BASIC RADIO PROPAGATION PREDICTIONS
FOR JULY 1947
THREE MONTHS IN ADVANCE

ISSUED APRIL 1947

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 BASIC RADIO PROPAGATION PREDICTIONS
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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:

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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.

\[ f^o\ F_2 = \text{ordinary-wave critical frequency for the } F_2 \text{ layer.} \]

\[ f^x\ F_2 = \text{extraordinary-wave critical frequency for the } F_2 \text{ layer.} \]

\[ E_s = \text{sporadic, or abnormal, } E. \]

\[ fE_s = \text{highest frequency of } E_s \text{ reflections.} \]

II. WORLD-WIDE PREDICTION CHARTS AND THEIR USES

The charts, figures 5 to 11, present world-wide predictions of monthly average usable frequencies for July 1947. Conditions may be markedly different on disturbed days, especially in or near the auroral zones, shown on the map of figure 1. The method of prediction as discussed in the IRPL Radio Propagation Handbook, Part 1, War Dept. TM 11–499, Navy Dept. DNC–13–1, p. 52, 53, has been modified, substantially as indicated in reports IRPL–R11, 15, 16, and 19. The charts are constructed using data through January 1947 together with a predicted 12-month running-average Zurich sunspot number of 116, centered on July 1947.

Although ionosphere characteristics are roughly similar for locations of equal latitude, there is also considerable variation with longitude, especially in the case of the \( F_2 \) 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 \( F_2 \) 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 \( F_2 \) 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 \( f^o\ F_2 \) charts appearing in the previous IRPL reports “Radio Propagation Conditions.” (Values of \( F_2 \)-zero-muf exceed those of \( f^o\ F_2 \) 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 \( fE_s \) with geomagnetic latitude seems to be well marked and important. Consequently, the \( fE_s \) charts are constructed on the basis of geomagnetic latitude.

Since there are as yet insufficient correlated data, the \( fE_s \) 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 Occurrence for \( E_s \)-2000-muf in Excess of 15 Mc,” does not necessarily coincide with the 3-Mc contour in figure 12, “Median \( fE_s \), 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 1 and 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.

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 F2 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 greater 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.
IV. CALCULATION OF MAXIMUM USABLE FREQUENCIES, OPTIMUM WORKING FREQUENCIES

1. PROCEDURE FOR DETERMINATION OF MUF AND OWF FOR TRANSMISSION DISTANCES UNDER 4000 KM (PROPAGATION BY THE REGULAR LAYERS)

a. The use of a work form similar to CRPL form AF is suggested (see table 1 and the blank form AF following figure 17). Note that form AF provides for the inclusion of sporadic E (Es), which will be discussed under 3 below.

In following the instructions of this section (for propagation by the regular layers) form AF should be modified by omitting columns a, b, f, i and j. The item on procedure in column m should read: "Higher of g, h," and in column n: "Higher of k, l."

b. Locate the midpoint of the transmission path using the methods of section III above and by laying the great-circle path transparency back on the world map of figure 1, with the ends of the path in their proper location, determine in which geographical zone, E, I, or W, the midpoint falls.

c. To determine the maximum usable frequency (muf):

   (1) Place the great-circle transparency over the F2-zero-muf chart for the proper zone of the midpoint of the path, and, keeping the equatorial line of the transparency over the equatorial line of the chart, slide the transparency horizontally until the Greenwich meridian coincides with either 00 or 24 (not labeled) on the time scale.

   Note that all points on the great-circle path are in their proper local time relationship to Greenwich because 24 hours on the time scale of a muf chart is drawn to the same scale as 360° of longitude on the world map.

   (2) Read the value of F2-zero-muf for the midpoint of the path and enter in column d of form AF.

   (3) Repeat for 02, 04, etc., on the time scale. Frequently it will be necessary to make the Greenwich meridian of the transparency coincide with an imagined 26, 28, etc., on the time scale. A convenient aid is to place marks at two-hour intervals on the equatorial line of the transparency.

   (4) Repeat steps (1), (2), and (3) for the F2-4000-muf chart for the proper zone and again for the E-layer 2000-muf chart, figure 11, entering values in columns c and e, respectively.

