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FEDERAL COMMUNICATIONS COMMISSION, ENGINEERING DEPARTMENT  
(September 28, 1944)*VHF Radio Field Strength Measurements 1943-1944*

The data from which this report was prepared were obtained under a project for the continuous recording of selected FM and Television stations in the frequency range from 42 to 84 mc. After some preliminary tests at a temporary site in Washington, D.C. in 1942, four recorders operating from a single half wave antenna were set up at the Commission's Monitoring Station at Laurel, Md., and recordings were begun on February 1, 1943. The four stations scheduled for recording were KYW-FM, Philadelphia; W2XMN, Alpine; WDRC-FM, Hartford and WGTR, Paxton. The stations lie in the same general direction from the recording site at distances of 104, 197, 267 and 337 miles, respectively. The stations were chosen so as to provide data on the magnitude of the effects of the lower atmosphere at various distances and times, which would furnish a measure of the reliability of the Commission's theoretical signal range charts. Clear channels were selected so that the signals could be identified by frequency without aural supervision.

In addition to the signals which travel via the lower atmosphere, commonly called tropospheric signals, an unexpected signal of entirely different type was observed, particularly on the more distant stations, which will be referred to herein as a "burst" signal. A third type of signal, which is reflected from patches of abnormally high ionization in the E layer and known as a sporadic E signal, was known to exist and to be capable of spanning long distances. However, insufficient data were available as to the times of occurrence and the field strengths to be expected at various distances for this frequency range. In order to obtain the maximum utility of the four recorders, it was planned to record any sporadic E signals encountered during monitoring rather than to record continuously on the frequency of a distant station. The fourth type of signal which is known to exist at these frequencies is propagated over long distances via the  $F_2$  region at certain times of day during the maximum of the sunspot cycle. No  $F_2$  signals are receivable at this time in the band above 42 mc.

During the summer and fall of 1943 additional equipment became available and 11 more recorders were installed at other monitoring stations as follows: 5 at Allegan, Mich; 3 at Grand Island, Neb; 2 at Atlanta, Ga; and 1 at Portland, Ore. The installation of recorders at

the additional locations was extremely desirable by reason of the need for information on atmospheric effects with other types of terrain and climate, and also because of the need for comprehensive information on the frequency of occurrence and the field strengths to be expected over long distances for signals arriving via "bursts" and sporadic E layer paths. Continuous recording at four locations has made it possible in a relatively short time to obtain what is believed to be a reliable measure of the relative magnitudes of burst signals at various distances and times and an estimate for the period of recording of the amount of interference via sporadic E from a plurality of co-channel stations.

The three types of signals dealt with in this report, tropospheric, bursts and sporadic E, are due to different causes and have different modes of variation with regard to time, distance and frequency, and for this reason the results are treated in separate sections.

#### TROPOSPHERIC SIGNALS

Attention is called to Figure 1 (A) in which is reproduced a typical record of a tropospheric signal. Both slow and rapid fading are evident, with the signal varying in intensity over a range from less than 1 uv/m to above 20 uv/m as indicated by the meter calibration marked at the left end of the chart. This chart also shows the trend toward higher signal strengths in the late afternoon and early evening hours, which is characteristic of the measurements which were made over land paths.

*Analysis.* The method of analysis of tropospheric charts is to determine for each hour the level which is exceeded by the signal for 30 minutes of the hour. This level is called the 50% hourly value. The line indicating the 50% hourly value for the hour 5 to 6 P.M. can be seen on the chart as a level of 4 uv/m. The 50% hourly values are tabulated on a monthly summary sheet from which the monthly median value (the middle value in order of size) for any desired hour can be extracted.

*Variations of monthly median values.* Figure 2 is a set of graphs of the diurnal variations of the monthly median values of KYW-FM recorded at Laurel, a distance of 104 miles, for the months February through September 1943. The values have been corrected for power and antenna height so as to convert them to equivalent values for a radiated power of one kilowatt and for half-wave transmitting and receiving antennas 500 feet and 30 feet high, respectively. In converting the value to a theoretical height of 500 feet, the height-gain functions for ground wave propagation were used, on the assumption that low-level propagation would prevail on the average. The effect of assuming the signals to be reflected from a layer with an average height of 1.5 kilometers (0.93 miles) will be shown in connection with the later discussion of Table 1.

The diurnal trend toward higher field strengths in the evening is apparent for all months except February, and is more marked for the warmer months. The warmer months also have generally higher sig-

nal levels. The median value for July (5.9) is over three times as high as the median value for April (1.77).

The higher field strengths recorded during the warmer months and the characteristic upward diurnal trend had been anticipated by reason of prior correlation between weather and VHF propagation conditions over land made by Ross Hull.<sup>1</sup> However, insufficient data were available from which to make a quantitative determination of tropospheric effects at various distances and frequencies, which is the purpose of the present investigation.

The graphs for July, August and September show greater irregularities than do the remaining months and this is probably due to a smaller amount of available data. Station KYW-FM and the four other FM stations in Philadelphia began a shared time schedule on July 4, 1943, so that each point on the graphs for July, August and September represents the median value of five or six hours of recording as against about thirty hours for each point on the other five graphs. There are no data for the months of October, November and December 1943 and for January 1944, as it became necessary to divert the recorder for more urgent tests in connection with burst signals.

Figure 3 is a similar set of graphs for station W2XMN recorded at Laurel, (197 miles) for the twelve month period from February 1943 through January 1944. All graphs except May show the upward diurnal trend. Again July has the highest median value (0.37) and the lowest median value is April (0.089), the ratio being above four to one.

Figure 4 is a corresponding set of graphs for station WMFM recorded at Allegan over the period October 1943 through August 1944. The path is 122 miles in length, most of which is across Lake Michigan. The time scale is Central Standard Time since this is approximately local sun time for the path concerned. The absence of the diurnal effect, which is in agreement with such data as were previously available for paths over water, is immediately apparent, and the graphs are more irregular in general than for the path over land. The ratio of the highest monthly median value, June (2.3), to the lowest April (0.64) is almost four to one.

Recordings of tropospheric signals were also made on FM station WGTR, Paxton and television stations WPTZ, Philadelphia and WBKB, Chicago. However, insufficient data were obtained to permit any determination of the variations of monthly median values. Summaries of the data are included in Table I, which will be referred to in detail at a later point in the report.

*Comparisons with theory.* Figure 5 is a reproduction of Figure 1 of a report by K. A. Norton entitled "A Theory of Tropospheric Wave Propagation", (F.C.C. Mimeo. 40003). It contains a theoretical 50 mc ground wave curve for average land together with three theoretical curves of tropospheric field intensities for a 1.5 kilometer layer height and dielectric discontinuities of  $10^{-4}$ ,  $10^{-5}$  and  $10^{-6}$ , which latter were assumed to be the average ranges encountered in practice. Plotted in relation to the curves are the maximum 50% hourly values and

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<sup>1</sup>The 10%, 50% and 90% values were taken from the graphs of monthly median values shown in Figures 2, 3 and 4.

the values exceeded for 10%<sup>1</sup>, 50%<sup>1</sup> and 90%<sup>1</sup> of the time for distances of 104, 122 and 197 miles. For the 337 mile distance (WGTR) the 50% and 90% values were below the noise level, so that only the maximum and 10% values were obtainable.

It will be observed that all of the values for the 104 and 122 mile distances and that all but the maximum value at 197 miles lie within the predicted range of the theoretical curves. The values for 122 miles are not strictly comparable to the remaining values and to the theoretical curves since they are for a propagation path partly across Lake Michigan, for which both the dielectric constant and conductivity are different than for average land. They have been plotted on the same sheet, however, in order to determine whether different standards of allocation should apply for stations in the Great Lakes region. From their conformity to the average land values, it appears likely that one set of standards can be made to apply.

Figure 6 consists of the same experimental values plotted in relation to the theoretical ground wave curve and tropospheric curves for a  $10^{-3}$  discontinuity at heights of 1, 1.5 and 3 kilometers (Figure 2 of F.C.C. Mimeo. 40003). The measured values at the nearer distances do not fit the theoretical curves nearly so well as they do for Figure 5, whereas at 337 miles the measured and theoretical values are in closer agreement. This indicates that the high signal levels at the nearer distances are primarily due to large discontinuities whereas at long distances high layer heights have a greater effect.

Certain inferences may be drawn from a comparison of various ratios between measured and theoretical values as obtained from the two preceding Figures. For convenience these values and ratios have been tabulated as Table I, together with values for certain television stations. Paths 1, 2, 3 and 4 are for FM stations KYW-FM, WMFM, W2XMN and WGTR, respectively. Path 5 is for television station WPTZ, Philadelphia, recorded at Laurel, and path 6 is for television station WBKB, Chicago, recorded at Allegan. The numbers of hours of recording for the television stations, 181 and 31 hours, are very small in comparison with the hours of recording for any of the FM stations. This fact and the shorter and more intermittent periods of operation prevented the preparation of diurnal graphs for the television stations similar to those for the nearer FM stations. The 10%, 50% and 90% values shown for paths 1 to 4 under the heading "Field strength corrected for low layer height", are the same as those plotted in Figures 5 and 6, and are taken from the monthly median values used in the preparation of Figures 2, 3 and 4. The ground wave values (G.W.) are taken from the theoretical ground wave curves of Figures 5 and 6 at the specified distances. The values for the television stations, paths 5 and 6, are derived directly from tabulations of all data rather than from monthly median values. The values for path 6 have not been corrected to the standard conditions of 1 kw radiated from a 500 foot transmitting antenna, since the recording site is approximately in the direction of the null of the cardioid trans-

<sup>1</sup>The 10%, 50% and 90% values were taken from the graphs of monthly median values shown in Figures 2, 3 and 4.

mitting antenna pattern and no satisfactory figure could be arrived at for the actual power output in that direction. For this reason no ratios of recorded signal to ground wave signal levels are given for this path.

