NBS

Technical Note No. 9

FREQUENCY DEPENDENCE OF VHF IONOSPHERIC SCATTERING

BY JAMES C. BLAIR

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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APRIL 1959

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James C. Blair

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FREQUENCY DEPENDENCE OF VHF IONOSPHERIC SCATTERING

by

James C. Blair

1. INTRODUCTION

An accurate knowledge of frequency-dependence of scattered power is not only of importance in the establishing of communication circuits, but theoretical studies of previous data[1] have pointed out that it is a vital parameter in basic understanding of the scattering mechanism.

Earlier experiments of frequency-dependence[2] were limited to observations of mean signal intensity at three frequencies, but only a pair simultaneously.

This report contains data obtained by recording received signal intensities simultaneously at five frequencies over the 1295 km path between the Long Branch transmitting station at Long Branch, Illinois, and the receiving site at Boulder, Colorado (Table Mesa field station). The data presented here cover the period of September 1, 1957 to June 30, 1958 (except for some later data on meteor bursts and sudden ionospheric disturbances). Good simultaneous signal intensity records were obtained for most of this period on 30, 40, 50 and 74 Mc. The available transmitter at 108 Mc was not suitable for continuous reliable records prior to June 5, 1958.

In addition to the routine, 24 hour-a-day recording of average received power, a set of high-speed records was made for 10-minute intervals at different times during one day and analyzed for amplitude-distribution and fading-rate. Also, a low-sensitivity recording was made for the study of meteor bursts.

Data presented here show the measured results of frequency dependence of average received power and illustrate how the level of average received power is influenced by meteoric ionization, sporadic-E ionization, and ionospheric and magnetic disturbances. A summary of hourly median and upper and lower decile values on all frequencies is included, as well as data on amplitude distributions and fading rates.

2. EXPERIMENTAL FACILITIES

All signals recorded in obtaining the data presented here were transmitted from the Long Branch Radio Propagation Transmitting Station near Kilbourne, Illinois, and received at Boulder, Colorado. The recorded signal intensities were adjusted to equivalent line losses and transmitter powers. The geographical coordinates of the terminals are:

Long Branch field station 40° 13 N; 90° 01 W

Boulder (Table Mesa field station) 40° 08 N; 105° 15 W.

The path length is 1295 kilometers.

The frequencies used and the periods of operation are listed below:

Frequency	Period
30.00 Mc	Sept. 1, 1957 - Dec. 5, 1957
30.005	Dec. 5, 1957 - June 30, 1958
40.00	Sept. 1, 1957 - Dec. 5, 1957
40.006	Dec. 5, 1957 - May 1, 1958
40.88	May 1, 1958 - June 30, 1958
49.60	Sept. 1, 1957 - Nov. 21, 1957
49.64	Nov. 21, 1957 - Mar. 25, 1958
49.88	Mar. 25, 1958 - June 30, 1958
73.88	Sept. 1, 1957 - Oct. 18, 1957
73.84	Oct. 18, 1957 - June 30, 1958
107.80	Nov. 9, 1957 - Dec. 9, 1957
	Mar. 26, 1958 - Apr. 5, 1958
	May 29, 1958 - June 30, 1958

2.1 Antennas

In order to illuminate the scattering volume uniformly at all frequencies, scaled rhombic antennas were used at both the transmitters and receivers. This means that the dimensions and heights of the antennas were made proportional to the wave lengths of the signals they transmitted and received. These rhombic antennas have a calculated plane wave gain of approximately 20 db, relative to a dipole, with the axis of the main lobes inclined at angles of 4.6 degrees above the horizon. The beam widths are approximately 6^{o} to the half-power points in the horizontal and vertical planes. The results given herein are presented prior to completion of actual calibrating measurements on all antenna systems and are subject to some review after such measurements are available.

2.2 Transmitters

Unmodulated continuous-wave signals were transmitted in all cases. The transmitter powers for most of the transmission were as follows: 2 kilowatts at 30 Mc and 40 Mc, 10 kilowatts at 50 Mc, 9 kilowatts at 74 Mc, and 4 kilowatts on 107.8 Mc. The limitations of available transmitters of proper capacity made the logical arrangement of greater power on higher frequencies impossible.

2.3 Receiving and Recording Equipment

In order to realize usable signal-to-noise ratios, receivers of the double-conversion type were used to make narrow-bandwidth operation possible. The 30, 40, 50 and 74 Mc signals were recorded with bandwidths of 300 cycles per second and the 108 Mc signals were recorded with a bandwidth of 25 cycles per second. Receiver local oscillators with a high degree of precision were employed to assure the receivers were always properly tuned.

The continuous signal recordings were made on a one-milliampere pen recorder at a recording speed of three inches per hour. The amplitude-distribution and fading-rate data were recorded at a speed of 50 millimeters per second on a high-speed pen recorder. Meteor bursts were recorded at 10 millimeters per second.

The receivers were calibrated once each day by substituting a standard signal generator for the antennas. The calibration of the signal generator was checked by comparing its output with precise standards, and the data were adjusted to compensate for the errors found. A 6 db pad was inserted in the generator circuit to make the generator read open-circuit antenna voltage.

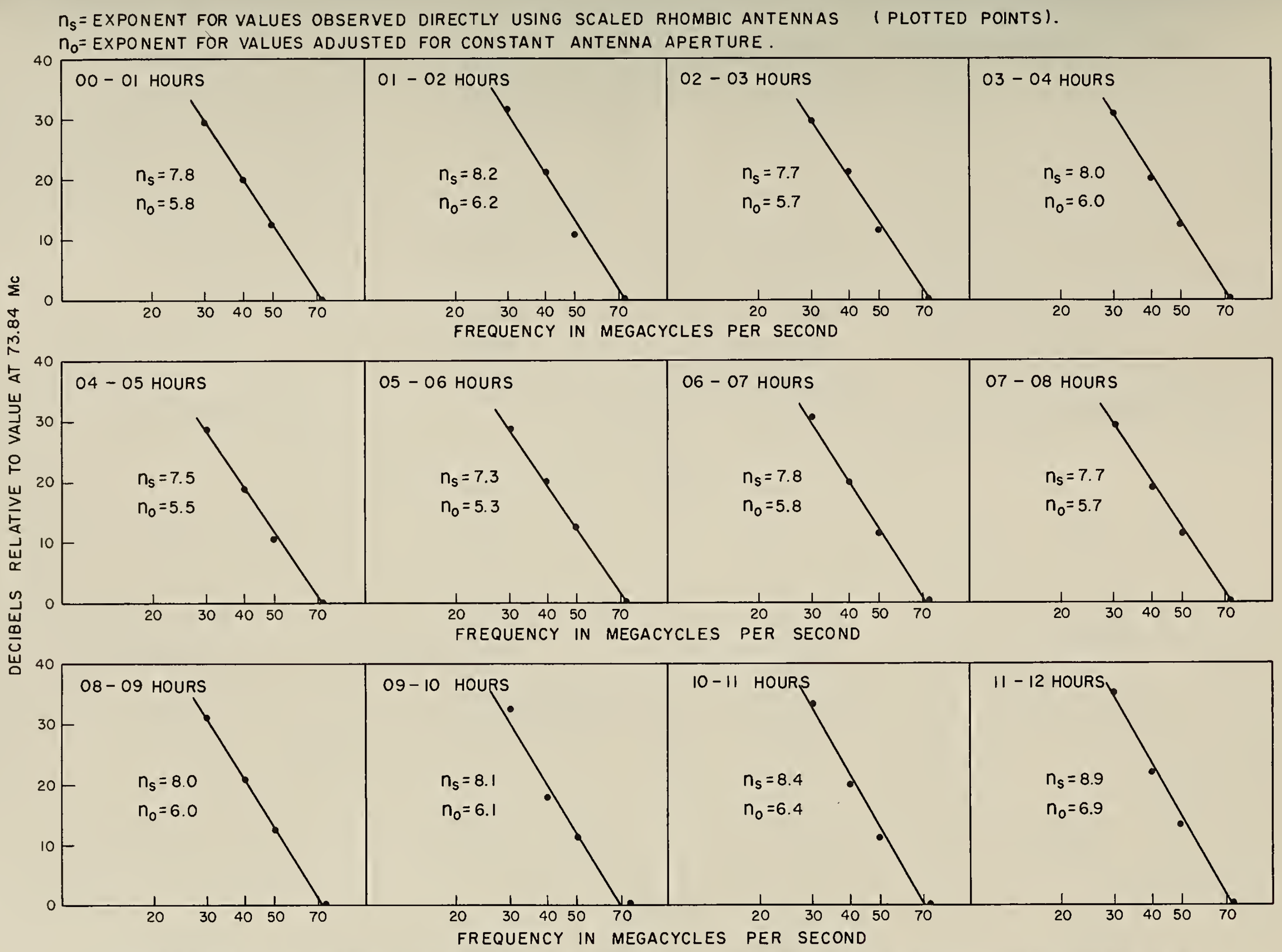
3. FREQUENCY DEPENDENCE OF AVERAGE POWER

3.1 Frequency Dependence Predicted by Theories

Earlier scattering theories have predicted that simultaneous transmissions on different frequencies over the same path, with the same antenna apertures and transmitter powers, will show that receiver available power varies inversely as frequency raised by some exponent, n. The Booker-Gorden scattering theory[3] gives a value of 4 for n. Eckersley's scattering model[4] indicates a value of 8. Later work by Wheelon[1] deals with the possibility that the exponent may be smaller for frequencies between 30 to 50 Mc than it is for frequencies from 50 to 100 Mc, as earlier measurements[2] indicated. Wheelon[5] also deals with the diurnal variations of the exponent.

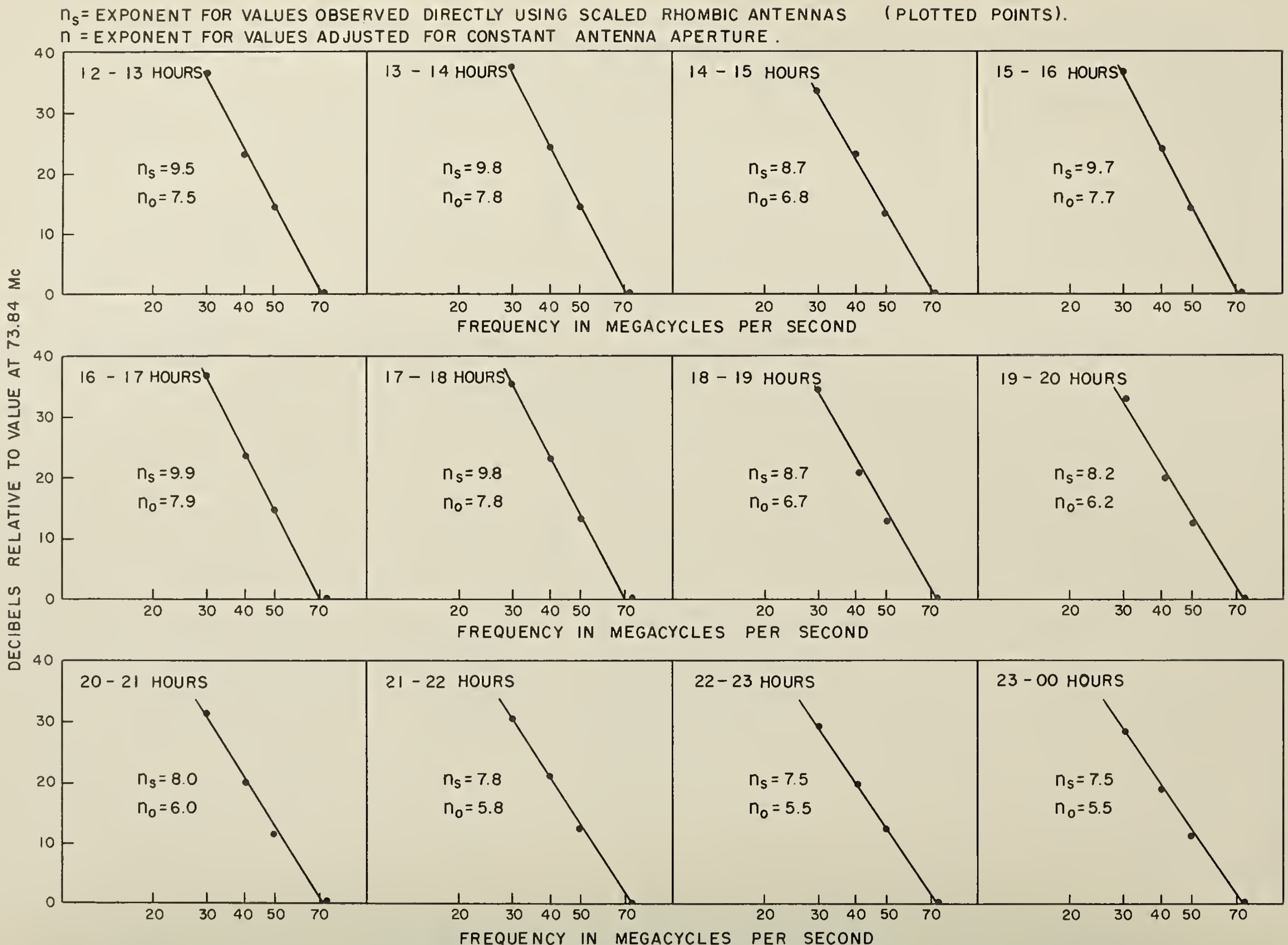
3.2 Measured Values of Exponent

One important objective of this experiment has been to test these theories and determine whether a single value of n is observed throughout the frequency range, or the nature of the curvature or cutoff of such a power law.[1] The data presented in figures 1 and 2 are plots of the median values of signals that were received simultaneously on four frequencies during March, 1958. The relative median values of received signal intensity are plotted for every hour of the day. Figures 3 and 4 are similar plots of data obtained on five frequencies during June, 1958. The deviations of the points from straight lines of average slope are small, which indicates that for any given time n is a constant and can be determined quite precisely.