   (5) For each hour place 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, figure 13, and read the value of the muf for the actual path length at the intersection point of the straightedge with the appropriate vertical distance line. Enter in column h.

Example:

F2-zero-muf=6.8 Mc. F2-4000-muf=23.0 Mc. For a distance of 2600-km the F2 muf is 19.1 Mc.

(6) For each hour place a straightedge between the value of the E-layer 2000-muf on the left-hand scale of the nomogram, figure 14, and the value of the path length on the right-hand scale, and read the E-F1-muf for that path length, off the central scale. (Example on nomogram.) Enter in column g.

(7) Compare the values of muf obtained by operations (1) to (6). The higher of the two values (columns g and h of form AF) thus determined is the muf for the path. Enter in column m.

d. To determine the optimum working frequency (owf):

   (1) Calculate the F2-owf from the F2-muf determined under e above by multiplying each figure in column h by 0.85 or by using the conversion scale in figure 13. Enter in column l.

   (2) Use for the E-owf the value of E-F1-muf determined under e (6) above. This represents a change from the previous practice of taking 97 percent of the E-F1-muf on the nomogram of figure 14. Enter in column k.

   (3) Compare the F2-owf and E-owf. The higher of the two values (columns k and l of form AF) is that of the path owf. Enter in column n.

2. PROCEDURE FOR DETERMINATION OF MUF AND OWF FOR TRANSMISSION DISTANCES GREATER THAN 4000 KM (PROPAGATION BY THE REGULAR LAYERS)

a. General considerations:

   The procedure outlined below is based on the following assumptions:

   (1) That there are F2-layer control points A and B and E-layer control points A' and B'.

   (See section III, 1 d above.)

   (2) That the highest frequency that will "take off" along the path at the A-end is the highest frequency that can be propagated at A and A' considered together.

   (3) That the highest frequency that will come in along the path at the B-end is the highest frequency that can be propagated at B and B' considered together.

   (4) That the highest frequency that can be propagated from the A-end to the B-end is the lower of the two frequencies of (2) and (3) above.

   (5) That the frequency obtained in (4) is the same for propagation from the B-end to the A-end.

b. The use of a work form similar to CRPL form AH is suggested (see table 2 and the blank form AH following figure 17). Note that form AH provides for the inclusion of the effects of sporadic E (Es), which will be discussed under 3 below.
In following the instructions of this section (for propagation by the regular layers) form AH should be modified by omitting columns a, b, e, g, h, and k.

The item on procedure in column m should read: "Higher of c, d," in column n: "Higher of i, j," in column o: "Higher of d, f," and in column p: "Higher of j, l.

c. Locate the control points A and A' at one end of the path and B and B' at the other end of the path as explained under section III, 1 d above. For very long paths the "short route." (minor arc of the great-circle path) and the "long route." (major arc) need be considered. Placing the transparency back on the world map, determine as in section IV, 1 e above, in which geographical zone, E, I, or W, each of the control points A and B falls.

d. To determine the muf:

(1) Place the great-circle transparency over the F2-4000-muf chart for the zone of control point A and, keeping the equatorial line of the transparency over the equatorial line of the chart, slide the transparency horizontally until the Greenwich meridian coincides with either 00 or 24 (not labeled) on the time scale.

(2) Read the value of F2-4000-muf for control point A. Enter in column c of form AH.

(3) Repeat for 02, 04, etc., on the time scale. Frequently it will be necessary to make the Greenwich meridian of the transparency coincide with an imagined 26, 28, etc., on the time scale. A convenient aid is to place marks at two-hour intervals on the equatorial line of the transparency.

(4) Repeat steps (1), (2), and (3) on the E-layer 2000-muf chart, figure 11, using control point A'. Enter values in column d.

(5) Determine the muf for the A-end as the higher of the F2-4000-muf, column c, and the E-layer 2000-muf, column d. Enter in column m.

(6) Read the value of F2-4000-muf for control point B, using the F2-4000-muf chart for the proper zone. Enter values in column i.

(7) Repeat for 02, 04, etc., on the time scale.

(8) Read the values of E-layer 2000-muf on the E-layer 2000-muf chart, figure 11, using control point B'. Enter values in column j.