TABLE. I — Measured field strengths, UV/M

[Based on 1 kw radiated from 500 ft. half wave doublet]

Path	1	2	3	4	5	6
Dist. (mi.).....	104	122	197	337	108	103
Freq. (mc.).....	45.7	45.5	42.8	44.3	71.75	65.75
No. Hours.....	993	3,140	2,268	6,884	181	31
<i>Field strengths corrected for low layer height</i>						
Max. Field.....	25.0	16.3	1.66	0.27	>34.0	5.1
10% Field.....	6.4	2.02	.32	.0116	15.4	3.6
50% Field.....	3.7	1.01	.145	-----	3.9	1.3
90% Field.....	1.86	.65	.092	-----	1.54	.2
G.W. Field.....	.77	.23	.0015	-----	.48	-----
Ratios:						
10%/90%.....	3.4	3.1	3.5	-----	10	18
10%/G.W.....	8.3	8.8	214	-----	32	-----
Ratios:						
D <sub>max</sub> /D <sub>gw</sub> .....	1.9	1.7	2.1	2.8	>2.0	-----
D <sub>10%</sub> /D <sub>gw</sub> .....	1.4	1.4	1.7	2.1	1.7	-----
<i>Field strengths corrected for layer height—1.5 kilometers</i>						
Max. Field.....	17.7	25.1	2.1	0.27	>16.8	5.1
10% Field.....	4.5	3.1	.41	.0116	7.6	3.6
50% Field.....	2.6	1.55	.185	-----	1.93	1.3
90% Field.....	1.31	1.00	.118	-----	.76	.2
G.W. Field.....	.77	.23	.0015	-----	.48	-----
Ratios:						
10%/90%.....	3.4	3.1	3.5	-----	10	18
10%/G.W.....	5.9	13.5	273	-----	16	-----
Ratios:						
D <sub>max</sub> /D <sub>gw</sub> .....	1.5	2.3	2.2	2.8	>1.8	-----
*D <sub>10%</sub> /D <sub>gw</sub> .....	1.3	1.5	1.7	2.1	1.5	-----

\*The field strengths for this path are not corrected for radiated power and antenna height. G.W.—Theoretical ground wave field strength.

$$D( )/D_{gw} = \frac{\text{Actual Distance}}{\text{Theoretical distance to give measured field}}$$

For the purposes of making quantitative comparisons of the field strengths measured at different distances and frequencies certain conventional ratios have been determined. The ratio of the field exceeded for 10% of the time to that exceeded for 90% of the time is a measure of the variability or fading of the signal. Fading over land (3.4) and over the Great Lakes (3.1) are of the same order at 45 mc. This is somewhat inconsistent with the ratio of fading at 65 to 70 mc which is nearly twice as great for the Lakes path. However, this inconsistency may be due to the uncertainties arising from the limited amount of data for 65.75 and 71.75 mc.

The ratios of the tropospheric field to the theoretical ground wave field are greater at longer distances so that tropospheric effects will increase the ranges of the interfering fields to a greater extent than the service fields. In fact, the present data indicate that it will not be possible to increase service fields above the theoretical value for dis-

tances under 120 miles. With reference to interfering fields, although it is not here suggested that the 10% field be adopted as standard, it has been used herein to show a ratio (10%/G.W.) between reasonable values of measured interfering field and the theoretical ground wave values obtained from the Commission's signal range curves. For a distance of 104 miles to the 5 uv/m theoretical contour of a FM station, the 10% interfering field would be 8.3 times as great, or 41.5 uv/m.

A somewhat different measure of the tropospheric effect, and one which is more directly applicable to the theoretical distance range curves, is expressed in the ratios of actual to theoretical distance for distances between 100 and 200 miles to the 5 uv/m contour the ratios are between 1.7 and 2.1 for complete protection and between 1.4 and 1.7 for protection 90% of the time. If a distance of 70 miles to the 5 uv/m contour is found from the theoretical signal range curves in a hypothetical case, 100% protection would require an increase to 150 miles and 90% an increase to 120 miles.

Similar ratios have been derived for an assumed tropospheric layer height of 1.5 kilometers and are shown in the lower half of the Table. While they differ somewhat from the values obtained when low level propagation is assumed, the differences do not appear to be significant.

#### BURSTS

A sample recording of typical burst signals is shown in Figure 1(B), a record of FM station WGTR recorded at Laurel on November 11, 1943. The usual burst consists of a sharp rise in signal strength over a period of a few tenths of a second duration. A burst of this type with a peak value of 40 uv/m is shown at I, near the calibration scale. Infrequently, a burst which may be sustained for several seconds or more, such as shown at S, is recorded. The significance of the differences in amplitude and duration of the bursts will be discussed at a later point.

When the bursts were first identified as being something other than peaks of rapidly fading tropospheric waves, several possible causes were advanced by those who had observed them, such as reflection from aircraft, from undulating tropospheric discontinuities or from patches of ionization. A further extension of the latter theory was to the effect that the patches of ionization were caused by the passage of meteorites through the upper atmosphere. The ionization effects of meteors in connection with radio propagation at lower frequencies had been investigated by A. M. Skellett<sup>4</sup> and J. A. Pierce<sup>5</sup>, and the occurrence at 10 mc of bursts of somewhat longer duration than those at 40-50 mc had been attributed to meteoric ionization by Pierce. Short distance scatter effects at 10 mc, which consisted of bursts of from one half to one second duration, had also been investigated by T. T. Eckersley<sup>6</sup> and attributed to patchy E-layer ionization.

Footnotes (references) 4, 5, 6 see p. 182.

Upon the installation of recorders at Allegan, Atlanta and Grand Island, signal bursts from WGTR were found to be received at all points, the numbers of bursts and intensities of the highest bursts decreasing with distance. Since the distance from WGTR to Grand Island, 1370 miles, is about the limit of distance for single reflections from the E-layer, theories of comparatively low level reflections such as aircraft and tropospheric were abandoned in favor of the ionic theory.

*Burst path length measurements.* In order to determine the propagation path lengths of the burst pulses, a series of pulse tests was made in conjunction with station W2XMN, in October 1943. This station, rather than WGTR, was selected because a steady signal was needed for reference pulses, between which the burst pulses would appear if there was any difference in path length. Our records show burst pulses from W2XMN on some days of poor low-level propagation, so that it was expected that the pulse tests would show bursts as well as reference pulses.

A unique method of pulsing was used which will be explained in conjunction with Figure 7. It consisted in frequency modulating the transmitter  $\pm 75$  kc by a continuous tone of 170 cycles per second. The FM signal was received on a Hallicrafters S-27 receiver, the IF of which was passed to a Super-Pro tuned to a narrow pass band at the lower end of the swing. This produced narrow pulses of tone frequency in the IF output of the Super-Pro which were placed on the vertical plates of an oscilloscope, indicated diagrammatically by the dashed circle. The horizontal sweep was set at one-half tone frequency so that two reference pulses appeared simultaneously on the screen. Any difference in path length  $D$  will cause the burst signal to be delayed by an interval  $D/c$ , where  $c$  is the velocity of propagation, so that the frequency deviations of the delayed burst will occur between those of the ground wave signal. In the Figure, the deviations of the burst signal are shown as a dashed curve lying between the cycles of the solid wave of the ground wave signal, the burst pulse on the oscilloscope screen appearing at a distance  $D$  to the right of the zero reference pulse.

During the tests the path differences ranged from about 150 to 900 miles, corresponding to total path lengths of from 350 to 1100 miles. The estimation of the shorter distances was made somewhat difficult by the pulse width, which tended to merge the delayed pulse with the reference pulse, but the values obtained indicate that the medium responsible for the shorter paths was separated from the sea level great circle path by a distance comparable to the height of the E layer. The greater distance can be interpreted as reflections from higher media or from media of height comparable to the E layer but lying to each side of the great circle plane. In the light of subsequent information, the latter interpretation is felt to be correct. The amplitudes of the burst pulses varied also, but insufficient periods of observation could be made to determine whether a correlation exists between amplitude and distance.

The maximum path difference which can be measured at a pulse frequency of 170 per second is about 1100 miles, as greater distances will cause the pulse to be delayed more than one cycle and to give a false indication of a shorter distance. Lower modulating frequencies were tried during the tests so as to be certain that path differences greater than 1100 miles were not involved. A special test was also devised to eliminate false indications of delay due to frequency shifts, such as the Doppler effect, which were not the result of path length differences. The tests indicated that no appreciable errors were being introduced from this source. A third possible source of error has been suggested as arising from the generation of spurious frequency components by the beating of the direct and reflected waves within the receiver circuits. No equipment has been available for making a test by which to evaluate this effect.

*Diurnal and annual variations of burst numbers.* The numbers of bursts per hour exceeding 5 microvolts recorder input (3.3 uv/m) received at Laurel from station WGTR have been tabulated for the period from February 1943 through May 1944. The results of a full year's data are shown in Figures 8 and 9.

Figure 8 is a graph showing the variation with time of day of the average of 12 monthly median values of the numbers of bursts per hour (February 1943 through January 1944). The maximum (36.5) occurs between 8 and 9 A.M. and the minimum (9.8) between 4 and 6 P.M. Plotted on the same sheet are, the average observed numbers of meteors per hour during night hours as reported by various workers in the field. The two smooth curves (e) and (f) are theoretical distribution curves for 40° North Latitude computed for meteors with parabolic orbits (e) and with the hyperbolic orbits (f). The agreement in the range of variation is excellent, the range in the numbers of the bursts (3.7) being between the hyperbolic distribution (2.8) and the parabolic (8.0). The time of the observed maximum and minimum do not coincide exactly with the theoretical, but the shift of the minimum to an earlier hour is consistent with the better radio propagation conditions which are found to prevail in the late afternoon and early evening hours, which will tend to increase the numbers of bursts exceeding a fixed reference level.

Figure 9 shows the annual variation of the monthly median numbers of bursts occurring during four selected hours. The period covered is from June 1943 through May 1944, over which period station WGTR was operating with the same power output and antenna pattern, day to day changes in which would have erroneous results. On the same sheet are shown six estimates of observed annual variation of meteors. The agreement is not so good as that of the diurnal variation. However, considerable differences are to be noted between the estimates of meteor numbers themselves. Whereas five estimates show the peak to occur during August, the estimate of Hoffmeister shows a dip in August and a peak in July, which agrees with the burst distribution. It should also be kept in mind that the estimates are long term, with considerable variation from year to year, whereas the burst numbers are for a single year.

*Short-time amplitude distribution* of the bursts is shown in Figure 10. The numbers are accumulated data from WGTR for six morning hours recorded simultaneously at Laurel and Allegan. Knowing the numbers of bursts which exceed any given level in a given hour, the curves permit a reasonably accurate estimate of the numbers from that station exceeding any desired level by means of a simple proportionality between the abscissa readings for the two levels in question. With a rate of 120 bursts per hour exceeding 5 uv/m at Laurel a burst reaching 30 uv/m will be expected once every 45 minutes. The maximum amplitudes at Laurel are greater than those at Allegan, whereas the average level at Allegan is greater. This is in qualitative agreement with the theoretical distribution for reflecting media of uniform height and with random distribution over an area lying within 700 miles radius of both transmitter and receiver, assuming attenuation with distance in accordance with the maximum measured values at 337, 720, 900 and 1370 miles, and assuming a circular transmitting antenna pattern and a figure eight receiving antenna pattern.

*Amplitude variation with distance.* The maximum measured values at each of the recording sites over the period of recording, which can be assumed to lie close to the plane of the great circle, and the corresponding inverse distance values and ratios are as follows:

	Laurel	Allegan	Atlanta	Grand Island
Distance.....	337	720	900	1370
Inverse (uv/m).....	15,100	7060	5650	3700
Max. (uv/m).....	55	45	34	13
Ratio.....	274	157	166	285

The signals are well below inverse distance. At the longer distances, cancellation of the direct and ground reflected wave will account for a large part of the difference. However, the ratios would not normally be as large as those indicated. Absorption at E-layer and below at these frequencies will be practically negligible. It therefore appears that some other effect is being obtained. If we assume reflection from a cylindrical track of ions caused by the passage of a meteor, it appears reasonable to assume that an additional divergence factor will result from reflection from the curved surface.