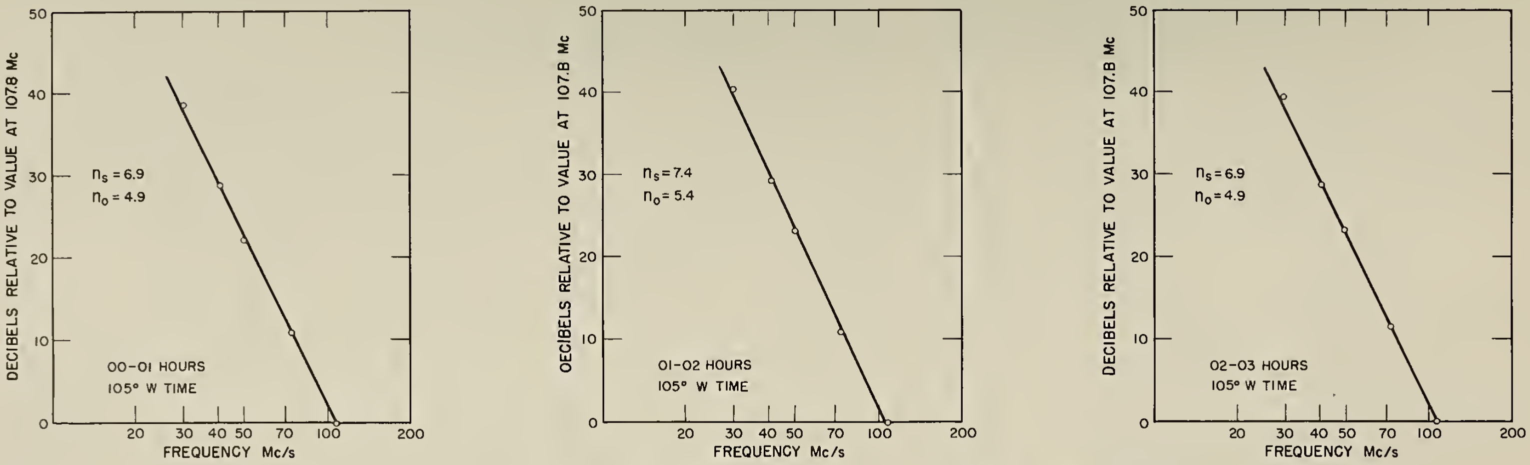
DEPENDENCE OF SIGNAL INTENSITY ON FREQUENCY FOR 15 DAYS OF MARCH 1958 (105° W. TIME)

FIGURE 1



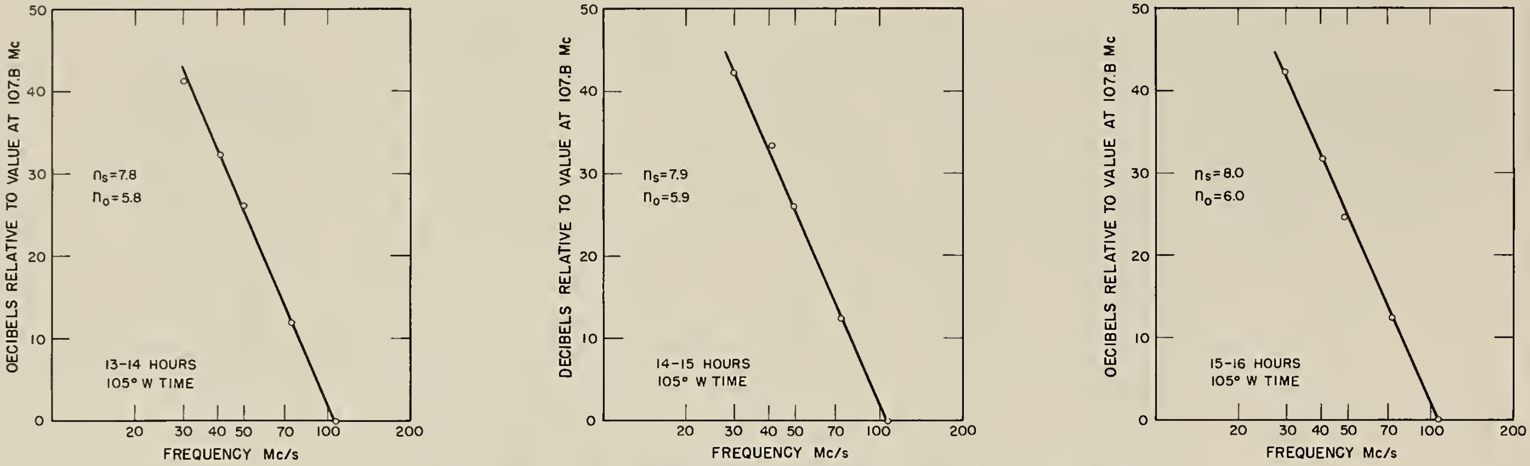
DEPENDENCE OF SIGNAL INTENSITY ON FREQUENCY FOR 15 DAYS OF MARCH 1958 (105° W. TIME)

FIGURE 2



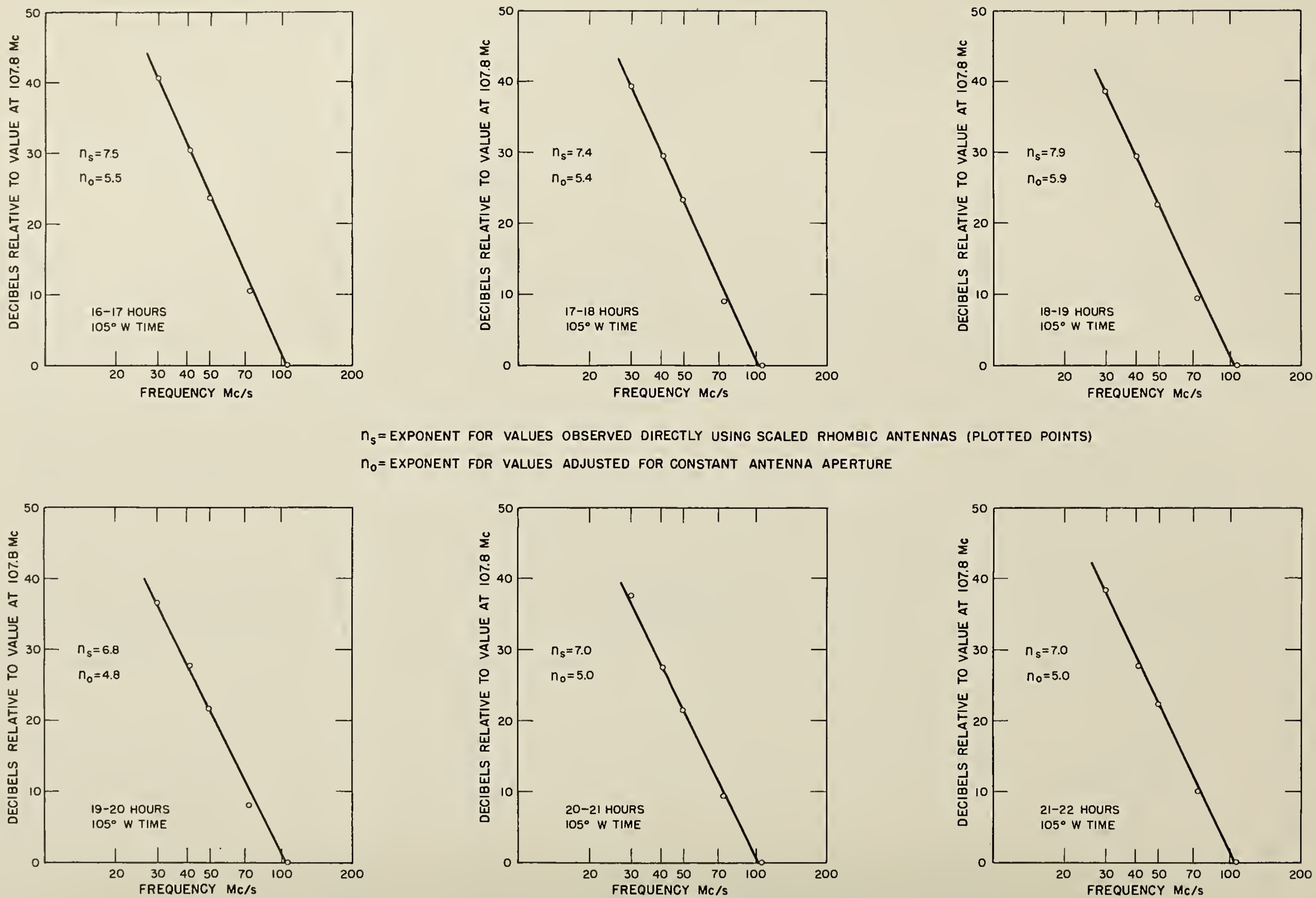
n_s = EXPONENT FOR VALUES OBSERVED DIRECTLY USING SCALED RHOMBIC ANTENNAS (PLOTTED POINTS)

n_o = EXPONENT FOR VALUES ADJUSTED FOR CONSTANT ANTENNA APERTURE



DEPENDENCE OF SIGNAL INTENSITY ON FREQUENCY FOR 10 DAYS OF JUNE 1958

FIGURE 3



DEPENDENCE OF SIGNAL INTENSITY ON FREQUENCY FOR 10 DAYS OF JUNE 1958

FIGURE 4

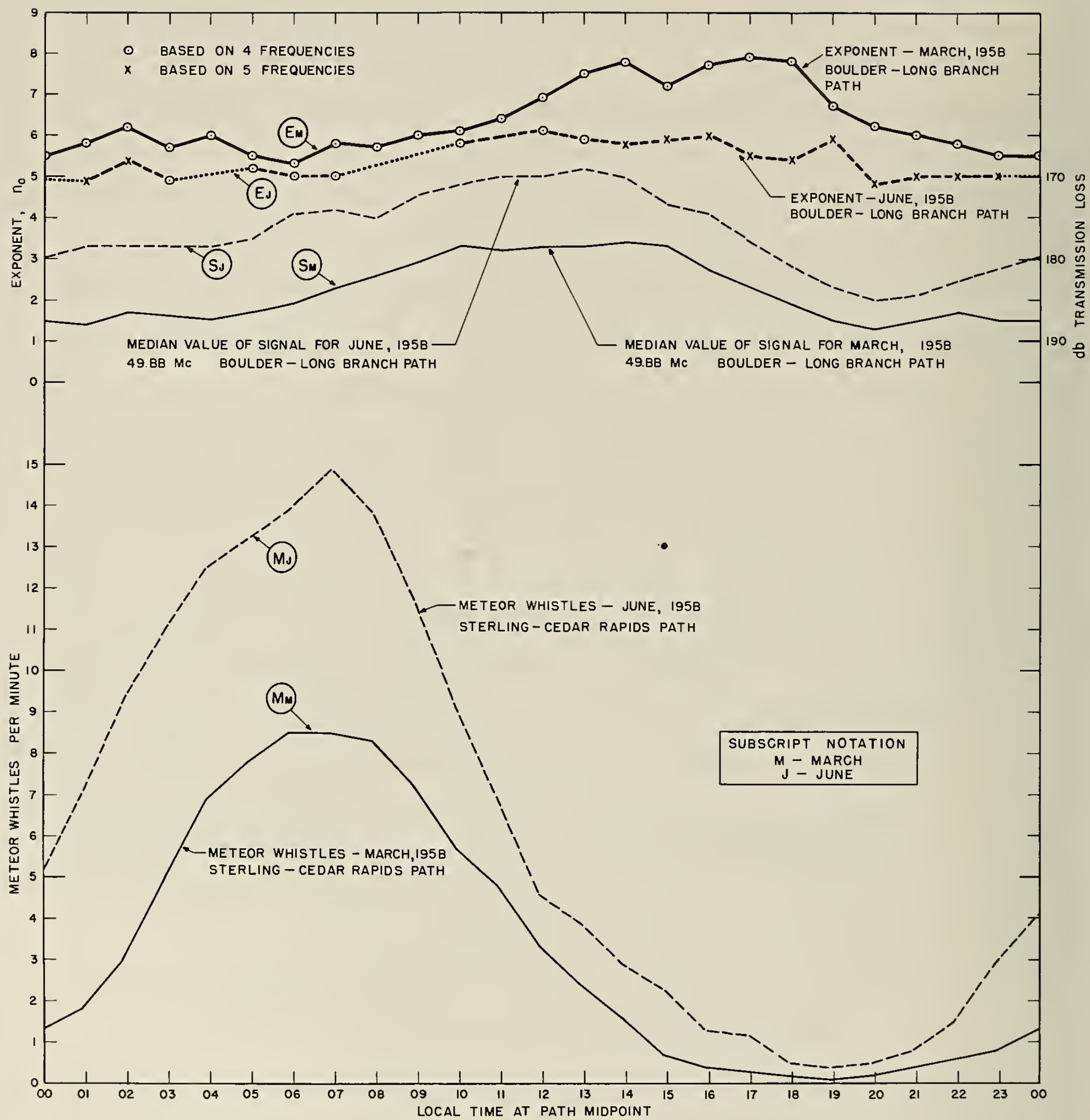
The average-slope lines drawn and the points plotted are those from values obtained directly using scaled rhombic antennas. The effective area of the receiving antennas varies as the wave-length squared; it is necessary to make a corresponding adjustment of the data if the frequency dependence is to be expressed on a per-unit or constant-with-frequency aperture basis. In figures 1 through 4, n_s is used to designate the value of the exponent using scaled antennas and n_o to designate the value expressed on a per-unit-aperture basis. The antenna-aperture adjustment lowers the value of the exponent by 2.