(9) Determine the muf for the B-end as the higher of the F2-4000-muf, column i, and the E-layer 2000-muf, column j. Enter in column n.

(10) Compare the two muf values of columns m and n. The lower of the two is the muf for the transmission path under consideration. Enter in column q.

e. To determine the owf:

(1) Use the scaled data of the previous procedure.

(2) Multiply the F2-4000-muf for the A-end, column c, by 0.85, or use the conversion scale in column p, the E-layer 2000-muf for the A-end, column d. Enter in column o.

(3) Multiply the F2-4000-muf for the B-end, column i, by 0.85 or use the conversion scale in column q, the E-layer 2000-muf for the B-end, column l. Enter in column r.

(4) Compare the F2-4000-muf for the A-end, column j, with the E-layer 2000-muf for the A-end, column d. The higher of the two is the owf for the A-end. Enter in column o.

(5) Compare the F2-4000-muf for the B-end, column i, with the E-layer 2000-muf for the B-end, column j. The higher of the two is the owf for the B-end. Enter in column p.

(6) Compare the two owf values of columns o and p. The lower of the two is the owf for the transmission path under consideration. Enter in column r.

3. PROCEDURES FOR INCLUSION OF THE EFFECTS OF Es

Sporadic-E (Es) propagation may often allow regular transmission when regular E- or F2-layer propagation would not. Es data are not yet sufficient to permit accurate calculations of such propagation, but the Es charts of figures 12 and 15 are given as a guide to Es occurrence.

As the Es charts are constructed from considerations of geomagnetic latitude, three latitude scales are provided at the right of the charts of figures 12 and 15, one for each of the three zones of figure 1 (E, I, and W).

Until further improvements are made, the following procedures should be used to include the effects of Es in the calculations of muf and owf.

a. For paths over 4000 km long:

(1) Place the great-circle transparency prepared in section III, 1, over the median Es chart, figure 12, using the latitude scale for the zone containing the control point.

(2) Scale Es at control points A' and B'. Enter in columns a and g, respectively, on form AH.

(3) Multiply Es by 5 in each case, obtaining the Es-2000-muf. Enter in columns b and h, respectively.

(4) In the determination of muf modify the procedure (steps (5) and (9)) of section IV, 2 d above to obtain the muf for the A- and B-ends, respectively, as the highest of the three items, the F2-4000-muf, the E-layer 2000-muf, and the Es-2000-muf. No other change is necessary.

(5) In the determination of owf subtract 4 Me from the Es-2000-muf to obtain the Es-2000-owf for the A-end and B-end, respectively, entering the results in columns e and k. Then modify the procedure (steps (4) and (5)) of section IV, 2 e to obtain the owf for the A- and B-ends, respectively, as the highest of the three items, the F2-4000-owf, the E-layer 2000-muf, and the Es-2000-owf. No other changes are necessary.

b. For paths under 4000 km long:

(1) Repeat step (1) of a above.
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 July 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 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. It will be noted that E-owf is the controlling frequency for the regular layers between the hours of 1200 and 2000. 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 July, Es-owf is the controlling frequency between the hours of 0400 and 1200 approximately. Values at these hours are used in plotting the dotted line in figure 16.

Figure 16 shows that skip will occur, on the average, during the night hours, if a frequency as high as 15.0 Mc is used. A frequency as high as 14.0 Mc will not skip, on the average, at any time of day, but its use is not advisable because of the day-to-day variability, causing some probability of skip during the night hours. Furthermore, because of ionospheric absorption during the daytime, which is more pronounced at low frequencies, it is advisable to use frequencies as little below the owf as possible.

A satisfactory plan to insure continuous trans-
mission 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 10.5 Mc, to be used from 2320 to 1300 GCT, and
a day frequency of 15.0 Mc, to be used from
1300 to 2300 GCT, would be satisfactory. The
periods of usefulness of these frequencies are
shown by the heavy dashed line on figure 16.
These values of frequency were obtained by in-
cluding Es-owf in the calculations, and conse-
quently, for the reason indicated in the last para-
graph of IV, above, some interruptions in service
may be expected on the night frequency, since the
night frequency, as shown in figure 16, was chosen
above the owf for the regular layers between 0350
and 1030. Better service may possibly be ob-
tained by choosing a lower night frequency, closer
to the regular-layer owf.