*Visual correlations of bursts and meteors.* During June 1944, after the agreement between the occurrence of meteors and bursts had been established, a few observations were made at Laurel in an attempt to obtain coincidences between bursts and visible meteors. Several meteors were seen, but none having a proper direction of flight, so that the ionized track was capable of reflecting the signal to the receiving point. Beginning on August 1, a continuous watch was kept between 9 and 10:15 P.M., E.S.T. on favorable nights by two or more observers at the home of one of the engineers. Two coincidences were observed on August 6, in which the meteor track was approximately transverse to the signal path. On August 8 and 11, two coincidences were observed each night in which the meteor track was along the plane of the signal path. The last meteor was of par-

ticular brilliance with a persistent visible train, and the signal was sustained for about ten seconds. The meteor was somewhat beyond the receiving point with sufficient inclination of the track to reflect the signal back at an acute angle. Had a meteor of this size with the proper orientation been near the center of the signal path, the duration would have been several times as great, and the sustained burst might easily have been recorded as similar to the burst marked S on Figure I (B). Sustained bursts of this type appear frequently on the records near the times of the regular showers of visible meteors. The date of the recording is November 11, the time of the annual Leonid meteor shower.

Bursts have also been recorded at Laurel on 71.75 mc from television station WRGB. They are less frequent than at 44.3 mc, of somewhat less duration on the average, and their maximum amplitudes are about the same for a given radiated power.

*Interference factor of bursts.* Tests conducted at Laurel, using bursts from station WTGR as the interfering signal and a frequency modulated signal generator as the desired signal, indicate that a 1 to 1 ratio of desired to undesired signal is sufficient to prevent objectionable interference in the output of the S-27 type FM receiver. No tests have been made for sustained bursts, for other types of FM receivers or for ratios applicable to AM receivers.

#### SPORADIC E SIGNALS

Figure 1 (C) is a sample recording of station WTGR made at Atlanta on July 8, 1944. The recorder sensitivity was set for the recording of burst signals and was not optimum for sporadic E of this intensity, which was driving the recorder above 400 uv/m a part of the time.

The analysis of these records consists in determining the times during which the signal exceeds 25 uv/m in intensity. This corresponds to the level at which the signal will begin to cause interference to an FM receiver having a 2/1 co-channel rejection ratio and located on the 50 uv/m contour of a station on the same frequency. In totalling the times of occurrence of the signal, short intervals of time of a minute or more during which the signal falls below the 25 uv/m level are omitted. These are indicated on the chart by a heavy line at the 25 uv/m level.

Table II shows the monthly and annual occurrence of fields above 25 uv/m for each of the four recording sites, together with combined figures for the four paths. The times of occurrence are expressed in minutes and the percentages are per cent of the time during which both the transmitter and recorder were in operation. The combined figures are not numerical totals of the four preceding columns but are the total numbers of minutes for the respective months or for the year during which the signal occurred on at least one of the individual paths. An inspection of the Table shows good agreement as to the relative occurrence on the four paths for the respective months, the 900 mile path to Atlanta having the largest values for each

month. The worst month is July, with occurrences of 12.0% of the time for the Atlanta path and 14.3% for the combined figures.

Since a sporadic E path which will permit a signal to be propagated from Paxton to a recording site will also permit a similar signal to travel back to Paxton from a hypothetical transmitter located at the recording site, the combined figures furnish a reliable measure of the amount of interference which would be sustained by a receiver located on the 50 uv/m contour at Paxton from four identical co-channel transmitters located one at each of the present recording sites.

Figures 11 to 15 are charts showing for each of the four paths and for the combined figures the actual times of occurrence above 25 uv/m throughout the year. One space horizontally is allotted to each day of the indicated month and one space vertically is allotted to each twelve minutes of the day.

Figure 11 is for the Paxton-Laurel path. Except for July 7 and 8 the interference is not severe. Particular attention is called to the intermittent type of signal shown on July 5 and 25, where on the latter date interference totalling 8 minutes was spread over a half hour period and could have caused a possible interruption of two separate programs. Similar periods of intermittent interference are prevalent for all paths and their significance should be kept in mind when evaluating the totals shown in Table II.

For all five Figures the times of occurrence are more prevalent in the P.M., so that the percentage occurrence will be greater for this period than the overall percentage.

In order to obtain a measure of the effect of increasing the level at which the analysis was made upon the occurrences, the records for each of the recording sites were also analyzed at 70 uv/m. The records for Grand Island, where the range of the recorder was such as to respond to higher signal levels, were also analyzed for occurrences at 250 uv/m.

TABLE II.—Sporadic E layer propagation, 1943-1944

[Occurrence of fields exceeding 25 microvolts/meter at four receiving sites from station WGTR, Paxton, Mass., 44.3 mc-63 kw]

Receiving Site.... Distance.....	Laurel		Allegan		Atlanta		Grand Is.		Combined	
	337 miles		720 miles		900 miles		1400 miles			
	min.	%	min.	%	min.	%	min.	%	min.	%
Sept. 1943.....	0	.....	1	0.003	1	0.003	0	.....	1	0.003
Oct.....	0	.....	0	.....	16	.05	2	0.006	18	.05
Nov.....	0	.....	0	.....	0	.....	0	.....	0	.....
Dec.....	0	.....	58	.22	166	.46	0	.....	222	.62
Jan. 1944.....	0	.....	0	.....	8	.02	0	.....	8	.02
Feb.....	0	.....	1	.003	20	.06	0	.....	21	.06
Mar.....	0	.....	0	.....	0	.....	0	.....	0	.....
Apr.....	0	.....	2	.006	.79	.23	0	.....	81	.24
May.....	0	.....	50	.17	1069	3.0	1169	1.24	1248	3.5
June.....	30	0.09	528	1.7	1865	5.9	796	2.5	2997	9.3
July.....	177	.63	790	2.9	3380	12.0	1125	4.0	4629	14.3
Aug.....	11	.04	25	.09	270	1.0	5	.02	331	1.2
Totals.....	218	0.05	1455	0.39	6874	1.71	2097	0.55	8956	2.23

<sup>1</sup> Antenna lead found broken and repaired May 19, 1944. This value is probably low as both Allegan and Atlanta show Es fields during May 1 to May 19.

The following Table gives a comparison of the annual totals for the three levels:

Field Strength	Laurel		Allegan		Atlanta		Grand Island	
	Min.	%	Min.	%	Min.	%	Min.	%
25 (uv/m).....	218	0.05	1455	0.39	6874	1.71	2097	0.55
70 (uv/m).....	22	0.005	1193	0.32	3820	0.95	964	0.25
250 (uv/m).....			263	0.07	422	0.11		

Insufficient recorders were available for continuous recording on the frequencies of television stations, so that data for these frequencies are not available.

#### REFERENCES

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3. Smith-Rose and Stickland, Jr. Inst. E.E., Part III, March 1943.
4. A. M. Skellett, Proc. I.R.E., Dec. 1932.
5. J. A. Pierce, Proc. I.R.E., July 1938.
6. T. L. Eckersley, Jr. Inst. E.E., Wireless Section, June 1940.

Disregard the following apparent occurrences of sporadic E:

Figure	Date	Time
11.....	June 18-21.....	8:00-9:00 A.M.
11.....	Aug. 8-9.....	9:00-9:24 A.M.
12.....	Apr. 17.....	5:10-5:12 A.M.
13.....	Dec. 24.....	9:06-9:07 A.M.
13.....	" ".....	9:55-10:00 A.M.
13.....	" ".....	2:31-2:32 P.M.
14.....	Feb. 1.....	6:18-6:20 A.M.
14.....	Apr. 4.....	11:55-12:00 P.M.
14.....	Aug. 2.....	3:45-3:48 A.M.
14.....	Aug. 8.....	2:37-2:38 A.M.
14.....	Aug. 17-18.....	2:00-2:12 P.M.
15.....	Jan. 5-6.....	4:00-4:12 A.M.
15.....	Sept. 4.....	2:22-2:24 A.M.
15.....	Nov. 29-30.....	10:45-10:56 P.M.

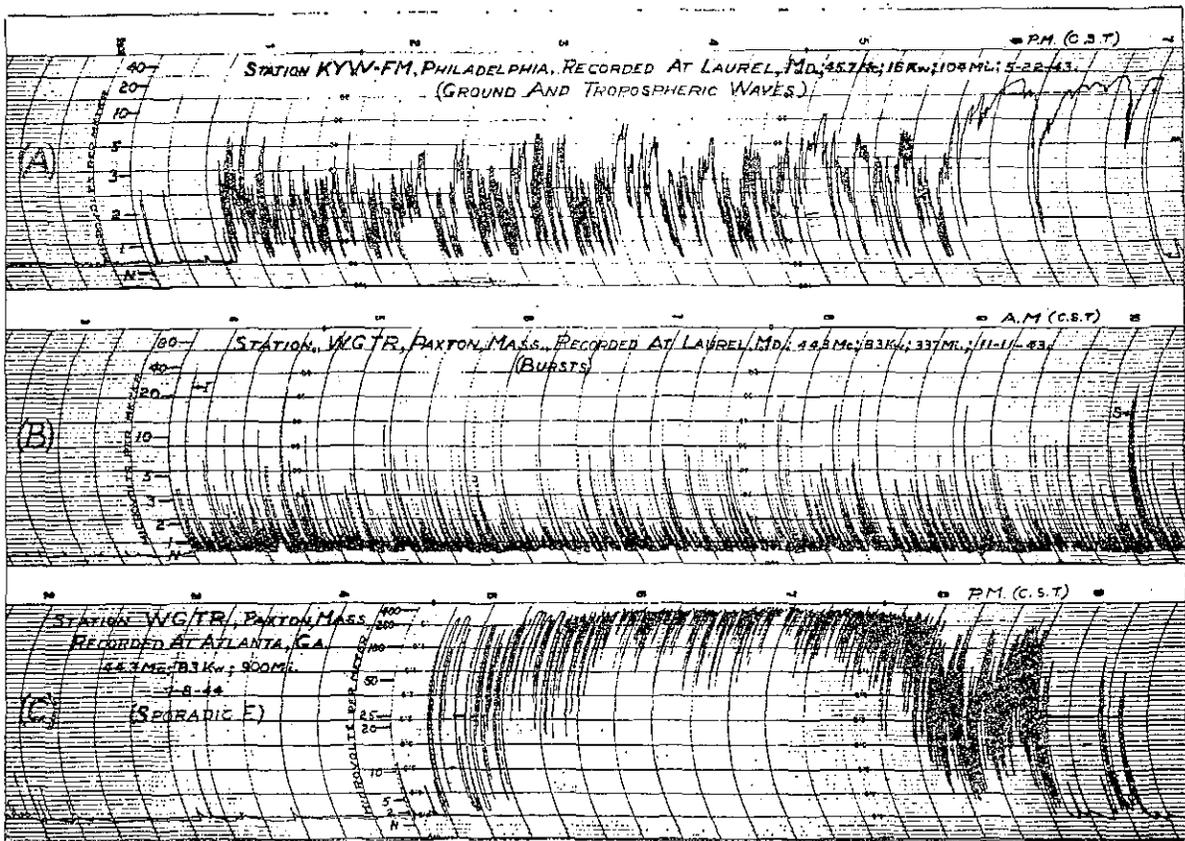
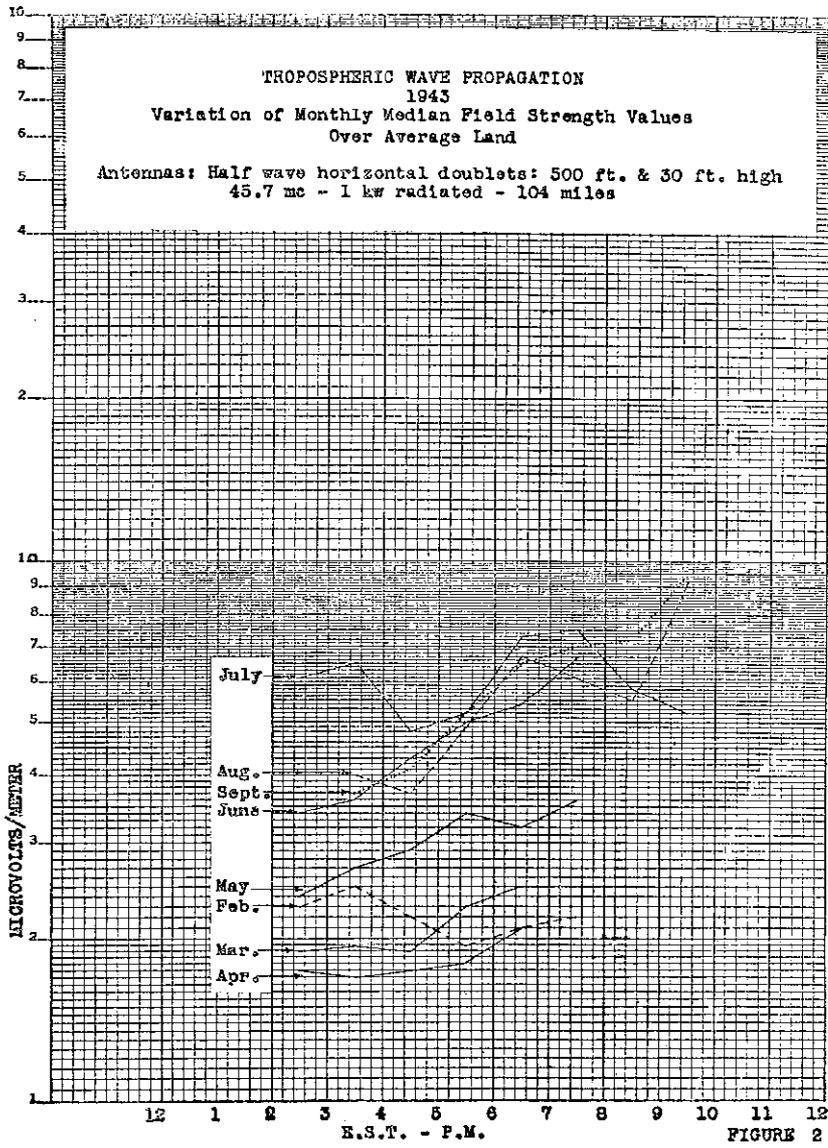