All values of signal intensity have been adjusted to the same transmitter power and equivalent line losses. Adjustments have been made to eliminate errors in the calibration generators. The antennas are assumed to have the same gains. Every possible attempt has been made to eliminate signals influenced by sporadic E from the data.

The diurnal variation of the exponent n_o is shown in figure 5. Curve E_m is for March and curve E_j is for June. The lowest value of n_o in March is 5.3 at 0600 hours, while the highest is 7.9 at 1700 hours. The values for June are slightly lower than those for March in the morning hours and are lower by an amount greater than 2 between 1700 and 1800 hours. There is a strong suggestion that the low midday exponents in June are an example of the same effect found during SID occurrences. At these times the high-frequency signal strength is increased in relation to the low-frequency strength, which may even decrease. This effect is described in Section 3.5.

3.3 The Influence of Meteor Bursts on the Received Signal

One effect of noticeable meteoric influence in the records is to lower the frequency exponent n_o. In other words, an apparent result contributed from meteor bursts is to raise the composite signal intensity disproportionately at the high frequencies compared to low frequencies.



RELATION OF METEORIC ACTIVITY TO CHANGES IN SIGNAL LEVEL AND EXPONENT VALUE

FIGURE 5

These tendencies can be discerned in figure 5, in which diurnal curves of meteoric activity[6], composite signal level, and frequency exponent are plotted on the same time scale. It is seen that the total signal intensity (curve S_j) is higher at all hours in June than in March (curve S_m). Both the March and June curves of signal intensity have their minima between 1800 and 2100, an effect that seems to be associated with the diurnal minimum of meteoric activity between these hours.

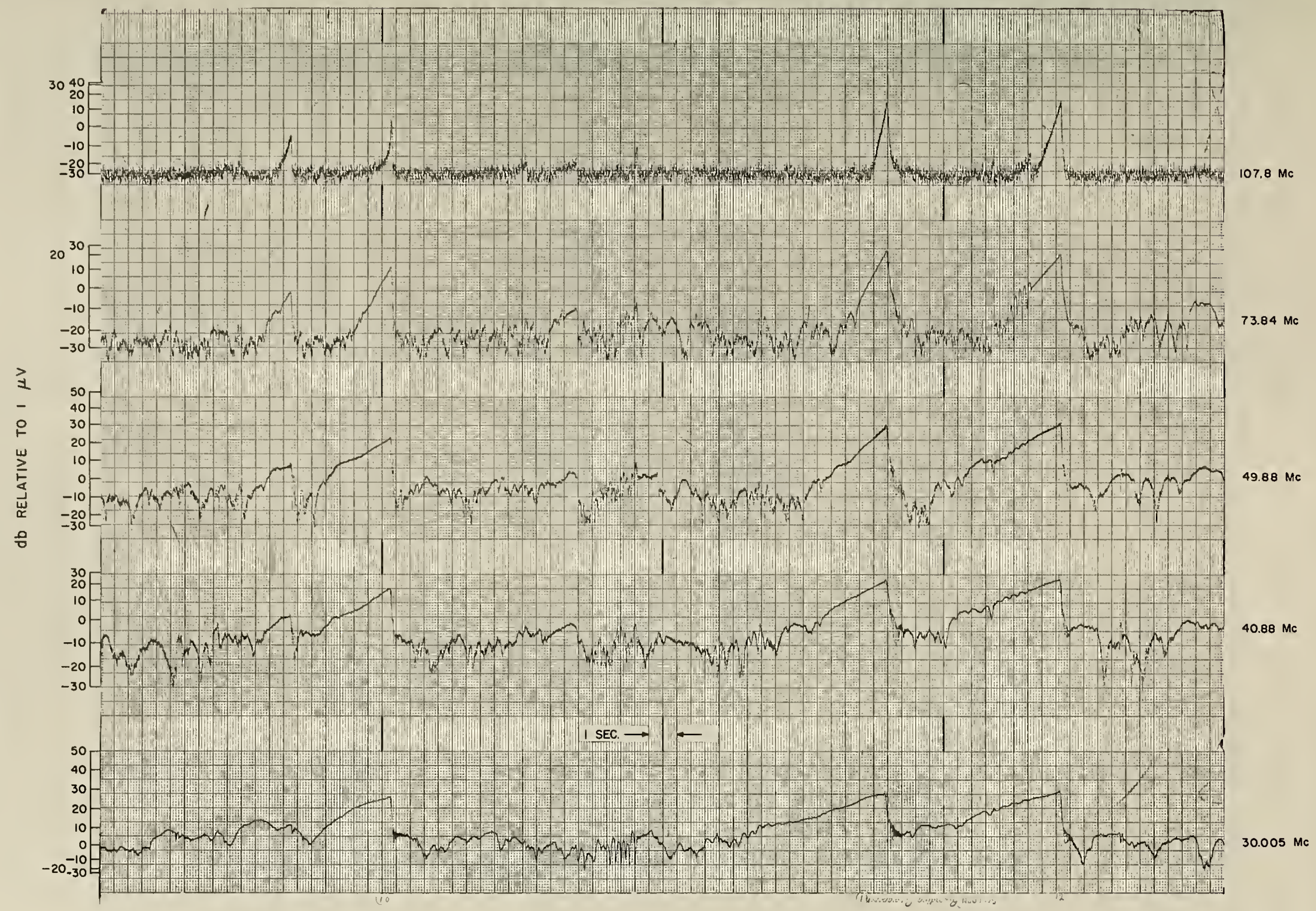
It should be pointed out that curves M_j and M_m are curves of meteor whistles and not bursts. However, these curves agree generally in both diurnal and seasonal variations with data from radar observations taken with a nondirectional antenna[7]. For this reason these curves should represent a fair approximation to the variations of meteor-burst activity.

Comparisons of the signal intensity and frequency exponent curves for the two months of March and June suggest certain possible meteoric effects. The increased meteoric activity in June compared with March may be related to the uniformly higher values of signal intensity in June, although this is only a conjecture. The diurnal curves of n_o in March and June may be interpreted as reflecting both meteoric and solar influences, with the solar influence predominating in the hours around midday and the meteoric influence having control at other hours.

Both the E_m and E_j curves maintain fairly low values from about 2100 in the evening until about 0600 the following morning. (Slightly increased values of n_o are found between 0100 and 0400, but the frequency exponent is very low at 0600, about the time when meteoric activity is at its diurnal maximum.) With increasing solar radiation during the early morning the value of n_o increases gradually, at least in March, even though meteoric activity is still high. This continues until about noon. During the afternoon the value of n_o maintains a broad maximum in June, while in March it increases to relatively high values. In these hours there appears to take place a transition between solar and meteoric control. The high values of n_o occur after the diurnal peak of solar activity has been passed. It thus appears that the low levels of meteoric activity are responsible for the high values of n_o in the late afternoon. Finally, by the time the S_j and S_m curves reach their diurnal minimum the values of n_o have also declined to low values.

It is of interest to note the correlation of the distance between ordinates of curves S_j and S_m with this distance between curves M_j and M_m. This shows clearly the effect of meteor-burst activity on average signal intensity and suggests one means of separating the two components. If curves such as S_j and S_m are drawn for different frequencies, it may be possible to compare them with meteor activity curves and establish values of n_o for the composite scatter signal minus specularly reflected meteor signal.

In order to obtain data on the frequency dependence of meteor bursts that would not be significantly influenced by scatter signals, a high-speed recording was made in the morning hours. Figure 6 shows this recording that was made with low receiver sensitivity. Five carrier frequencies were recorded simultaneously. The bursts are easy to identify because they appear in time coincidence on all frequencies. The stronger bursts usually have a saw-tooth shape on a decibel scale. On a linear scale of antenna voltage vs. time, this would be an exponential curve with a very steep rise. As can be seen in the figure, meteor bursts do not always have this ideal shape. But the customary practice of measuring the duration at $\frac{1}{e}$ times the peak value of antenna voltage and calling this value of duration the time constant of the meteor burst is followed here. Even though the bursts are easy to identify, it is not possible to determine how much of the signal rise is due to the meteor and how much is due to the scatter-signal fading pattern on weak meteor bursts. Indeed, in some cases the signal actually decreases on some frequencies during a burst. For



SIMULTANEOUS HIGH-SPEED RECORDINGS OF METEOR BURSTS
SEPTEMBER 12, 1958

FIGURE 6

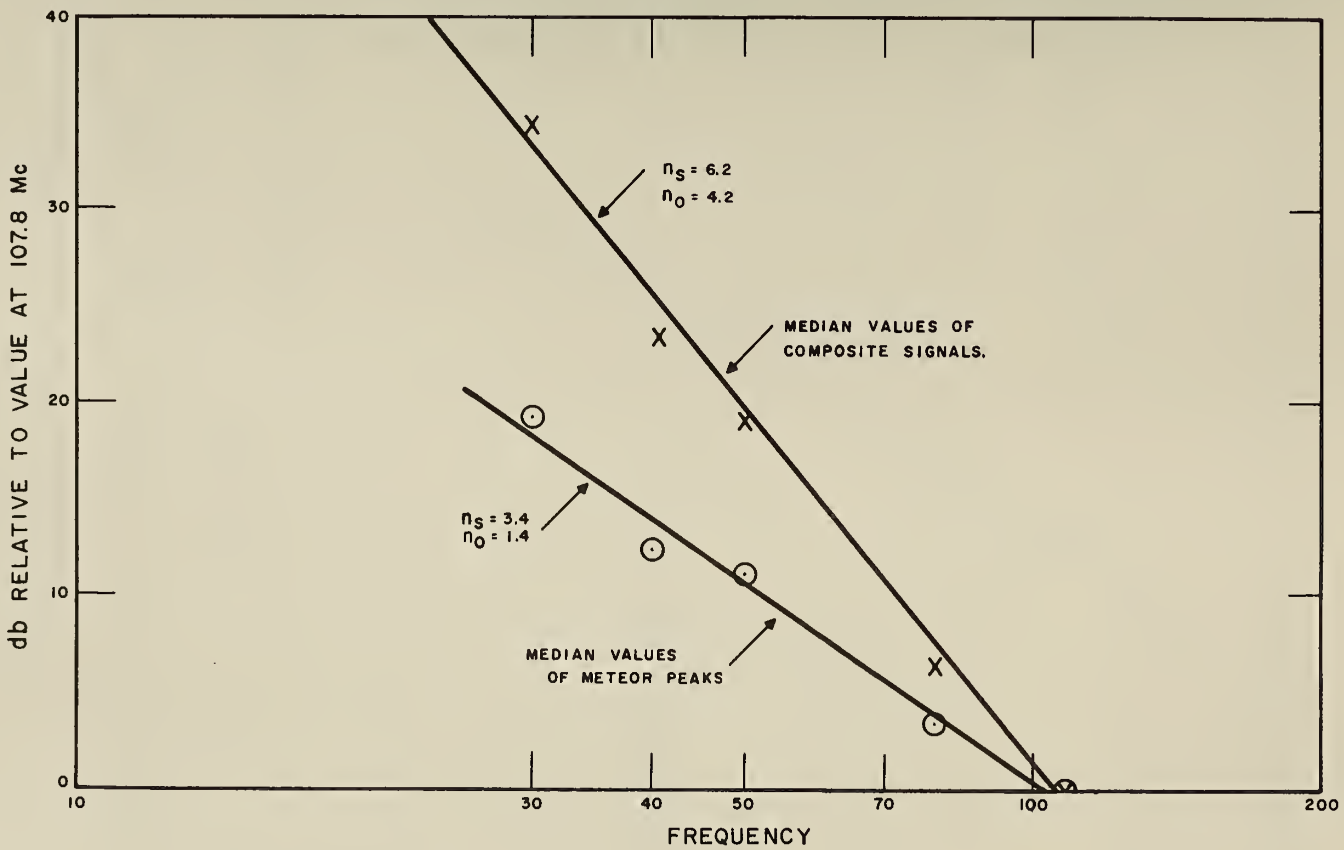
this reason, meteor bursts were included in the analysis only if they exceeded the median value of the signal level by 20 db.

Figure 7 is a plot of the median peak values of 35 meteor bursts at different carrier frequencies together with the median values of the composite signal. The value of n_o for the meteor peaks is 1.4 compared with 4.2 for the composite signal. Figure 8 shows the time constant to be about proportional to the 1.7 power of wave-length for this period. It can be shown that the integrated power supplied by meteor bursts with exponential decay is represented by a frequency exponent which is the sum of the frequency exponents applying to the time constant and the peak power. If the exponent for peak power is added to the time-constant exponent a value of 3.1 is obtained for the frequency dependence of received power during meteor bursts. This value is based on the assumption of equivalent antenna apertures at different frequencies. It is to be compared with Eshleman's theoretical value,[8] involving an exponent of 1.0 for meteor peak power adjusted for constant antenna aperture and an exponent of 2.0 for meteor duration.