2. FOR LONG PATHS

Required: The muf and owf for transmission
between Washington, D. C. (39.0° N, 77.5° W)
and Trieste (45.7° N, 13.8° E) for average condi-
tions during the month of July 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 F2-layer control points, A and B, respec-
tively, 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 transmis-
sion path, as determined by the procedure in sec-

tion 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 16.0 Mc is used, although higher frequen-
cies may be used during much of the twenty-four
hours.

A good, practical arrangement to insure con-
tinuous transmission at all times is to select three
frequencies in a manner similar to that suggested
in the preceding problem. A frequency of 11.5
Mc may be used from 0330 to 1015 GCT, a fre-
quency of 18.0 Mc may be used from 1330 to 0120
GCT, and a transition frequency of 14.5 Mc may
be used from 0120 to 0330 GCT, and from 1015 to
1330 GCT.

By inspection of the absorption chart and the
noise map (figs. 86 and 119, 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 fre-
quency over this path may be of considerable
importance in selecting frequencies for use. Con-
sequently, in cases of transmission failure on the
frequencies here recommended, particularly in the
case of the transition frequency, changing the fre-
quency 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

CRPL-D31, page 4, line 1 of heading: Change
"V" to "IV."
CRPL—FORM AF
MUF—OWF WORK SHEET FOR PATHS 4000 KM OR LESS

DATE 27 February 1947

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

Note: All frequencies are in megacycles.

<table>
<thead>
<tr>
<th>GCT</th>
<th>( f_{Es} ) 2000-muf</th>
<th>( E_s ) 2000-muf</th>
<th>( E_{layer} ) 2000-muf</th>
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### TABLE 2: Solution of Long-Path Transmission Problem

**MUFOWF WORK SHEET FOR PATHS OVER 4000 KM.**

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**Note:** All frequencies are in megacycles.

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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 JULY 1947
Fig. 6. $F_2$ 4000-MUF, IN Mc, W ZONE, PREDICTED FOR JULY 1947
Fig. 7. $F_2$ ZERO—MUF, IN Mc, I ZONE, PREDICTED FOR JULY 1947
Fig. 8. $F_2$ 4000-MUF, IN Mc, 1 ZONE, PREDICTED FOR JULY 1947
Fig. 9. $F_2$ ZERO–MUF, IN Mc, E ZONE, PREDICTED FOR JULY 1947
Fig. 10. $F_2$ 4000-MUF, in Mc, E Zone, Predicted for July 1947
Fig. II. E-LAYER 2000-MUF, IN Mc, PREDICTED FOR JULY 1947
Fig. 12. MEDIAN $f_{E_s}$, IN Mc, PREDICTED FOR JULY 1947
FIG. 13 NOMOGRAM FOR TRANSFORMING $F_z$-ZERO-MUF AND $F_z$-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, LAYER AT OTHER TRANSMISSION DISTANCES.
Fig. 15. PERCENTAGE OF TIME OCCURRENCE FOR $E_s$ 2000-MUF IN EXCESS OF 15 Mc, PREDICTED FOR JULY 1947
Fig. 16. Sample Solution of Transmission Problem for Short Path, July 1947
Transmission Path: Washington, D.C. (39.0°N, 77.5°W) to Miami, Florida (25.7°N, 80.5°W)

--- MUF Including Es
----- OWF for Regular Layers Only
- - - - Suggested Frequency Usage

Fig. 17. Sample Solution of Transmission Problem for Long Path, July 1947
Transmission Path: Washington, D.C. (39.0°N, 77.5°W) to Trieste (45.7°N, 13.8°E)

--- MUF
----- OWF
----- Suggested Frequency Usage
**CRPL**

**MUF-OWF WORK SHEET FOR PATHS 4000 KM OR LESS**

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**Note:** All frequencies are in megacycles.

**Distance:** ________ km  **Zone:** ________  **Predicted for:** ________

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From: ________  To: ________

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Done by: ________  Checked: ________
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Note: All frequencies are in megacycles.

From ___________________ To ___________________ Distance, __________ km Predicted for _______ 194

CRPL

U.S. GOVERNMENT PRINTING OFFICE: 1947
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