FIGURE 1

39 F.C.C.



39 F.C.C.

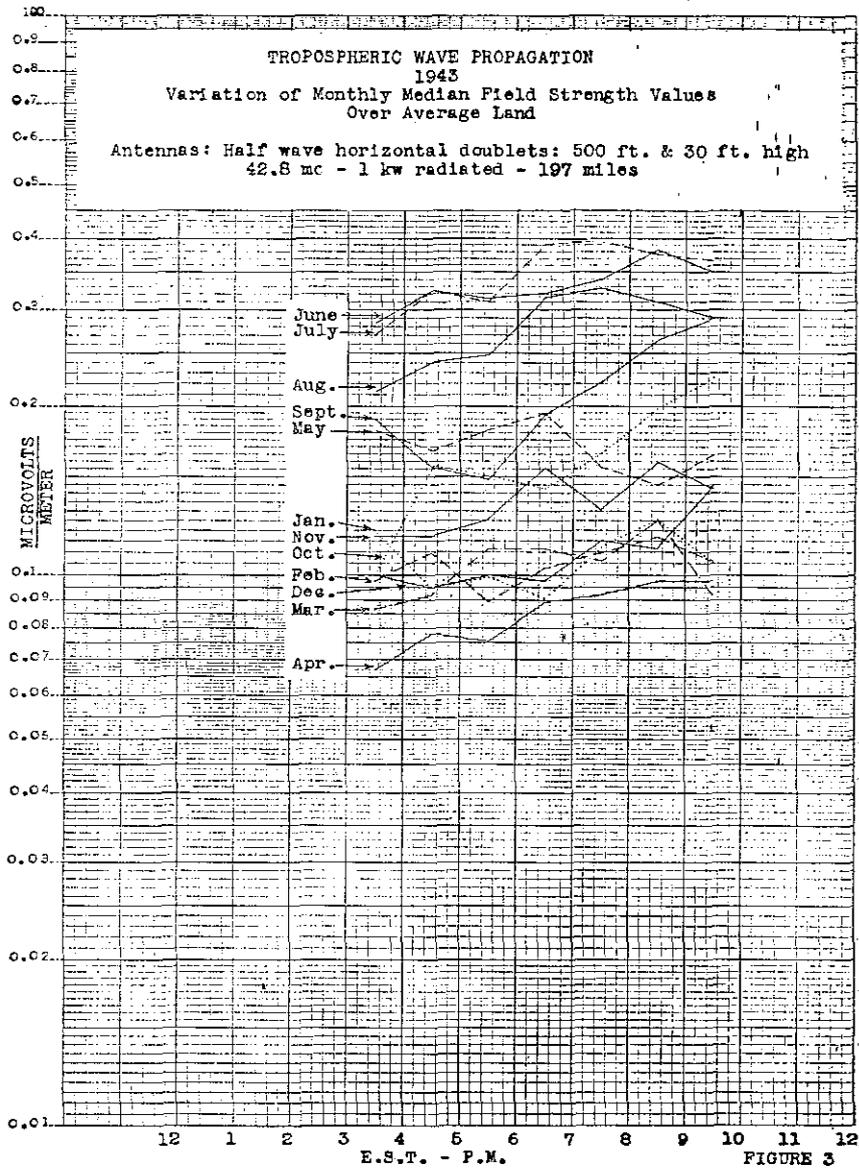
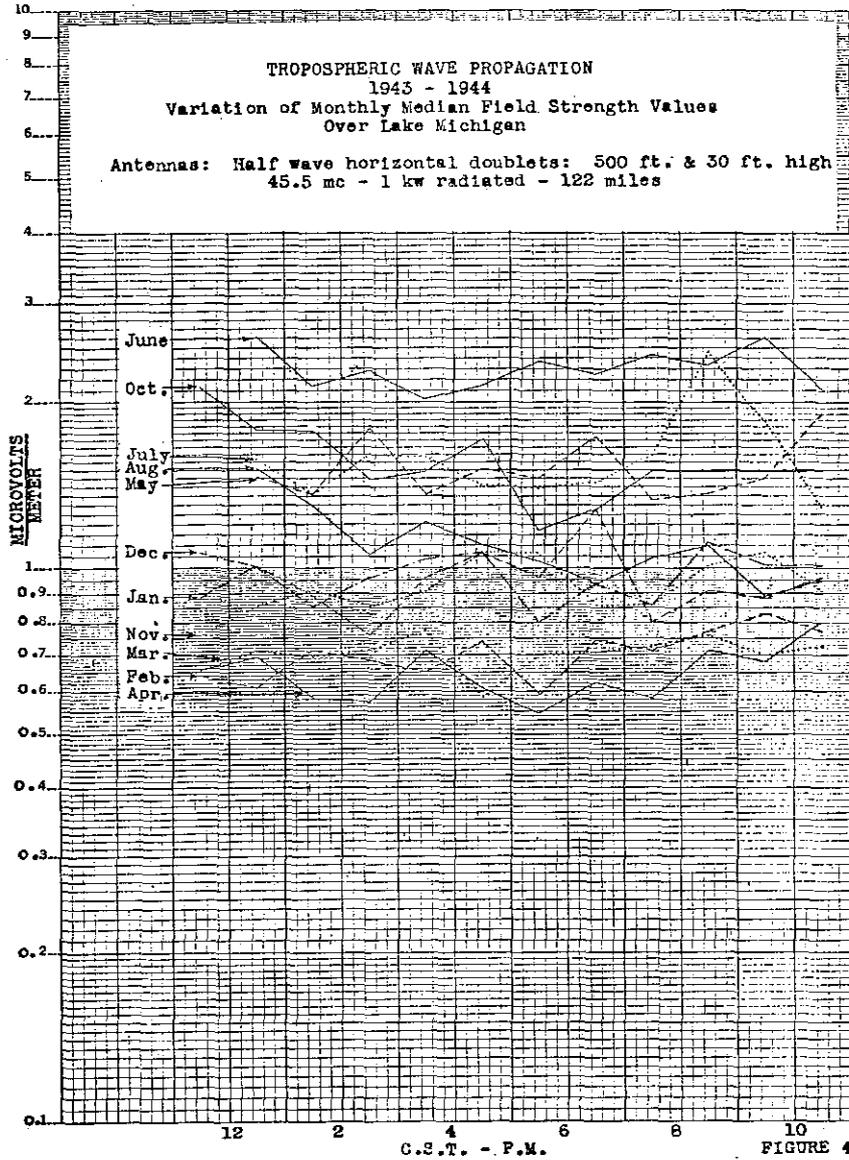