In conclusion, then, it appears that both meteoric activity and solar activity exert a strong influence on the frequency exponent. Its diurnal variation appears to arise from the changing resultant of these two forces throughout the day.

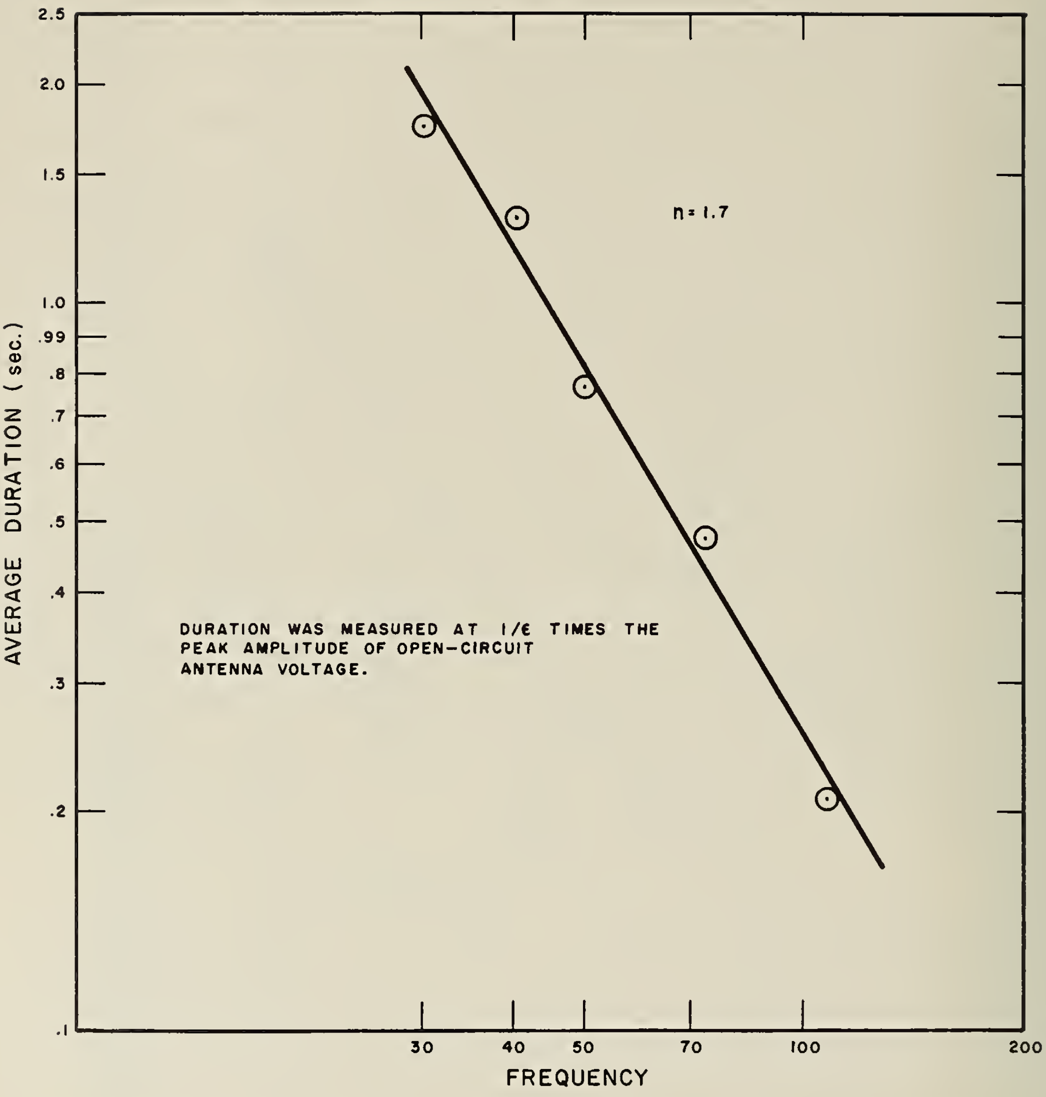
3.4 Frequency Dependence of Signals from Sporadic E

As a means of separating sporadic E signals from scatter signals, the following criteria were used to identify E_s signals: (1) signals must maintain a level of -60 db relative to inverse-distance values for at least 1 minute on the carrier frequency of 30 Mc, (2) the signal enhancement of 30 Mc must last 12 minutes, (3) any signal enhancements (signals clearly above the background scatter signals) on the higher frequencies that are in time coincidence with conditions of (1) and (2) on 30 Mc are considered sporadic E signals. It should be realized that this is a different criterion than has been used for other measurements when these data are compared with other results.



FREQUENCY DEPENDENCE OF PEAK VALUES OF STRONG METEOR BURSTS COMPARED WITH FREQUENCY DEPENDENCE OF THE COMPOSITE SIGNALS FOR 35 BURSTS OCCURRING DURING PERIOD OF 0430 TO 0545 MST, SEPT. 12, 1958

FIGURE 7



AVERAGE DURATION OF 35 STRONG METEOR BURSTS OCCURRING DURING PERIOD OF 0430 TO 0545 MST, SEPT. 12, 1958

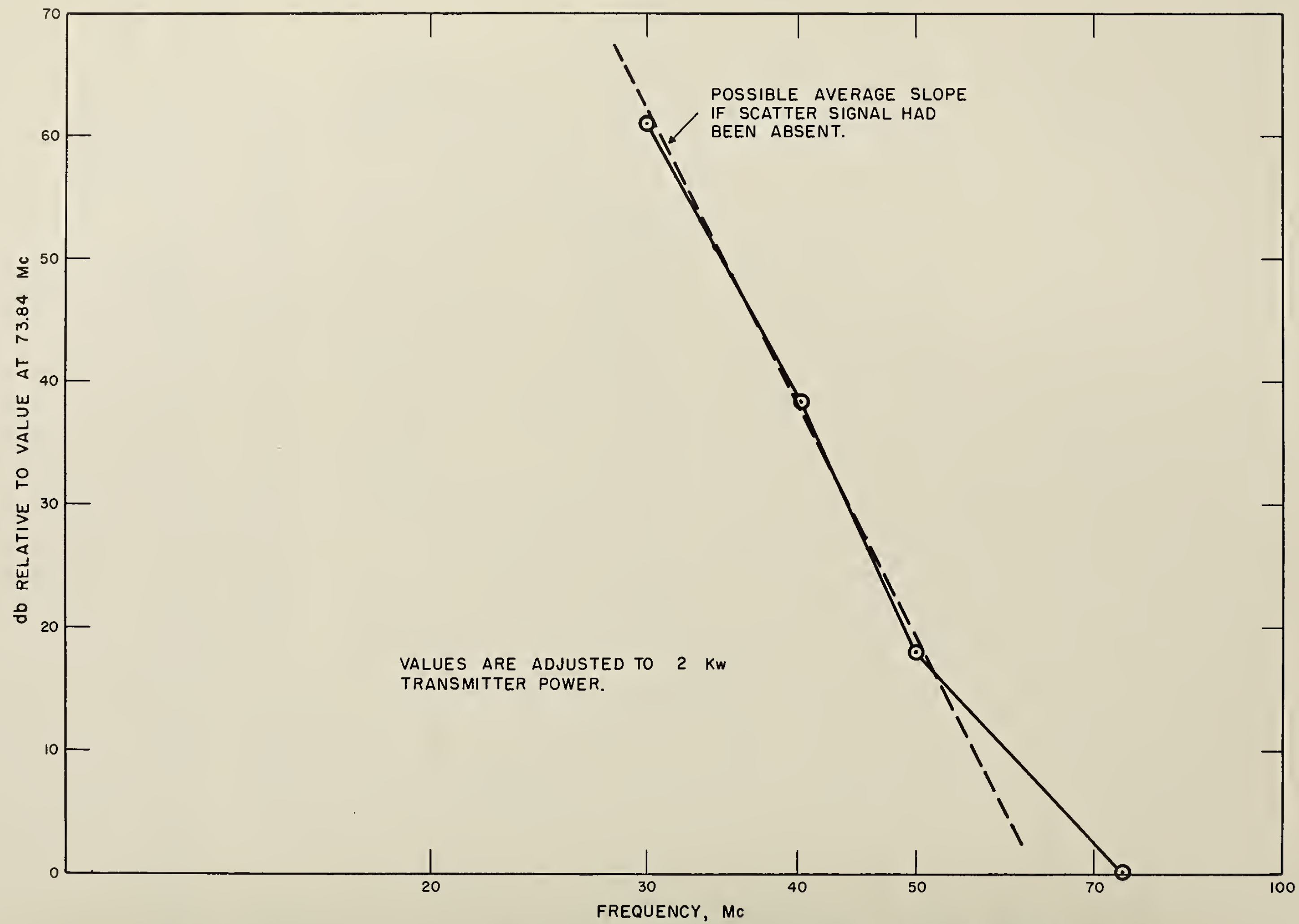
FIGURE 8

Figure 9 is a plot of the median values of eleven simultaneous occurrences of E_s on four frequencies. The eleven values were the only ones observed simultaneously between September 1, 1957 and June 30, 1958. Due to criterion used, the lower value of E_s on 74 Mc is necessarily too high because of contributions of scatter to its median value; that is, the average value of E_s was only about 5 db above the scatter signal. The curve does, however, show that the effects of E_s dimish rapidly with frequency. Figure 10 shows the total duration of E_s during the period of September 1, 1957 to June 30, 1958.

3.5 SID Behavior

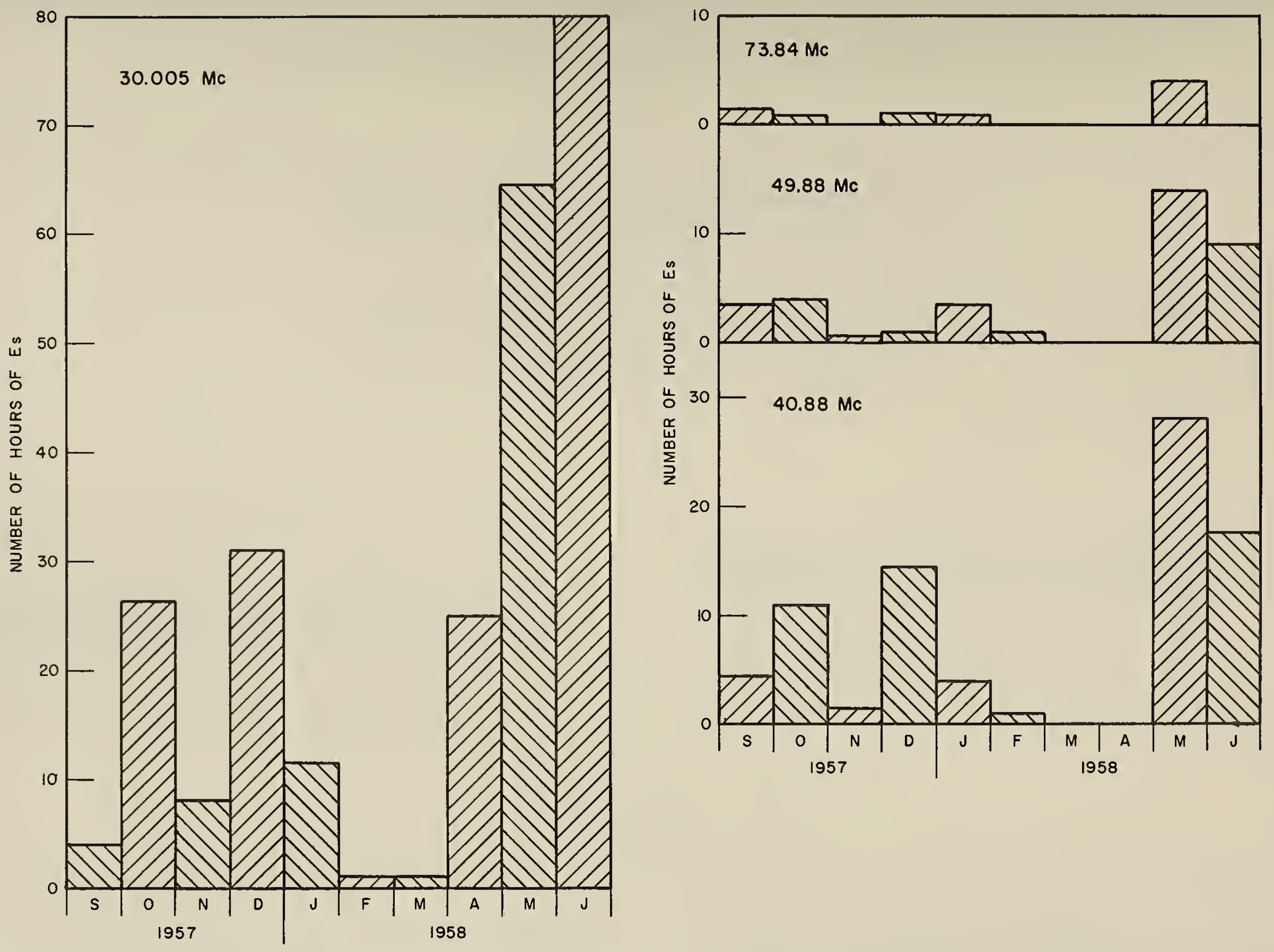
Figure 11 shows a set of records made during an SID on March 29, 1958. At about 1125 hours high absorption is seen on 30 Mc, but as the frequency is increased, this absorption condition gradually changes to one of enhancement. A plot of values of signal intensities from these records is shown in figure 12. These records were made, as usual, by transmitting and receiving on rhombic antennas. For comparison with these, a plot of signal intensities from records obtained by transmitting and receiving on Yagi antennas (from another installation) is shown in figure 13. It will be noticed here that absorption is present on all frequencies, although it is much greater at the lower frequencies. A possible explanation for this difference in behavior on antennas of different beam widths is that the Yagi signals came from off path and thus traveled a greater distance through the absorbing layer. Figures 14 and 15 are plots of an SID that occurred July 19, 1958. Similar behavior is observed here.

