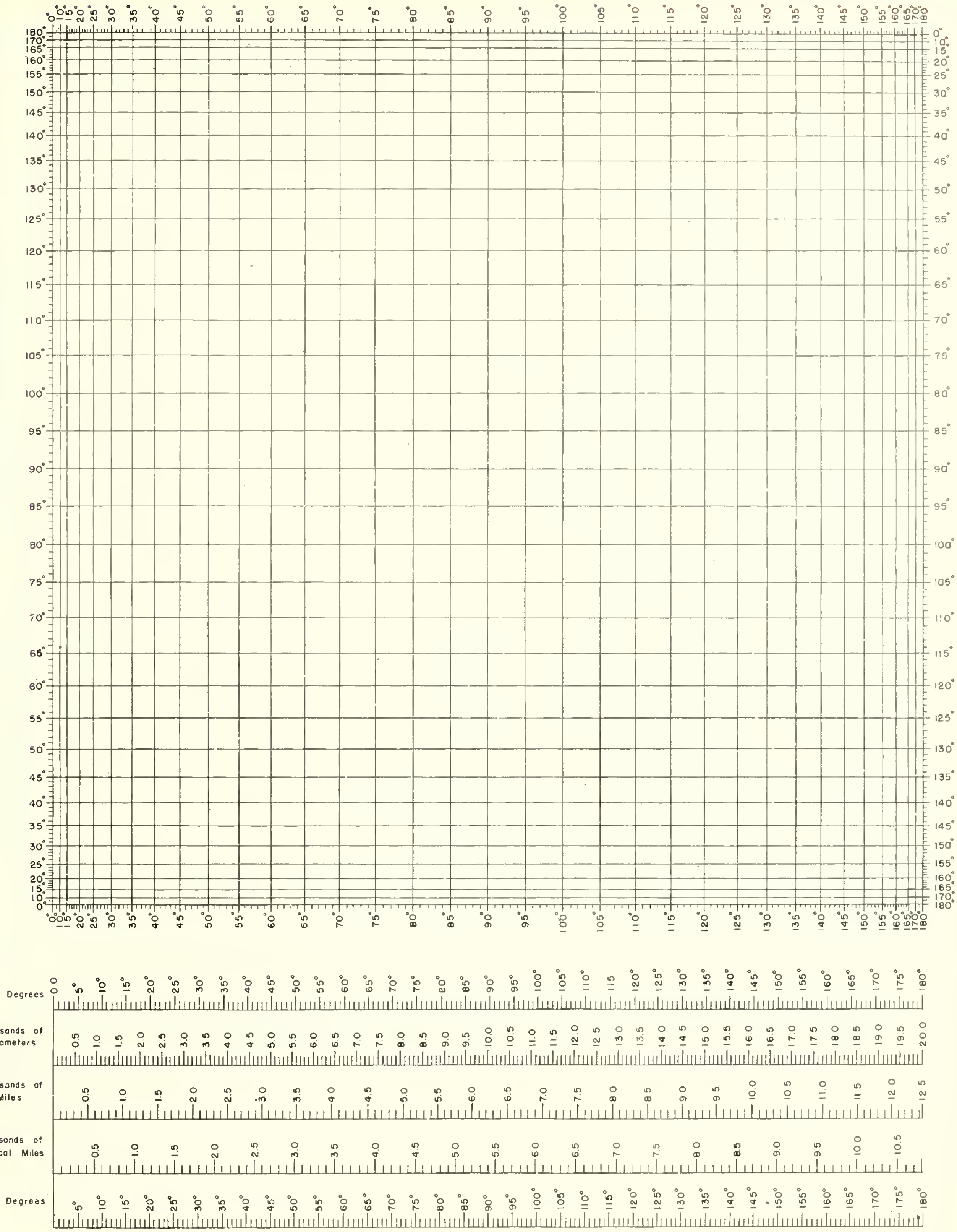

Fig. 15. Nomogram for obtaining great-circle distances, bearings, latitude and longitude of transmission control points, solar zenith angles.
Conversion scale for various distance units.