FIGURE 3

39 F.C.C.



39 F.C.C.

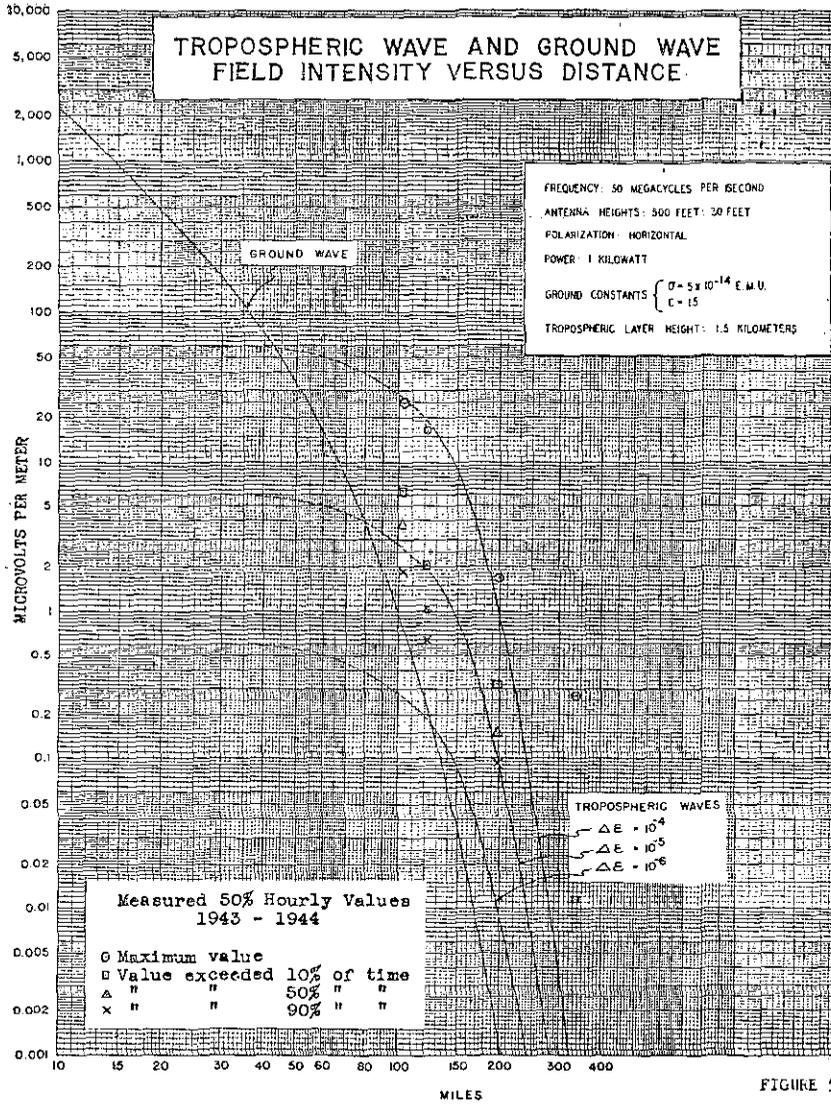


FIGURE 5

39 F.C.C.

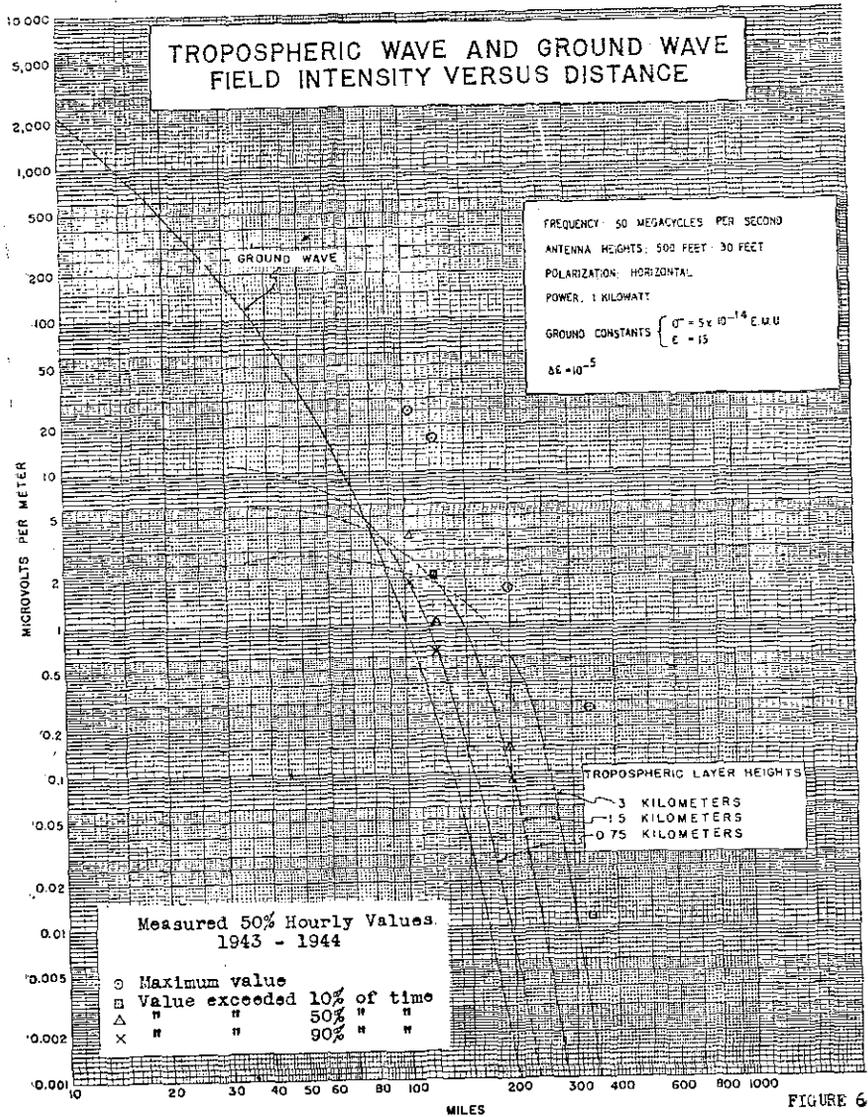


FIGURE 6

### METHOD OF MEASURING PATH LENGTHS OF VHF BURSTS

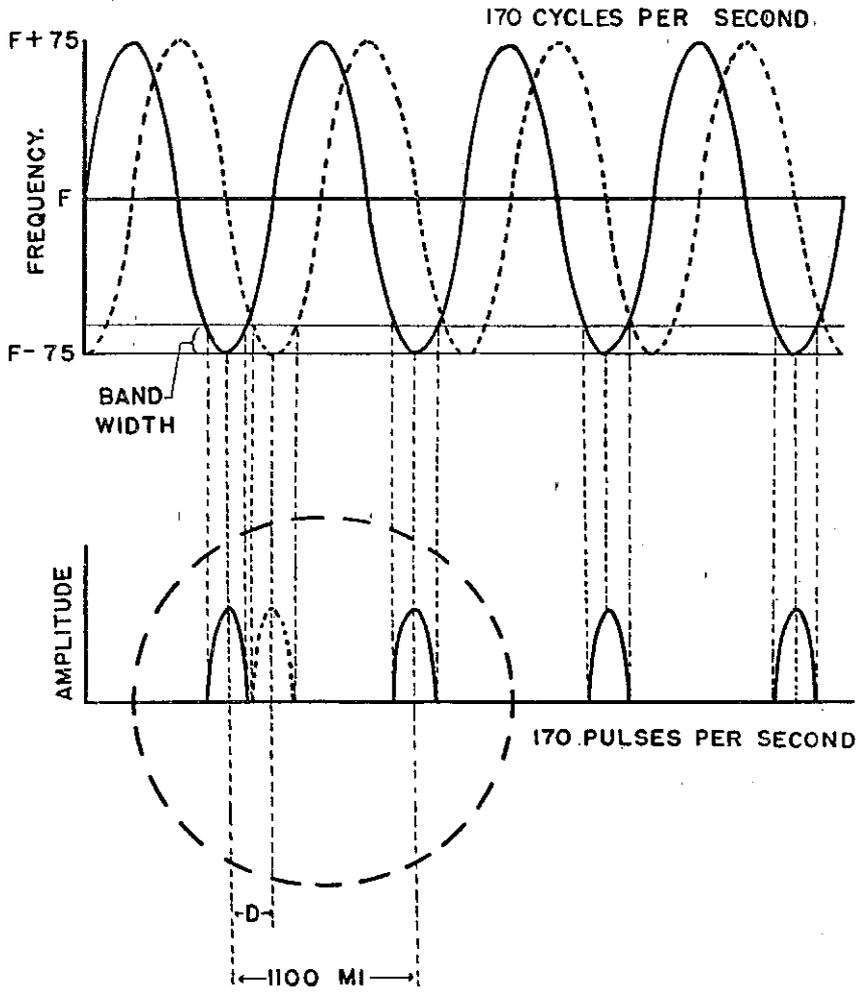
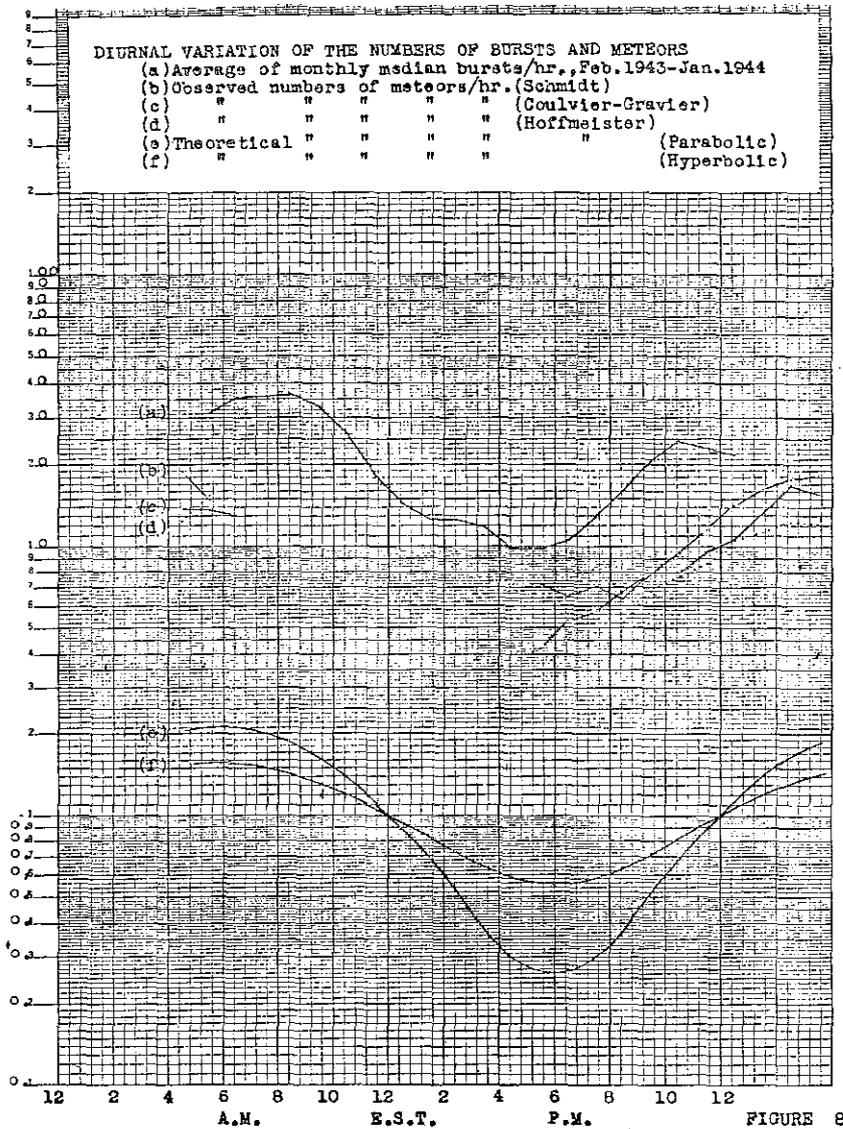
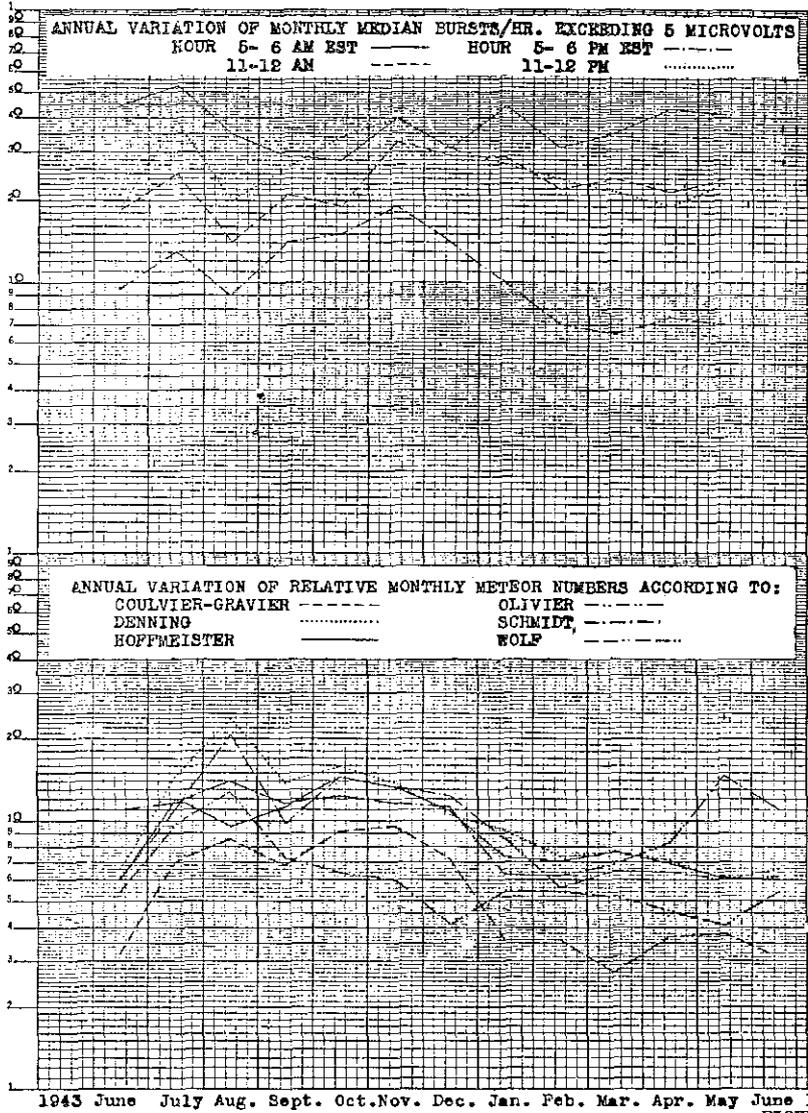