Figure 16 is a plot of signals received during a magnetic disturbance. Notice the absorption on 30 Mc is extremely great. The 30 Mc signal drops some 7 db below the value of the 40 Mc signal and reaches a value that is about equal to that of the 50 Mc signal. Rapid decrease in absorption is noticed with increase in frequency with enhancement starting at about 73 Mc and becoming significantly great at 108 Mc. It is of considerable interest to note that these effects correlate with the magnetic record made at Boulder, Colorado.



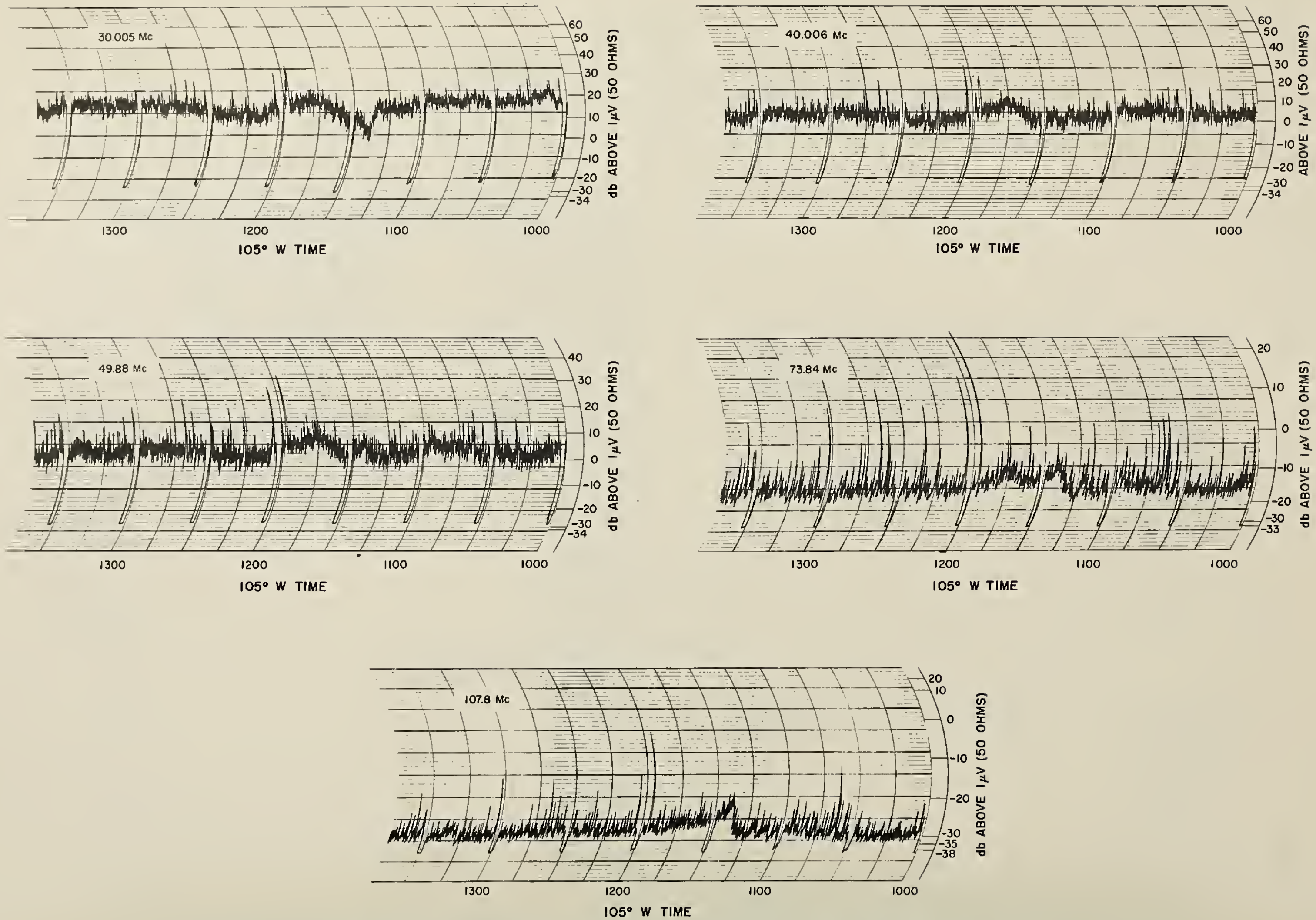
MEDIAN VALUES OF RECEIVED SIGNAL INTENSITIES DURING ELEVEN SIMULTANEOUS OCCURRENCES OF Es ON FOUR FREQUENCIES FROM SEPTEMBER 1, 1957 TO JUNE 30, 1958

FIGURE 9



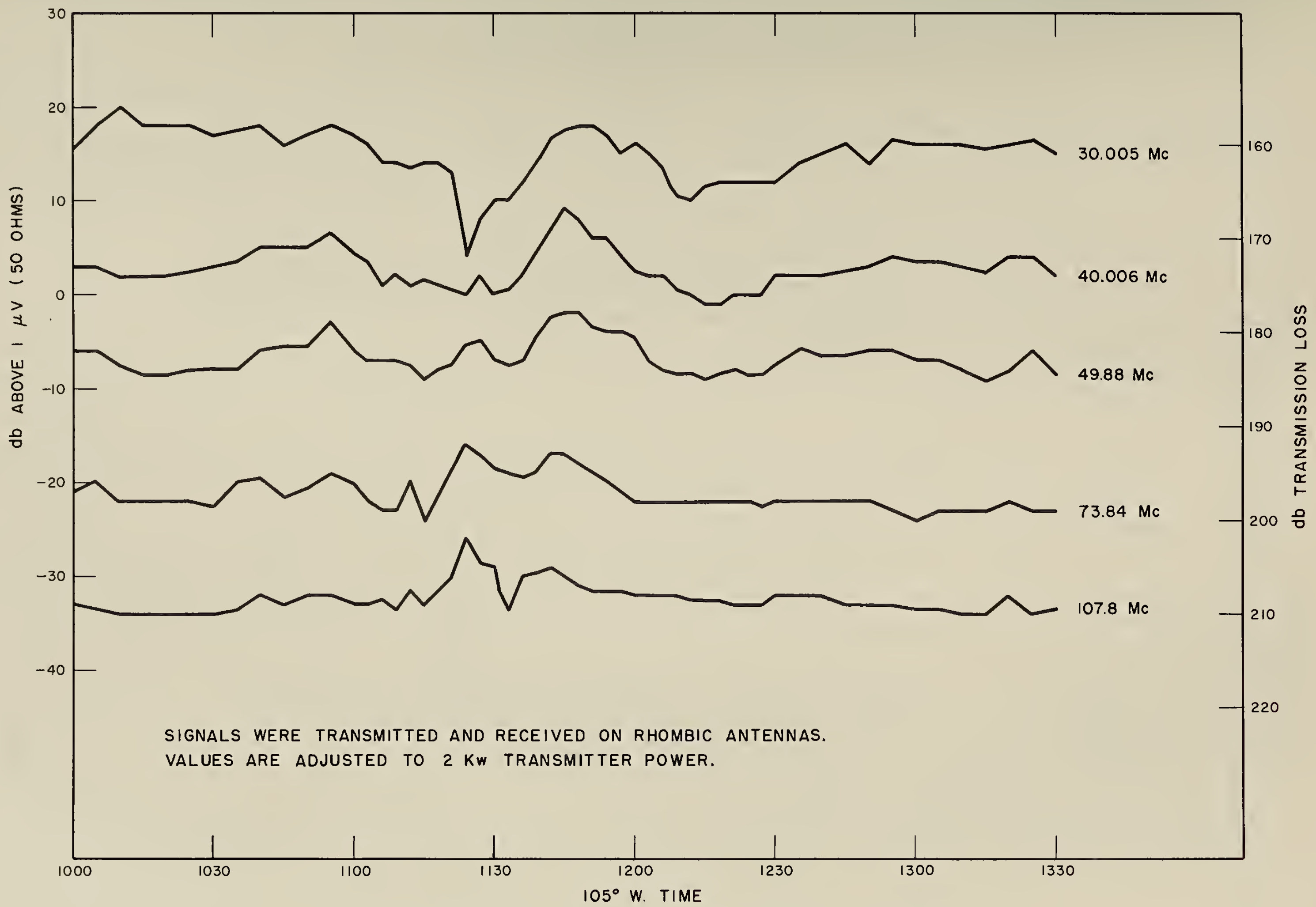
NUMBER OF HOURS SPORADIC—E OCCURRED FROM
SEPTEMBER, 1957 THROUGH JUNE, 1958

FIGURE 10



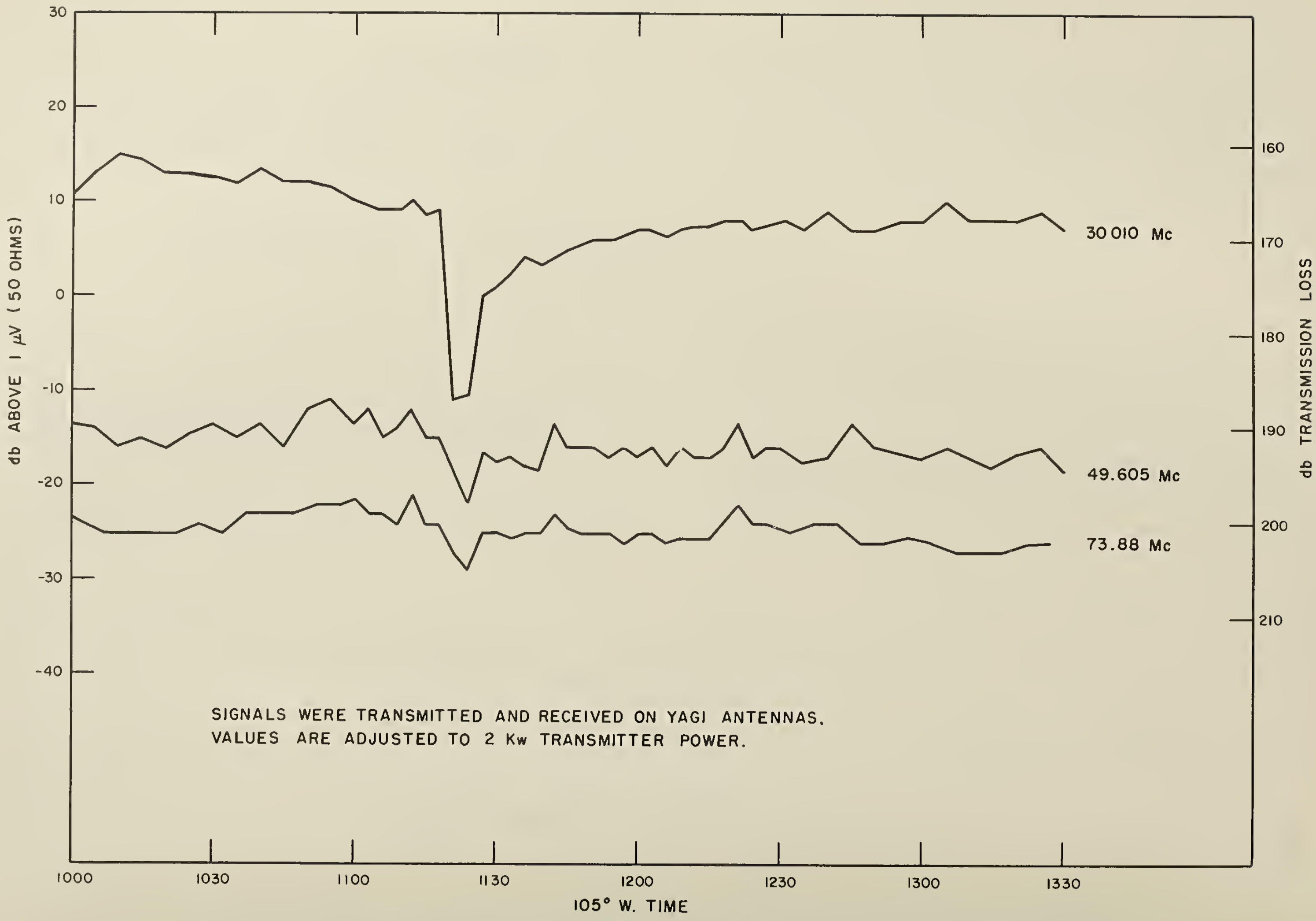
RECORDS MADE DURING AN SID ON MARCH 29, 1958 (RHOMBIC ANTENNAS)