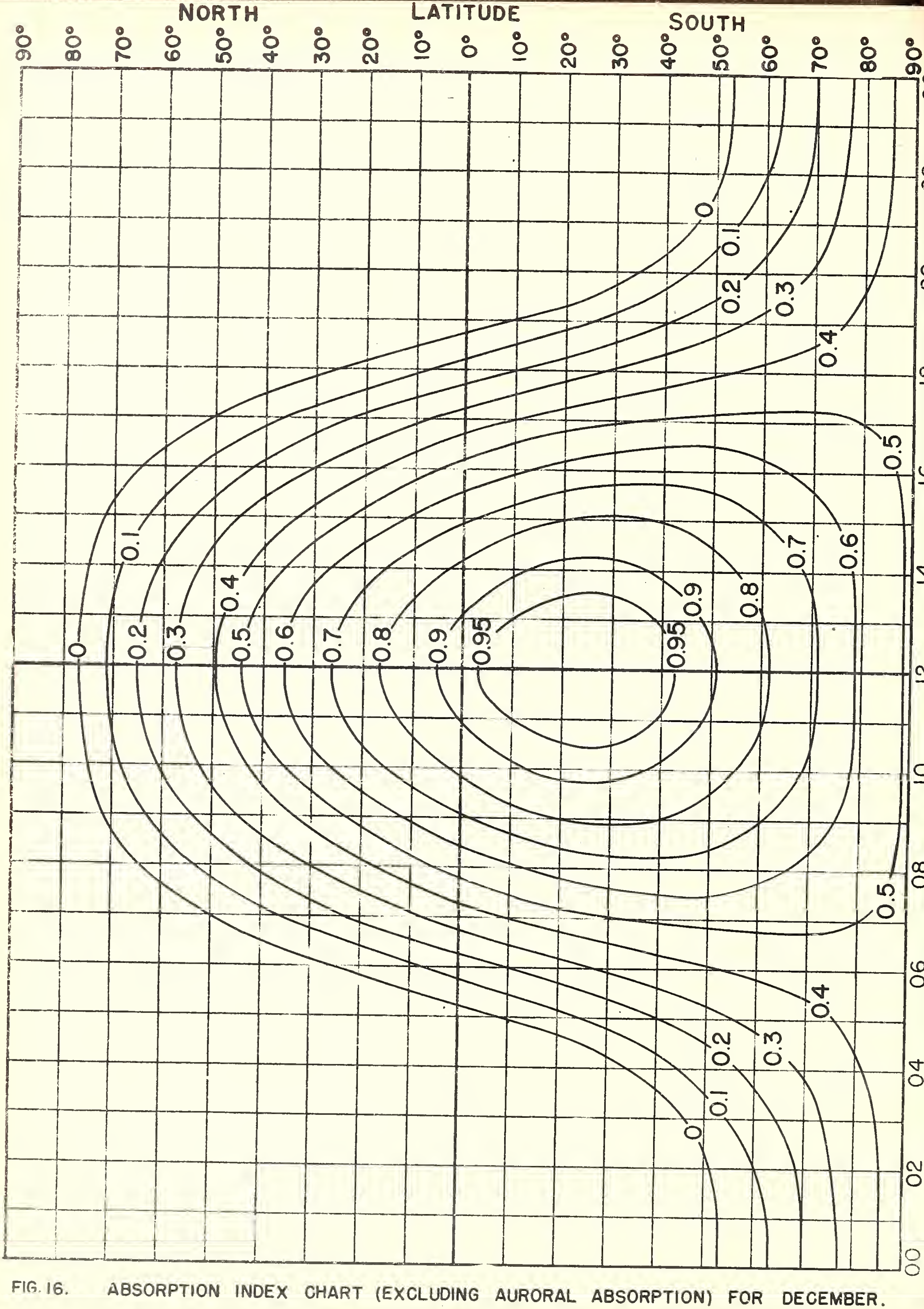

FIG. 16. ABSORPTION INDEX CHART (EXCLUDING AURORAL ABSORPTION) FOR DECEMBER.