FIGURE 7



39 F.C.C.



1943 June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June 1944  
FIGURE 9

39 F.C.C.

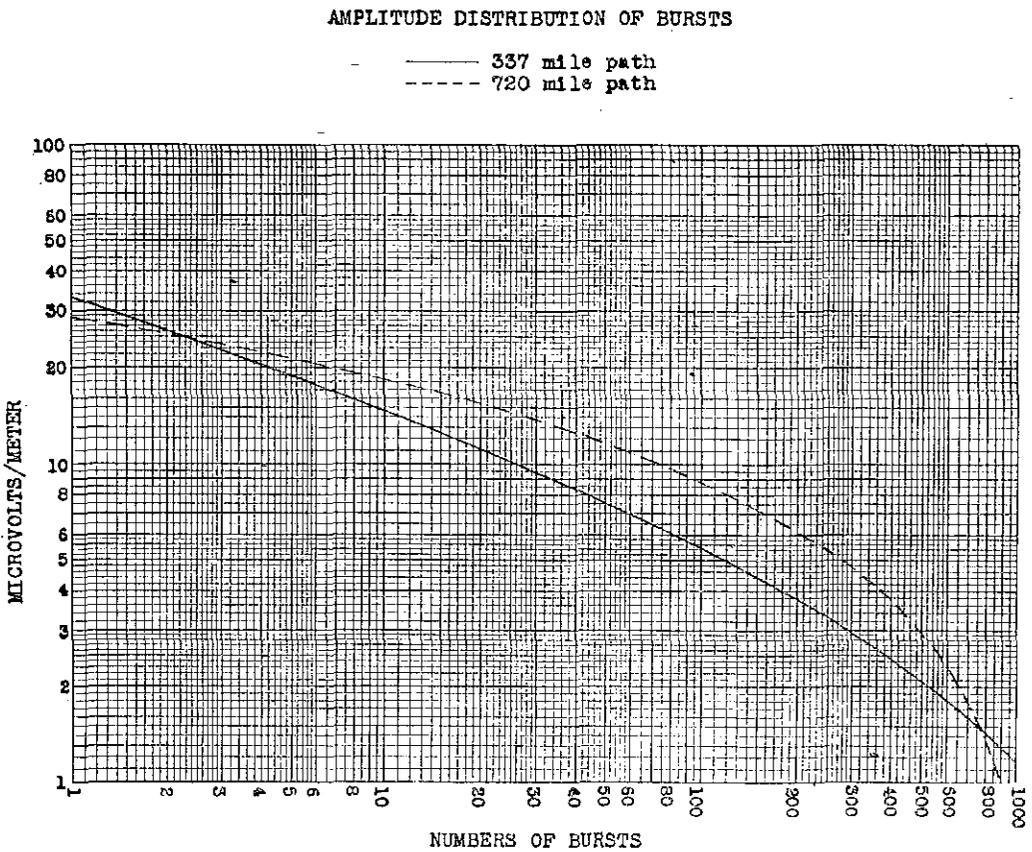


FIGURE 10

39 F.C.C.

SPORADIC E LAYER PROPAGATION  
 1943 - 1944  
 Occurrence of fields exceeding 25 microvolts/meter at  
 Laurel, Maryland from station W3TR, Paxton, Mass.  
 44.3 mc - 337 miles - 83 kw

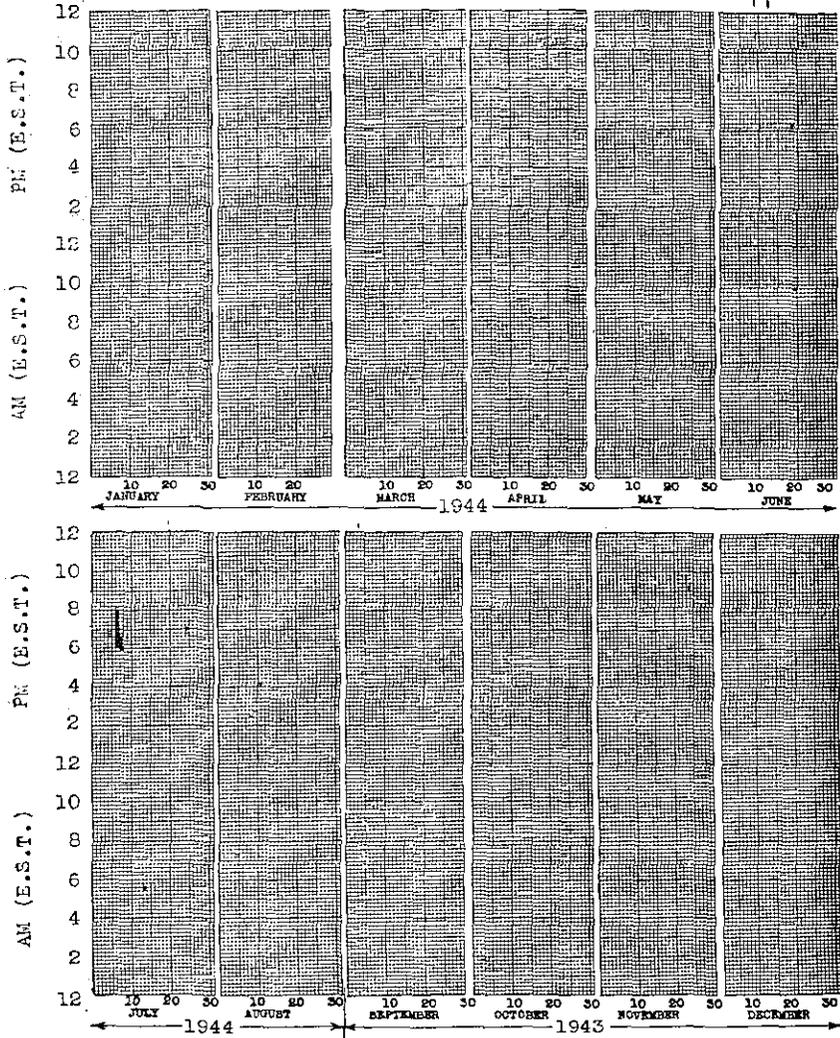


FIGURE 11  
 39 F.C.C.

SPORADIC E LAYER PROPAGATION  
1943 - 1944

Occurrence of fields exceeding 25 microvolts/meter at  
Allegan, Michigan from station WGTR, Paxton, Mass.  
44.3 mc - 720 miles - 83 kw

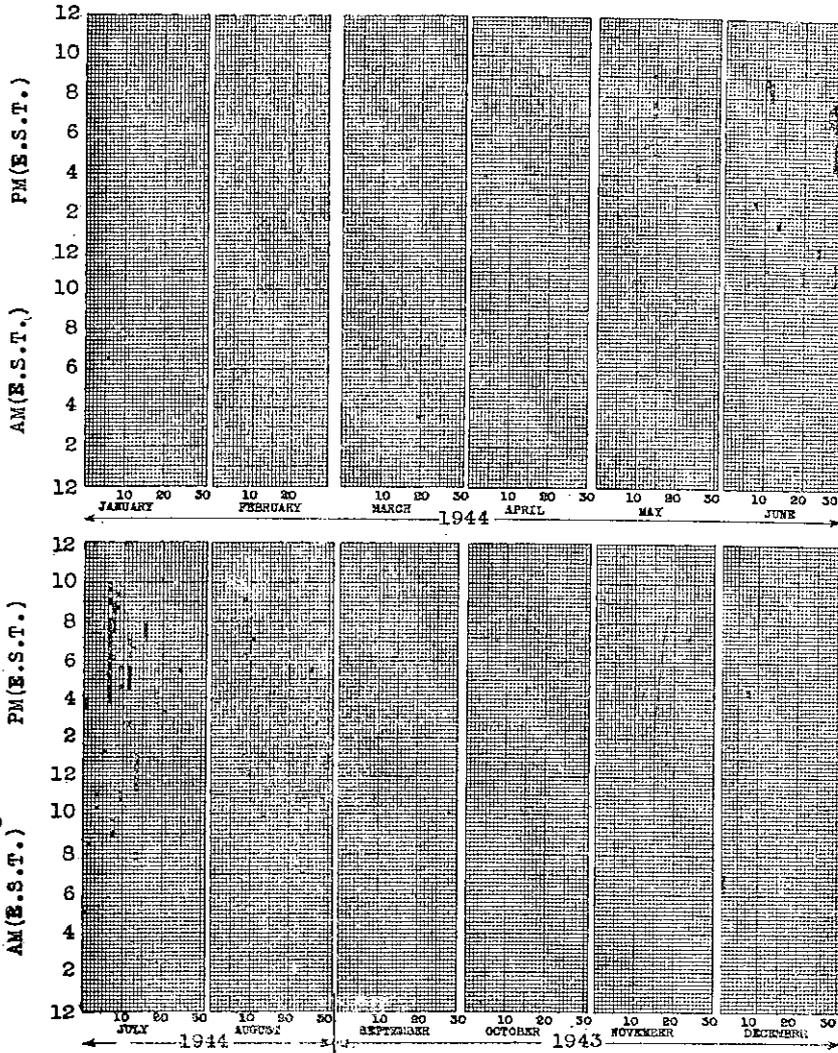


FIGURE 12

SPORADIC E LAYER PROPAGATION  
 1943 - 1944  
 Occurrence of fields exceeding 25 microvolts/meter at  
 Atlanta, Georgia from station WQTR, Paxton, Mass.  
 44.3 mc - 900 miles - 83 kw