FIGURE 11



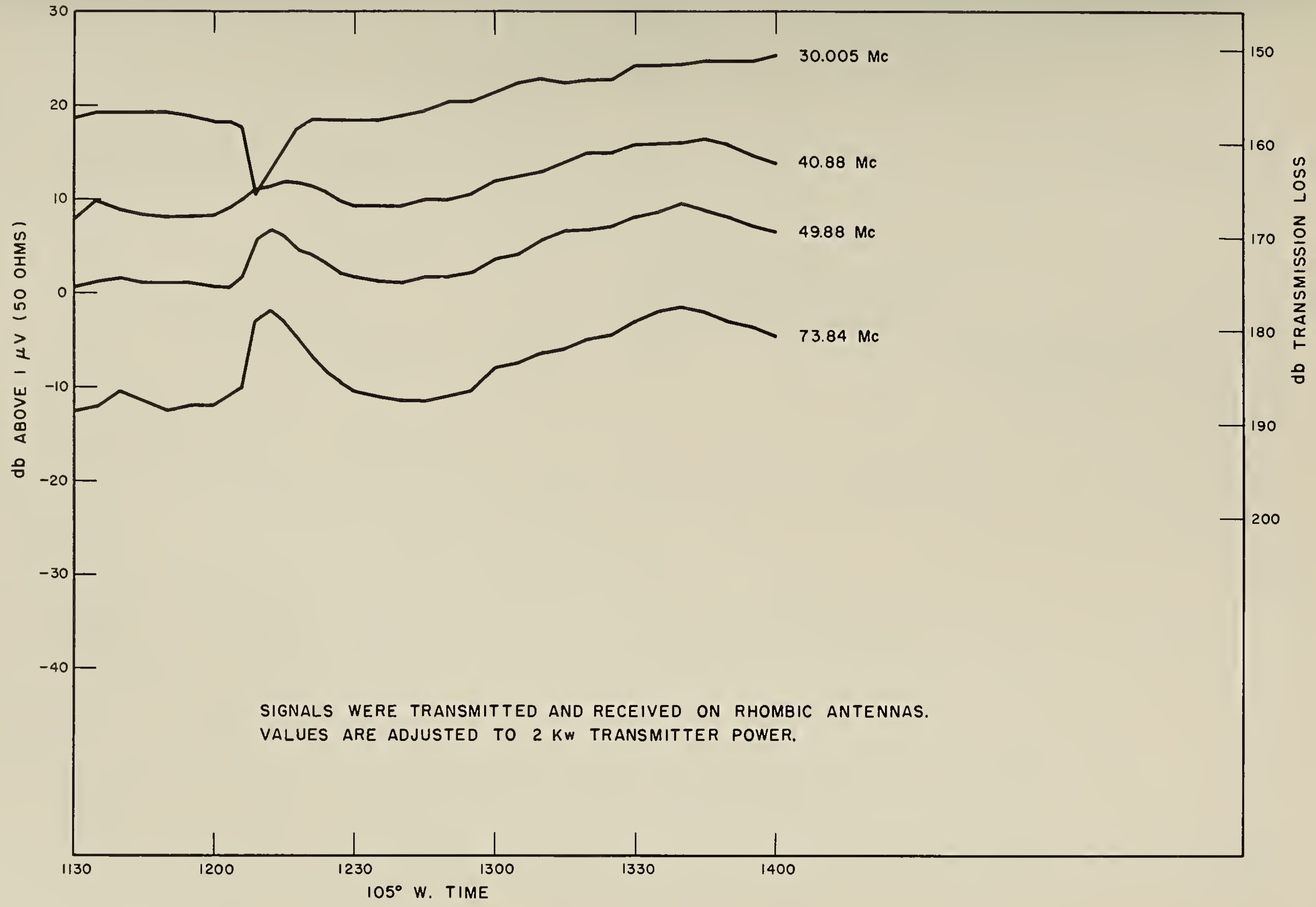
SIGNAL BEHAVIOR DURING SID OF MARCH 29, 1958

FIGURE 12



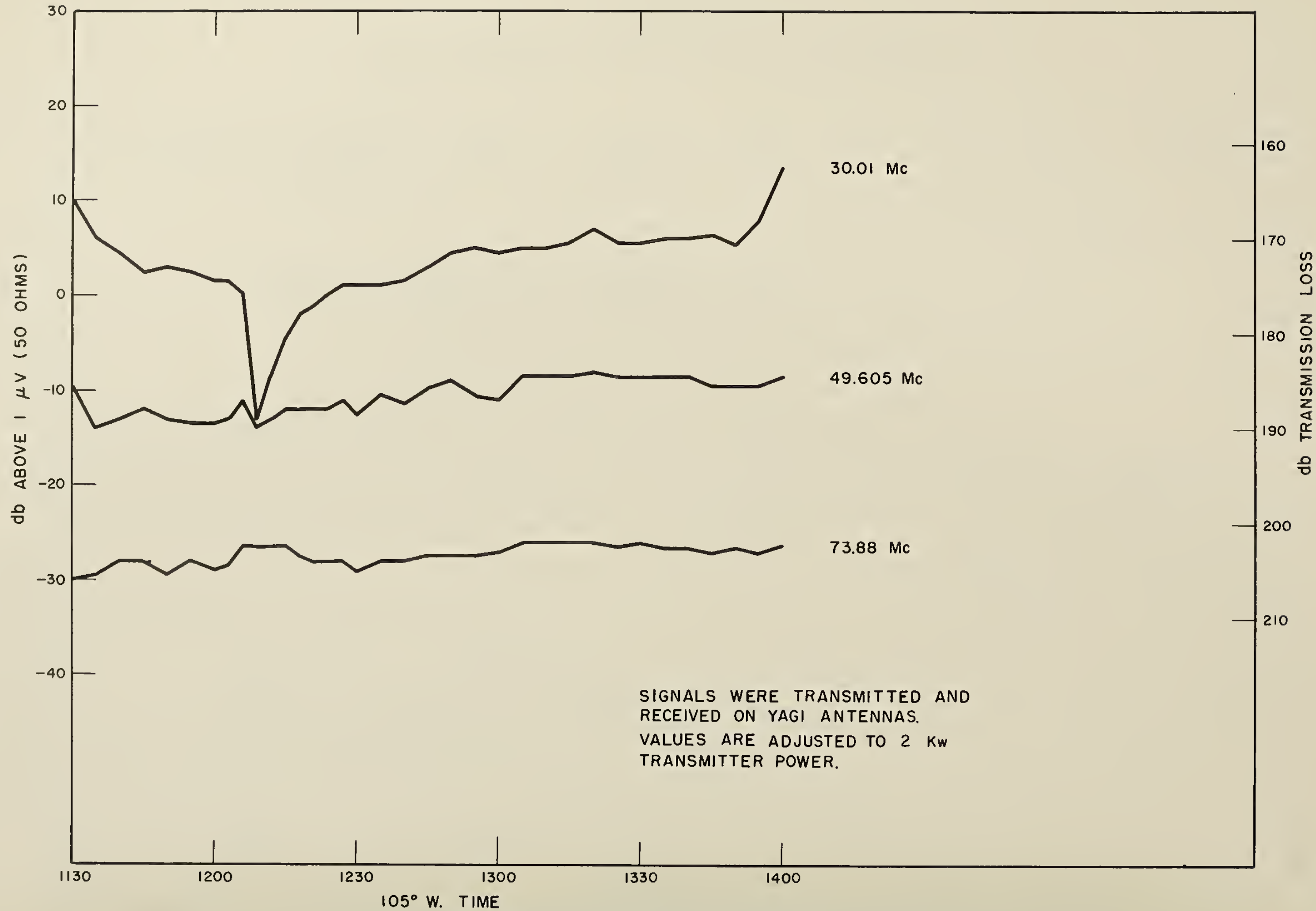
SIGNAL BEHAVIOR DURING SID OF MARCH 29, 1958

FIGURE 13



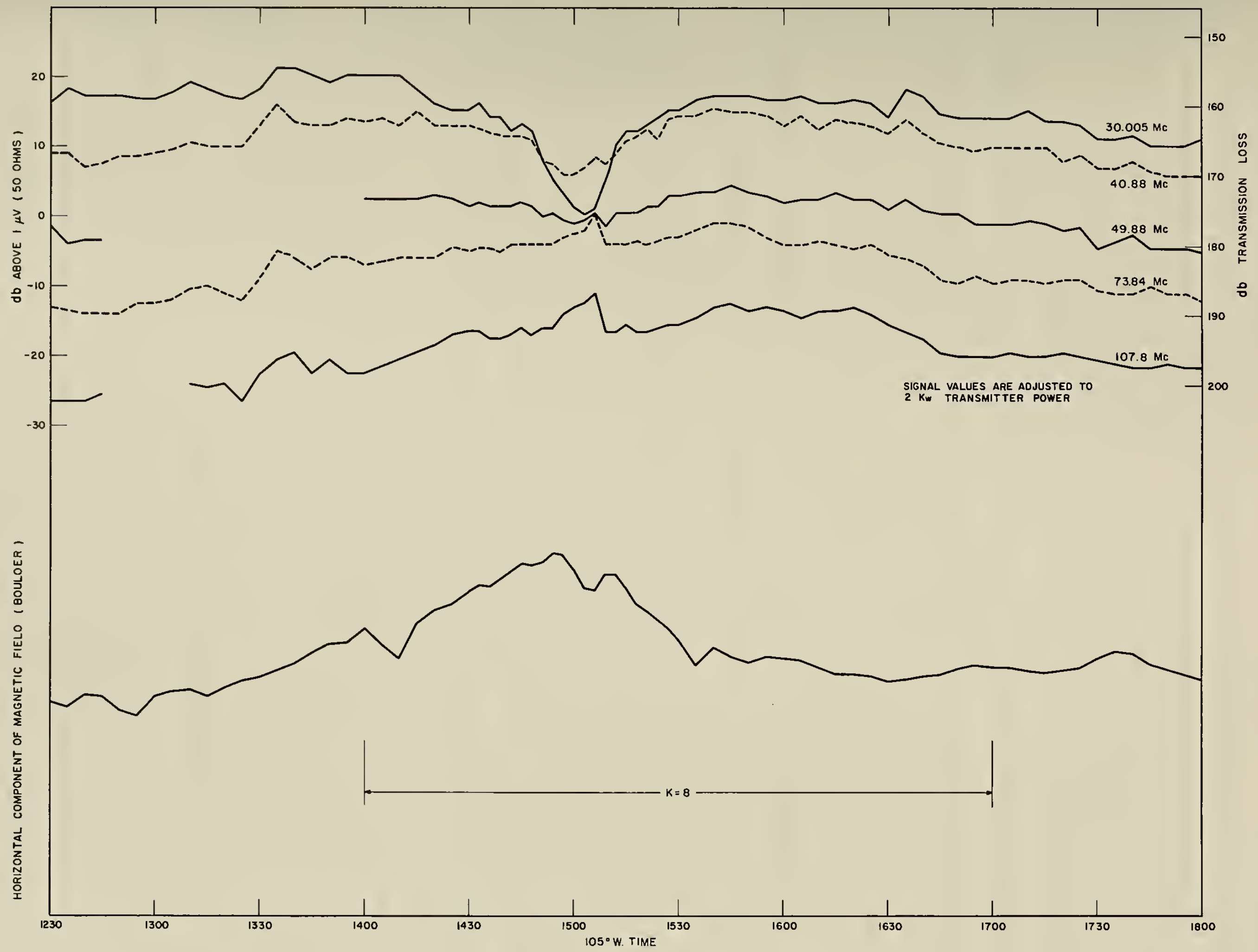
SIGNAL BEHAVIOR DURING SID OF JULY 19, 1958

FIGURE 14



SIGNAL BEHAVIOR DURING SID OF JULY 19, 1958

FIGURE 15



CORRELATION OF MAGNETIC ACTIVITY WITH SIGNAL BEHAVIOR FOR A MAGNETIC DISTURBANCE OCCURRING JULY 8, 1958

FIGURE 16

A comparison of signal behavior during SID's (figures 12 and 14) with that during magnetic disturbance reveals a difference that may have physical significance. In figures 12 and 14 the signal goes into its abnormal level in a relatively small time interval and recovers more slowly. This is the usual pattern of signal behavior during SID's. However, the magnetic disturbance shown in figure 16 displays just the opposite signal variations. The signal goes into its abnormal level relatively slowly and recovers in a much smaller period of time.

These effects are evidently extreme cases of general effects that are present all the time. Bailey, Bateman and Kirby[2] found correlations showing that in the Arctic, general increases in HF absorption were accompanied by stronger VHF scatter signals and that higher magnetic K-indexes were related to stronger VHF signals.

A study of these effects is of interest from a practical standpoint, because it adds an element of attractiveness to scatter communications in regions where HF blackouts are frequent. Such a study is also of considerable interest from the standpoint of obtaining a basic understanding of the ionosphere. For example, one school of thought has been that scatter signals are due primarily, if not entirely, to reflections or scattering from many meteor trails.[10] The foregoing relations between magnetic activity and signal intensity would tend to discredit such a theory.

This tendency of lower-frequency signals to show absorption at the same time enhancements occur with higher frequency signals may help to explain the lower value of the frequency-dependence exponent during the middle of the day in June.