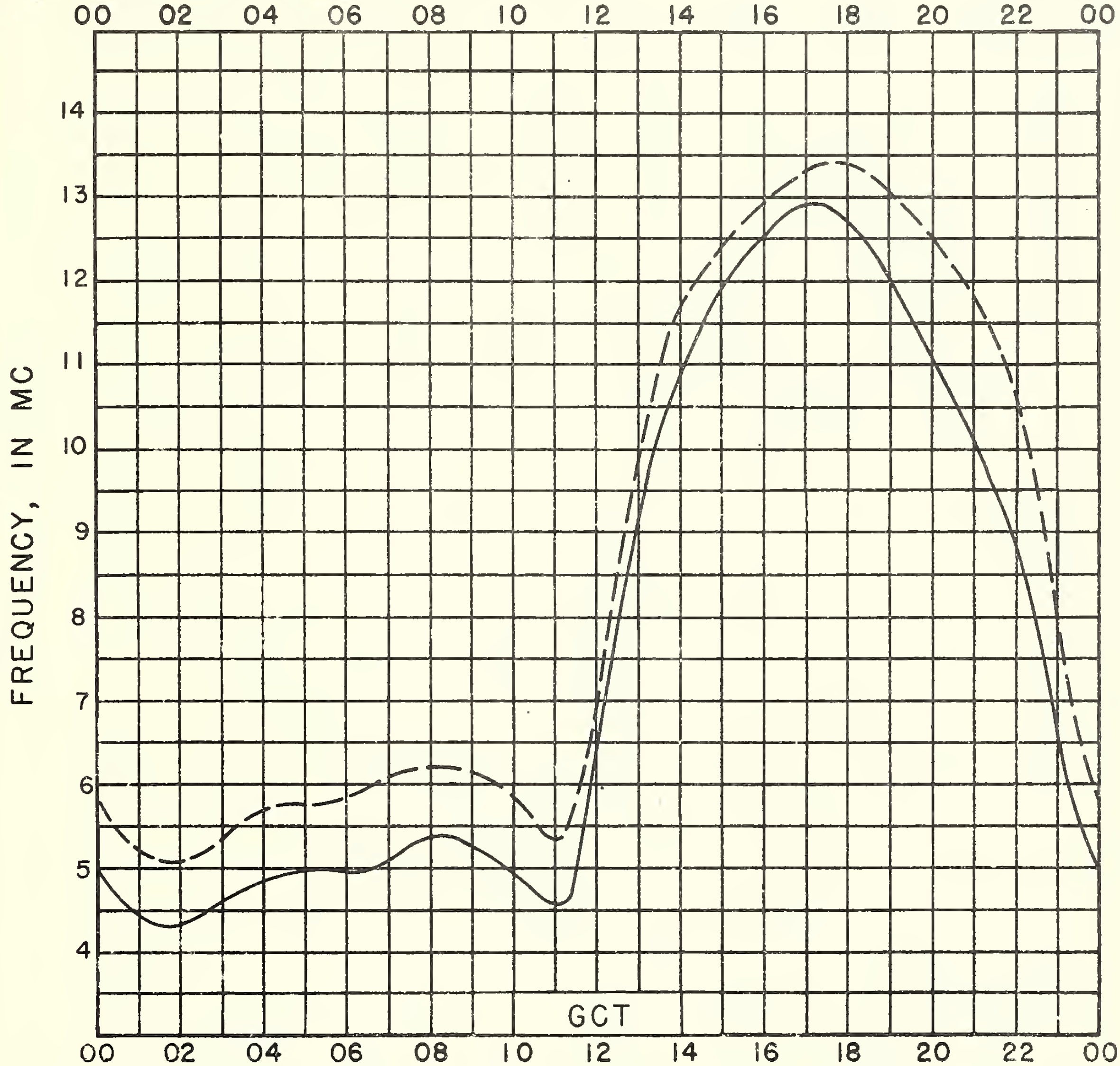

Fig. 17. SAMPLE SOLUTION OF TRANSMISSION PROBLEM FOR SHORT PATH, DECEMBER, 1944

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

— — — MUF ——— OWF

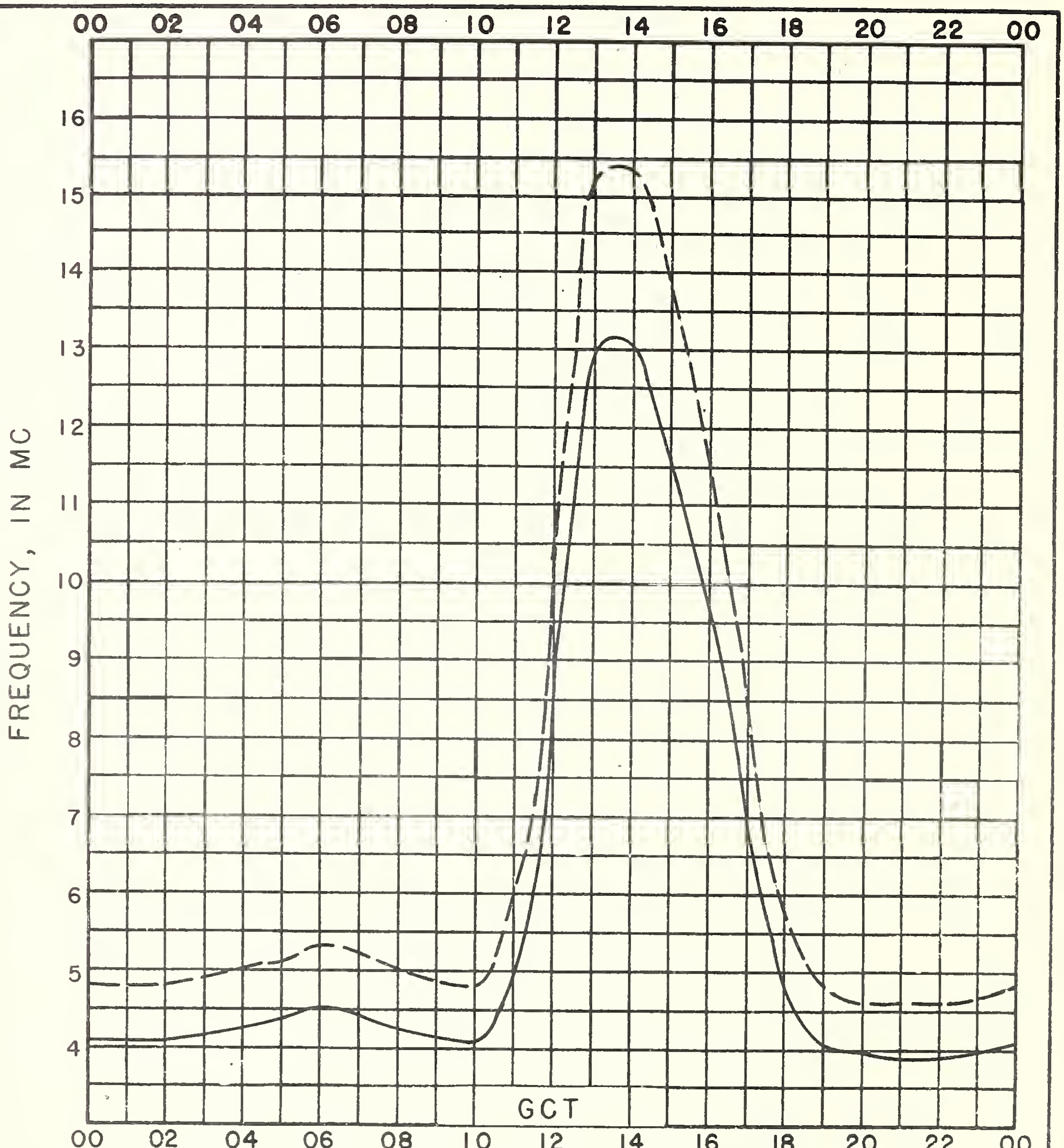

Fig. 18. SAMPLE SOLUTION OF TRANSMISSION PROBLEM FOR LONG PATH, DECEMBER, 1944
TRANSMISSION PATH: NEW YORK CITY, (40.5° N, 74.0° W) TO MOSCOW (56.0° N, 37.0° E)
— — — MUF ——— OWF

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