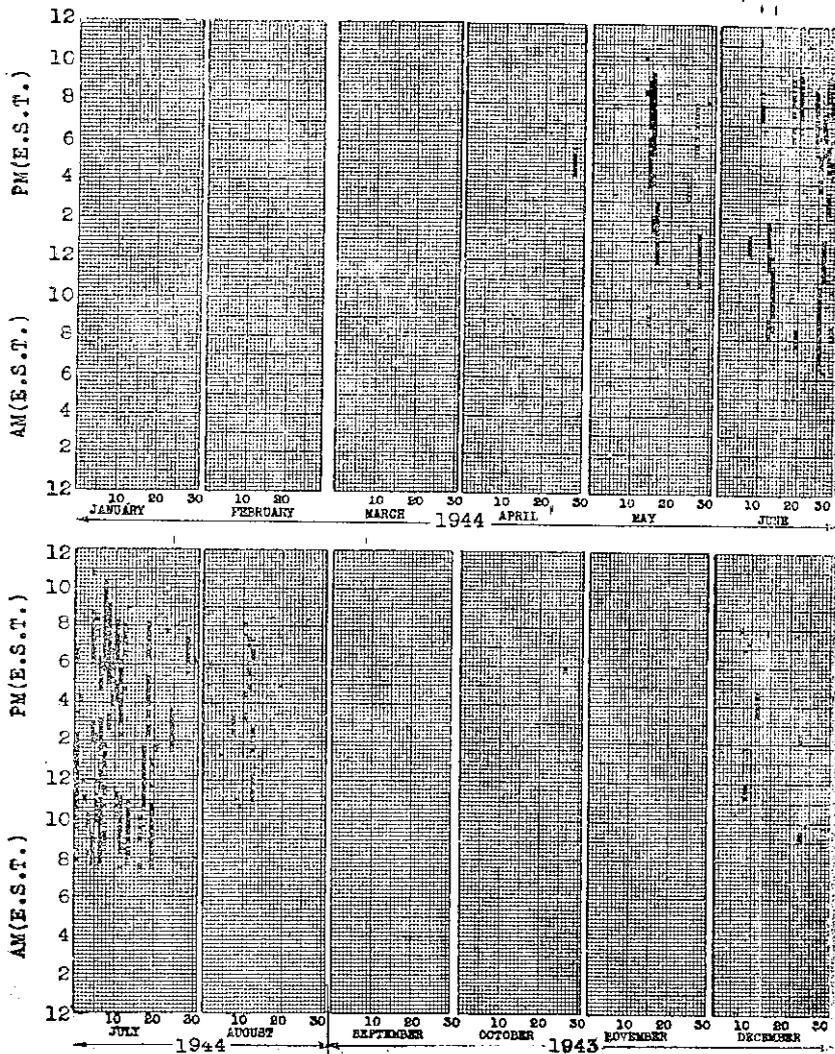


FIGURE 1.5  
 39 F.C.C.

SPORADIC E LAYER PROPAGATION  
1943 - 1944

Occurrence of fields exceeding 25 microvolts/meter at  
Grand Island, Nebraska from station WQTR, Paxton, Mass.  
44.3 mc - 1400 miles - 83 kw

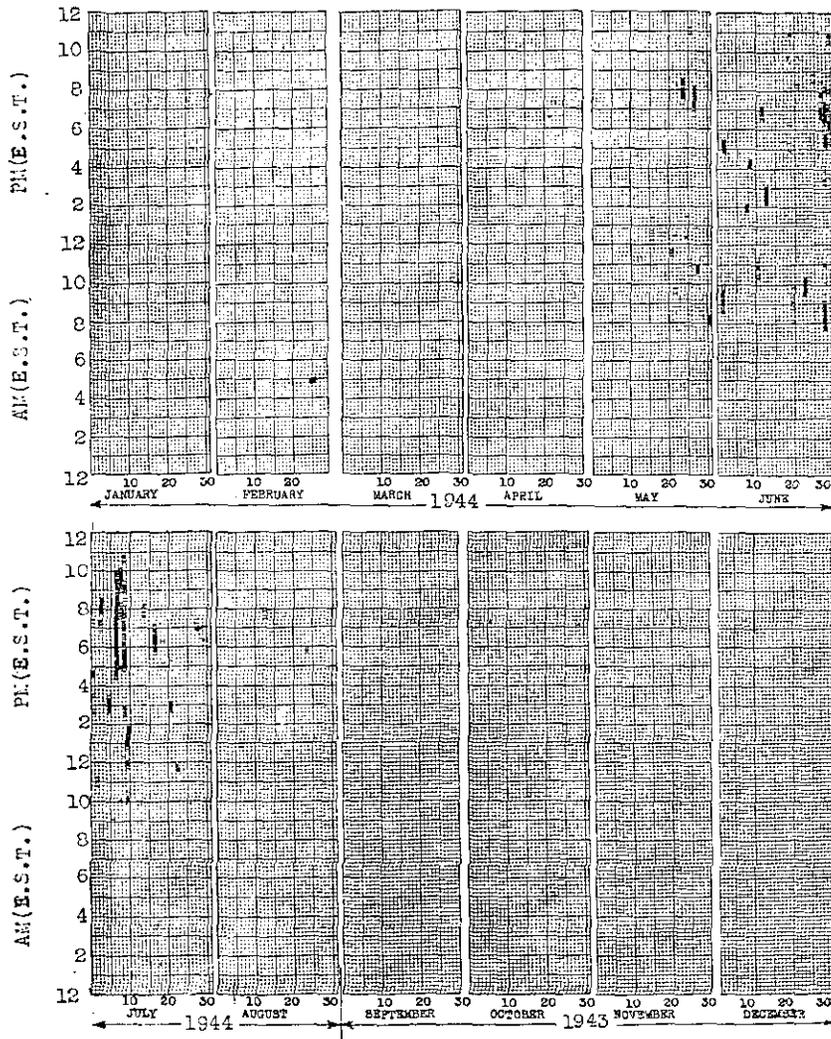


FIGURE 14

SPORADIC E LAYER PROPAGATION  
1943 - 1944

Estimated Interference via Sporadic E Propagation, to a PM Receiver on 50 Microvolt/Meter Contour of Station WGTR, Paxton, Mass., from Four Identical Co-Channel Stations Located at Laurel, Md. (337 mi.), Allegan, Mich. (720 mi.), Atlanta, Ga. (900 mi.) and Grand Island, Neb (1370 mi.). Frequency 44.3 mc, Power 83 kw.

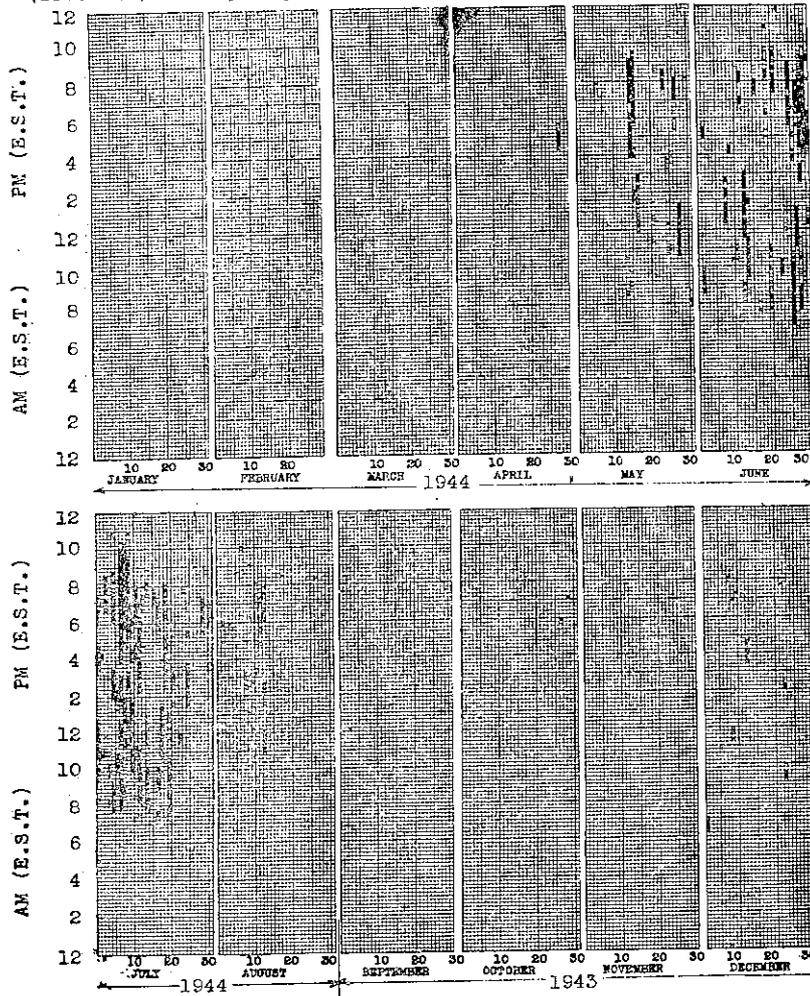
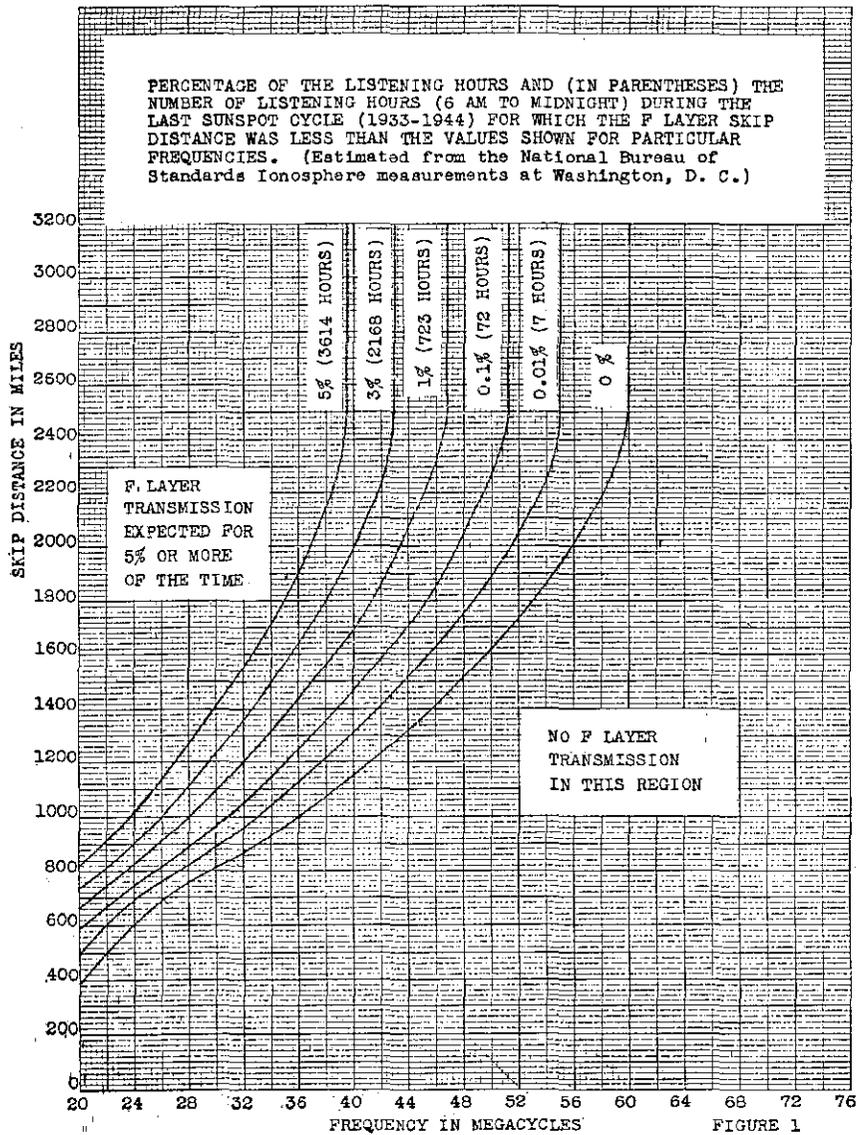