4. AMPLITUDE DISTRIBUTIONS AND FADING RATES

Amplitude-distribution and fading-rate data are important in modulation studies and useful in separating the components of received signal that are due to meteor bursts, scatter mechanisms and sporadic E. In this report, data are presented that were taken from high-speed signal intensity records during periods of 0430 - 0439, 1150 - 1200, 1917 - 1925 MST on June 27, 1958 and 0000 - 0010 MST, June 28, 1958. All frequencies presented in each figure were recorded simultaneously.

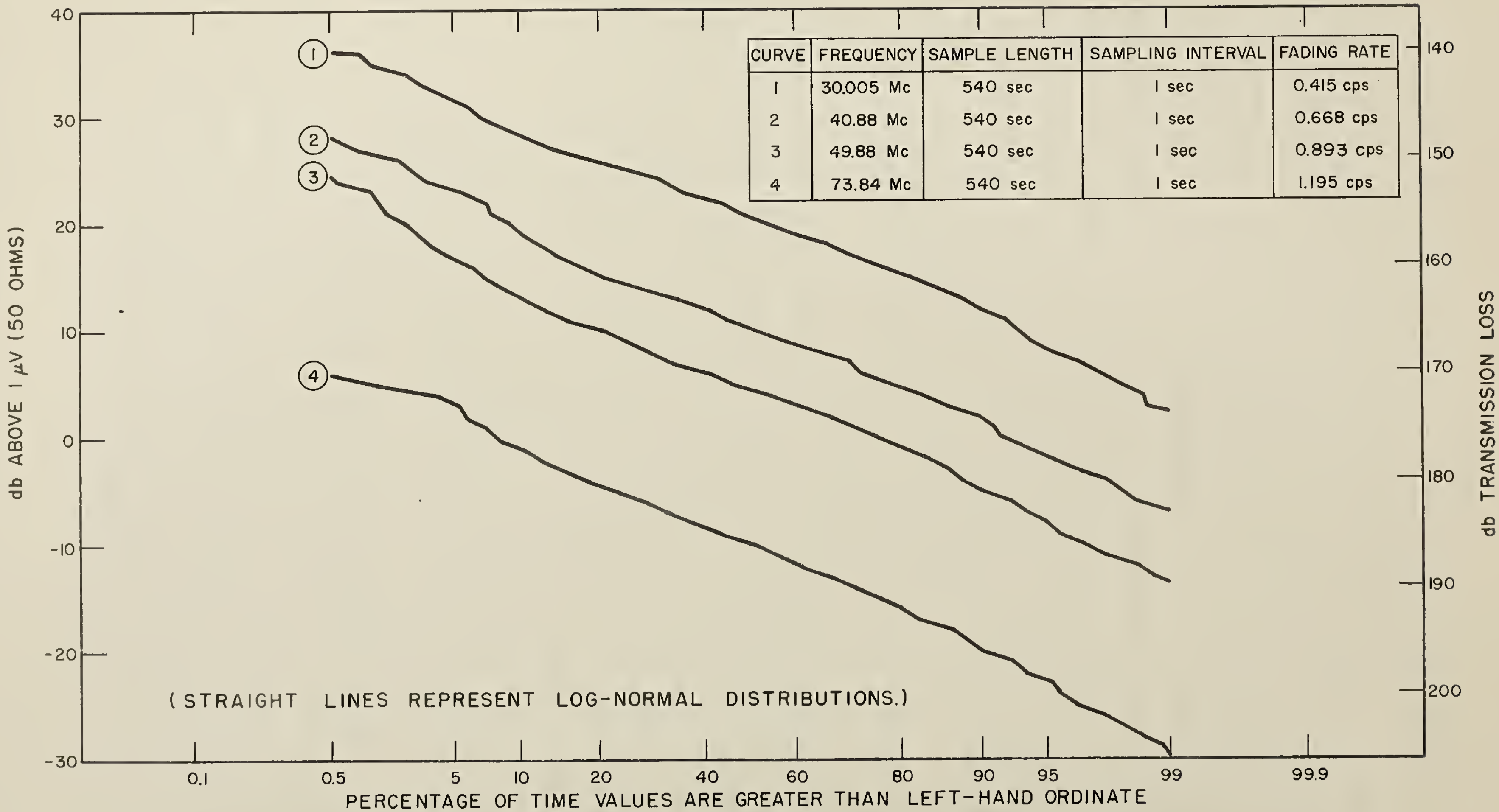
4.1 Amplitude Distributions

Amplitude distributions for the above periods are shown in figures 17 to 24, plotted on two different coordinate systems. It will be noticed that the distributions of the noon signals are very close to Rayleigh distributions for all but very weak signals while plots of the signals taken during the other periods are more nearly log-normal, as shown by the tendency of the points to form a straight line on normal probability coordinate systems. The reason for this change of shape of the distribution is very probably the effect of meteor bursts on the signal during these weaker-signal periods. The set of Rayleigh distributions that was obtained from signals not evidently perturbed by meteors is one of three sets that have been obtained during strong-signal periods and is in agreement with earlier work done by Sugar[9] and later Koch[11].

4.2 Fading Rates

Fading rates have been observed to vary over a wide range of values. In cases where sporadic E does not effect the signal, the extreme value may be as much as from 0.3 to 1.0 cps on 30 Mc and from 1.0 to 2.0 cps on 108 Mc. In cases of strong sporadic E signals the fading rates are much lower. Sporadic E fading rates of less than 0.10 cps were observed on 30 Mc. Simultaneous recordings on both rhombic and Yagi antennas reveal that fading rates of signals received on the Yagi antennas are much greater, in some cases 5 times as great.

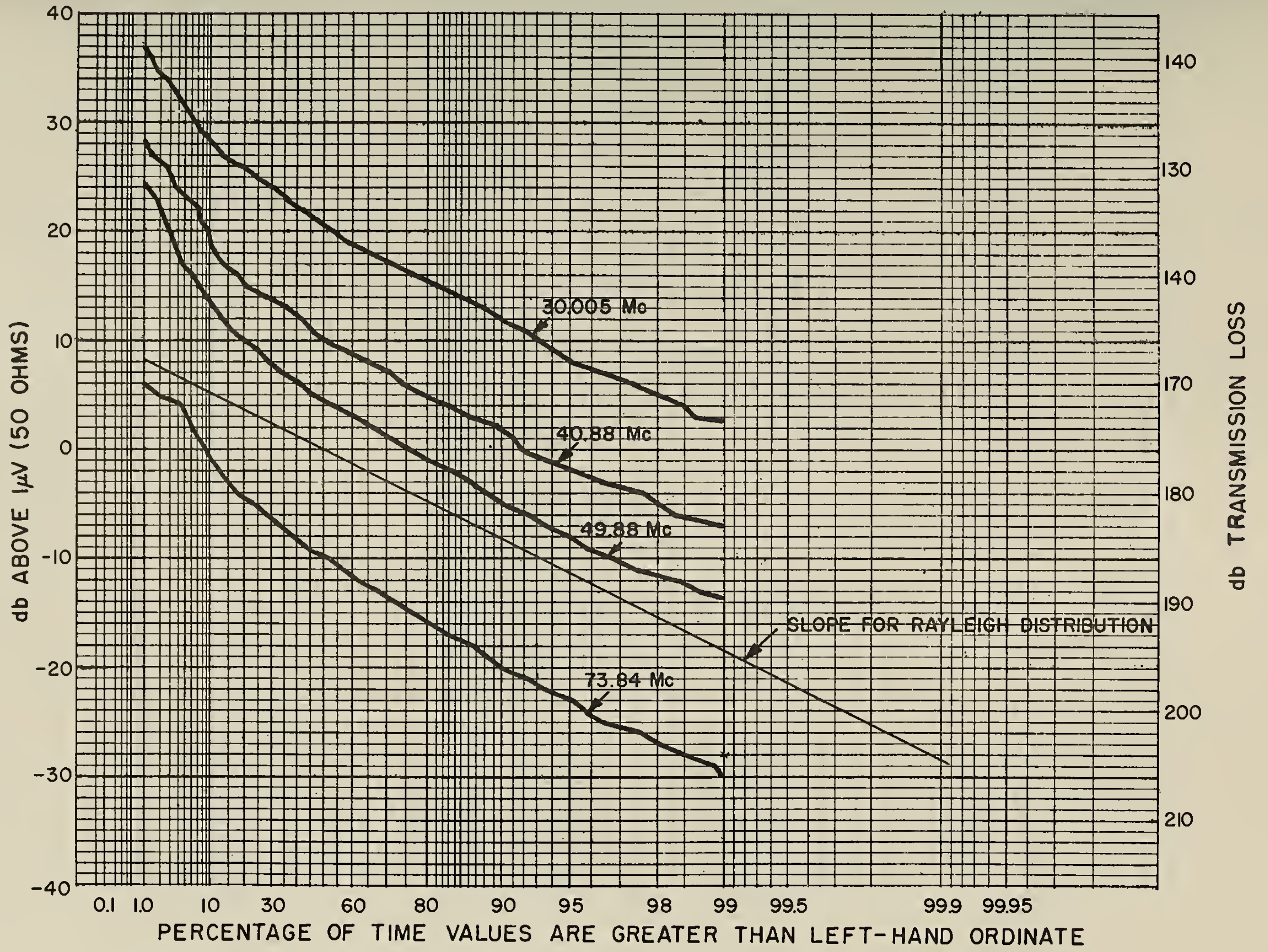
Figure 25 shows the dependence of fading rate on frequency for three ten-minute periods. The log of average fading rate is plotted against the log of frequency in megacycles. The average-slope lines indicate the values of the exponent n in the relation, fading rate $\propto f^n$, on the assumption that n is constant over the frequency range. The same value of n, 1.07, is found for the early morning and noontime periods. A lower value of n, 0.74, applies to the midnight period (curve 3). A comparison of the fading rates with the curve of meteoric activity (figure 5) fails to reveal a simple dependence between the two. It is of interest to note that the deviations of the points on curve 1, for



CURVE	FREQUENCY	SAMPLE LENGTH	SAMPLING INTERVAL	FADING RATE
1	30.005 Mc	540 sec	1 sec	0.415 cps
2	40.88 Mc	540 sec	1 sec	0.668 cps
3	49.88 Mc	540 sec	1 sec	0.893 cps
4	73.84 Mc	540 sec	1 sec	1.195 cps

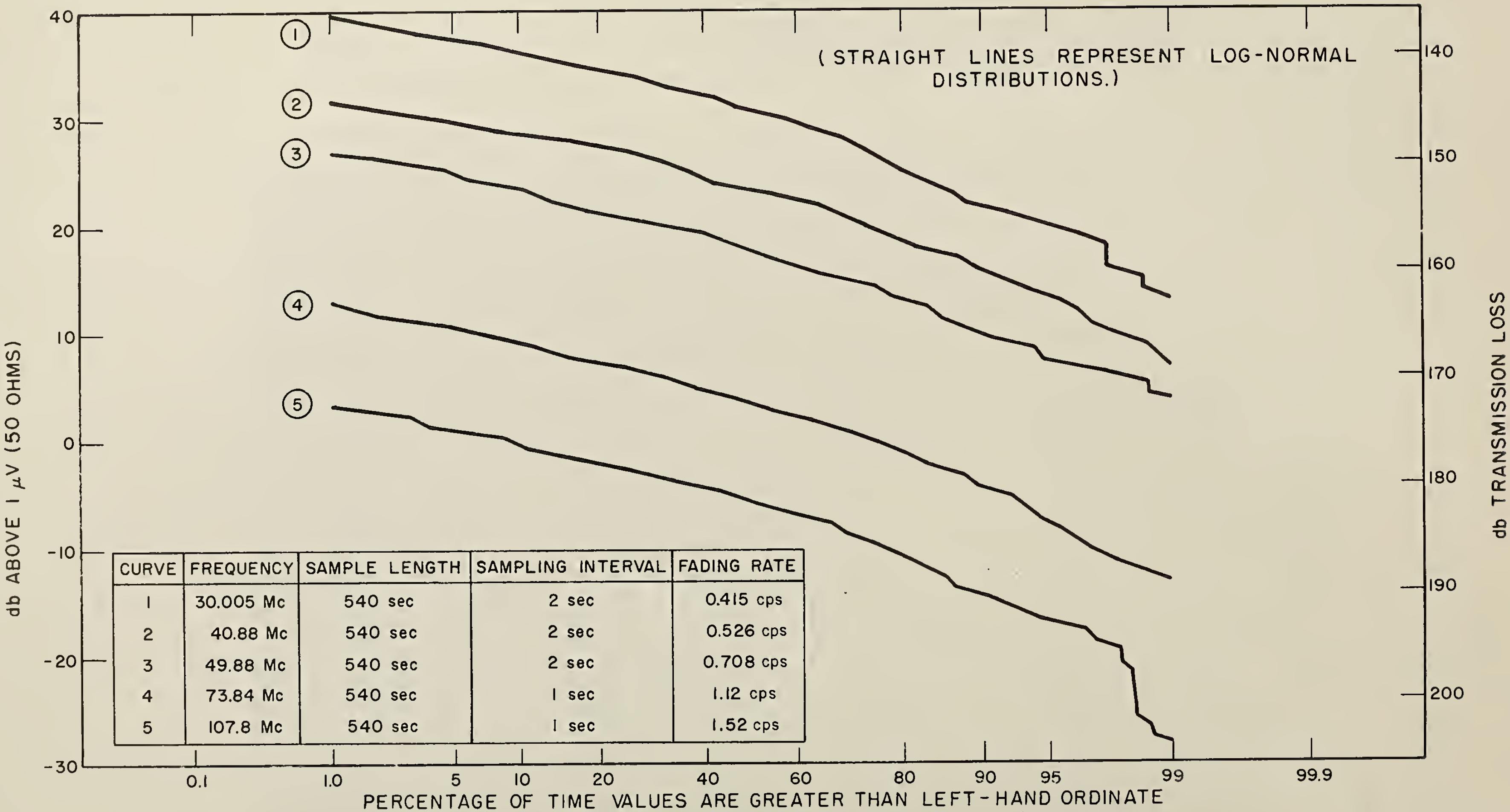
AMPLITUDE DISTRIBUTION OF SIGNAL INTENSITY VALUES RECEIVED DURING PERIOD OF 0430-0439 HOURS 105° W TIME, JUNE 27, 1958