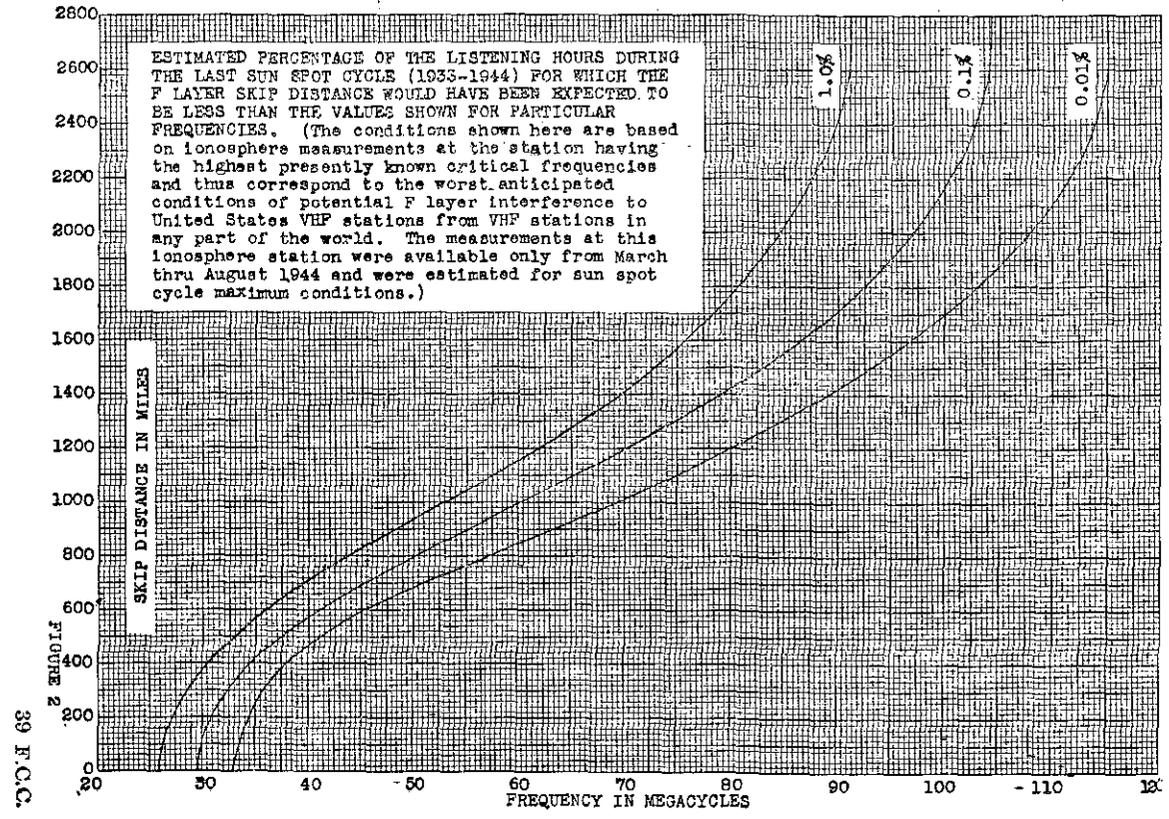
FIGURE 15  
39 F.C.C.

FEDERAL COMMUNICATIONS COMMISSION

DOCKET NO. 6651

EXHIBIT NO. 380





39 F.C.C.

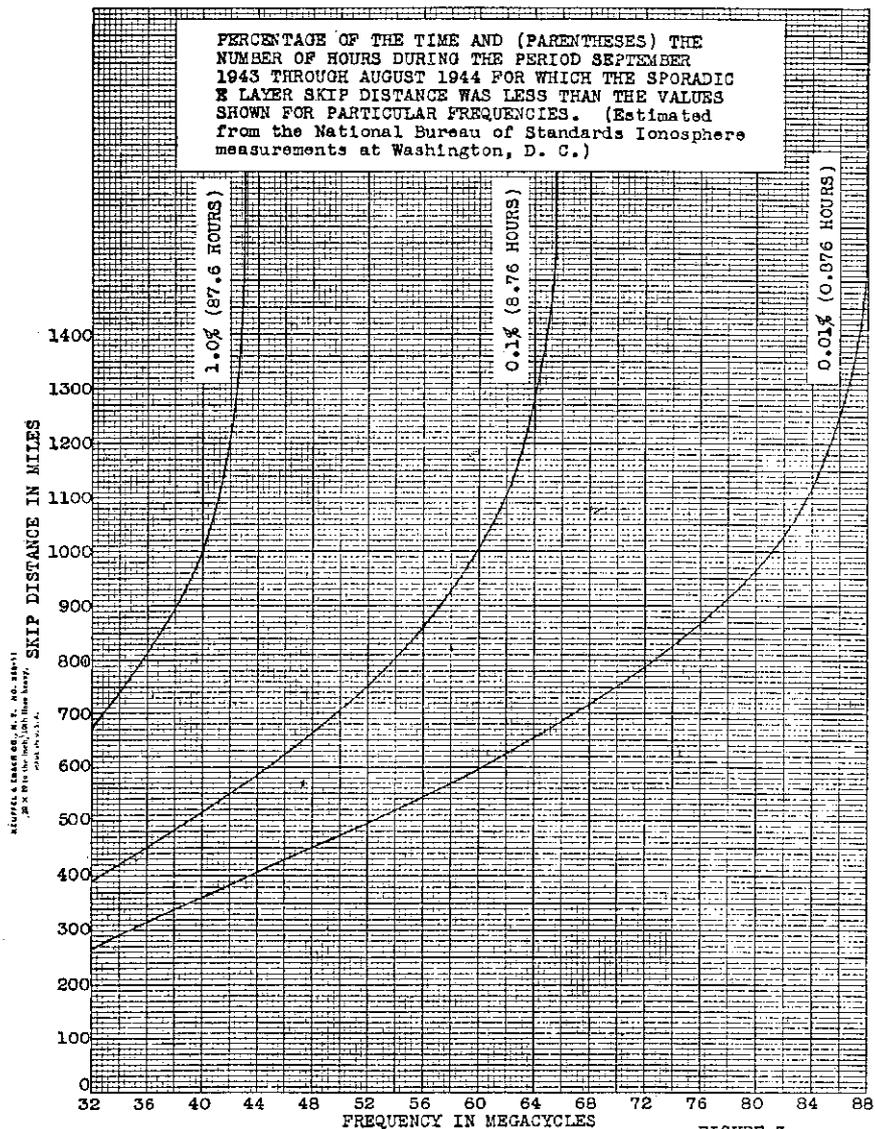
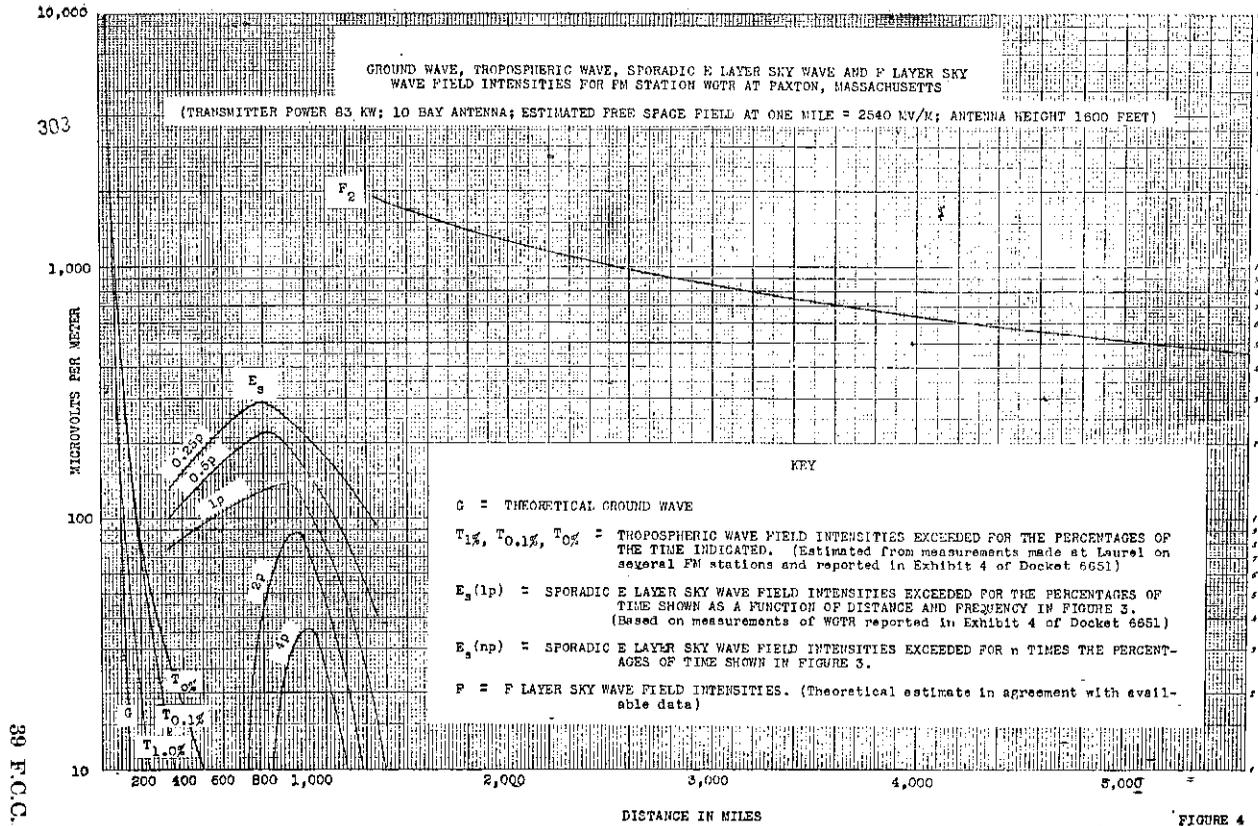


FIGURE 3

39 F.C.C.



39 F.C.C.