FIGURE 17



AMPLITUDE DISTRIBUTION OF SIGNAL INTENSITY VALUES RECEIVED DURING PERIOD OF 0430-0439 HOURS 105°W TIME JUNE 27, 1958

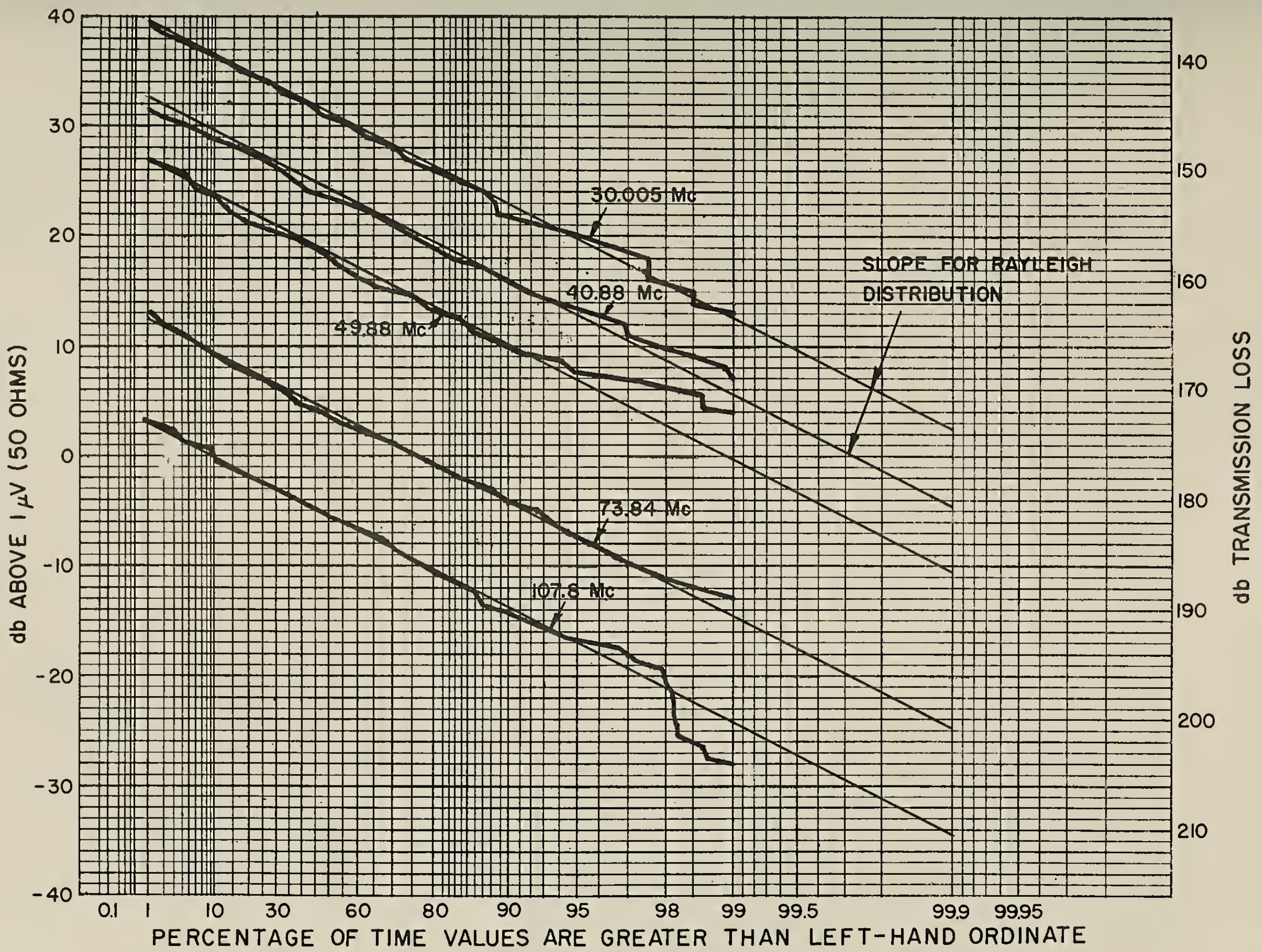
FIGURE 18



CURVE	FREQUENCY	SAMPLE LENGTH	SAMPLING INTERVAL	FADING RATE
1	30.005 Mc	540 sec	2 sec	0.415 cps
2	40.88 Mc	540 sec	2 sec	0.526 cps
3	49.88 Mc	540 sec	2 sec	0.708 cps
4	73.84 Mc	540 sec	1 sec	1.12 cps
5	107.8 Mc	540 sec	1 sec	1.52 cps

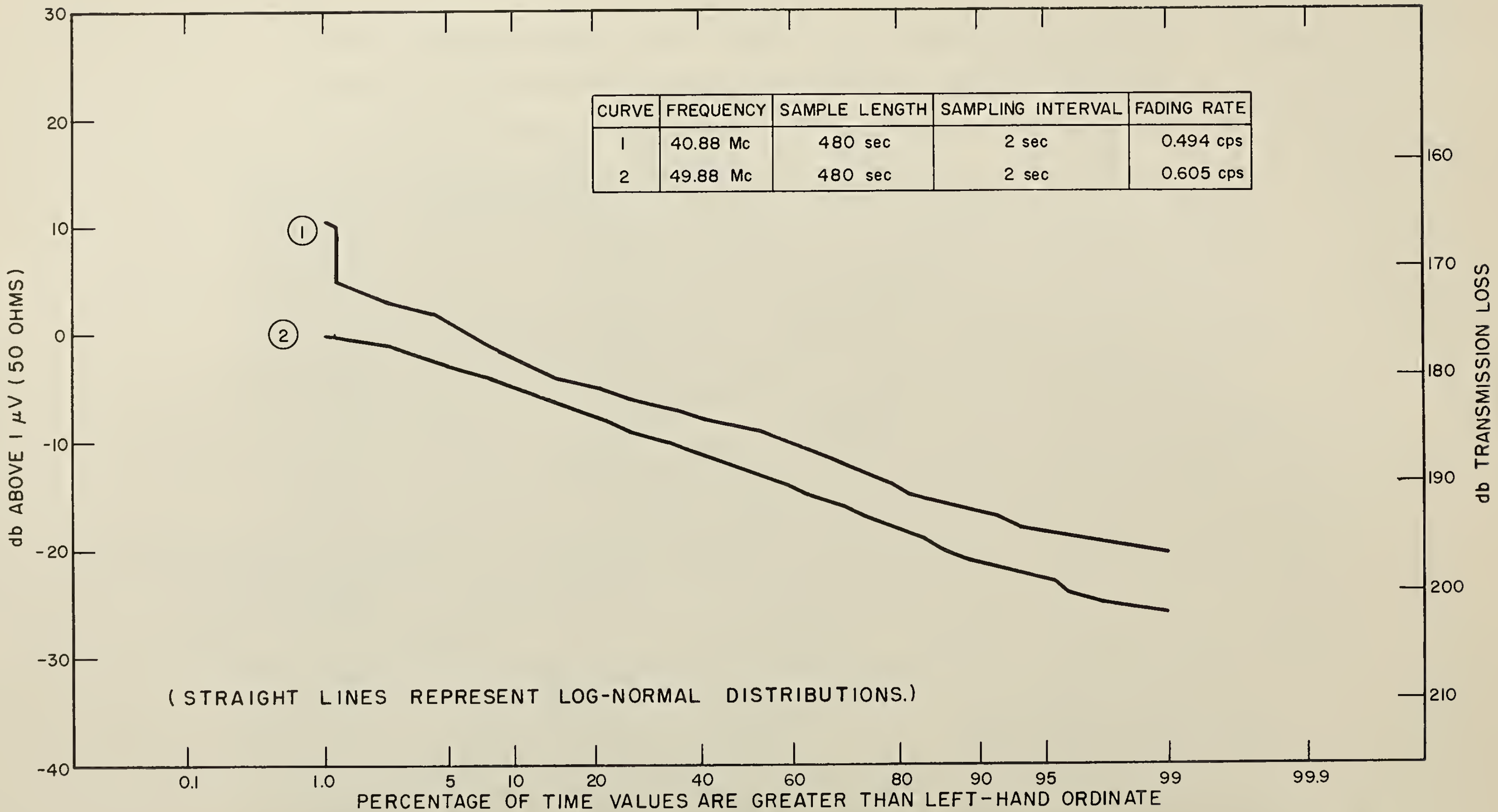
AMPLITUDE DISTRIBUTION OF SIGNAL INTENSITY VALUES RECEIVED DURING PERIOD OF 1150-1200 HOURS 105° W TIME JUNE 27, 1958

FIGURE 19



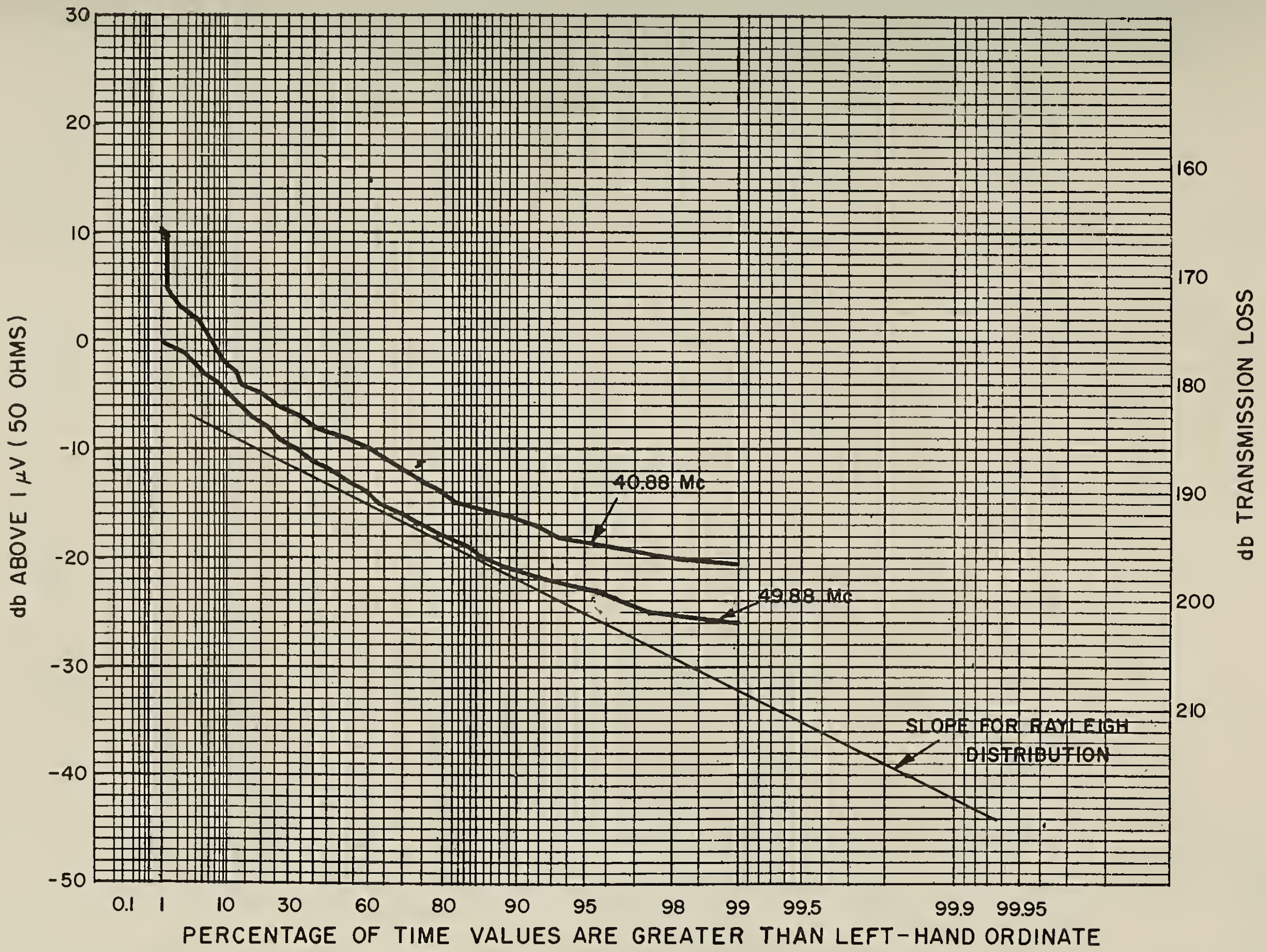
AMPLITUDE DISTRIBUTION OF SIGNAL INTENSITY VALUES RECEIVED DURING PERIOD OF 1150-1200 HOURS, 105° W TIME JUNE 27, 1958

FIGURE 20



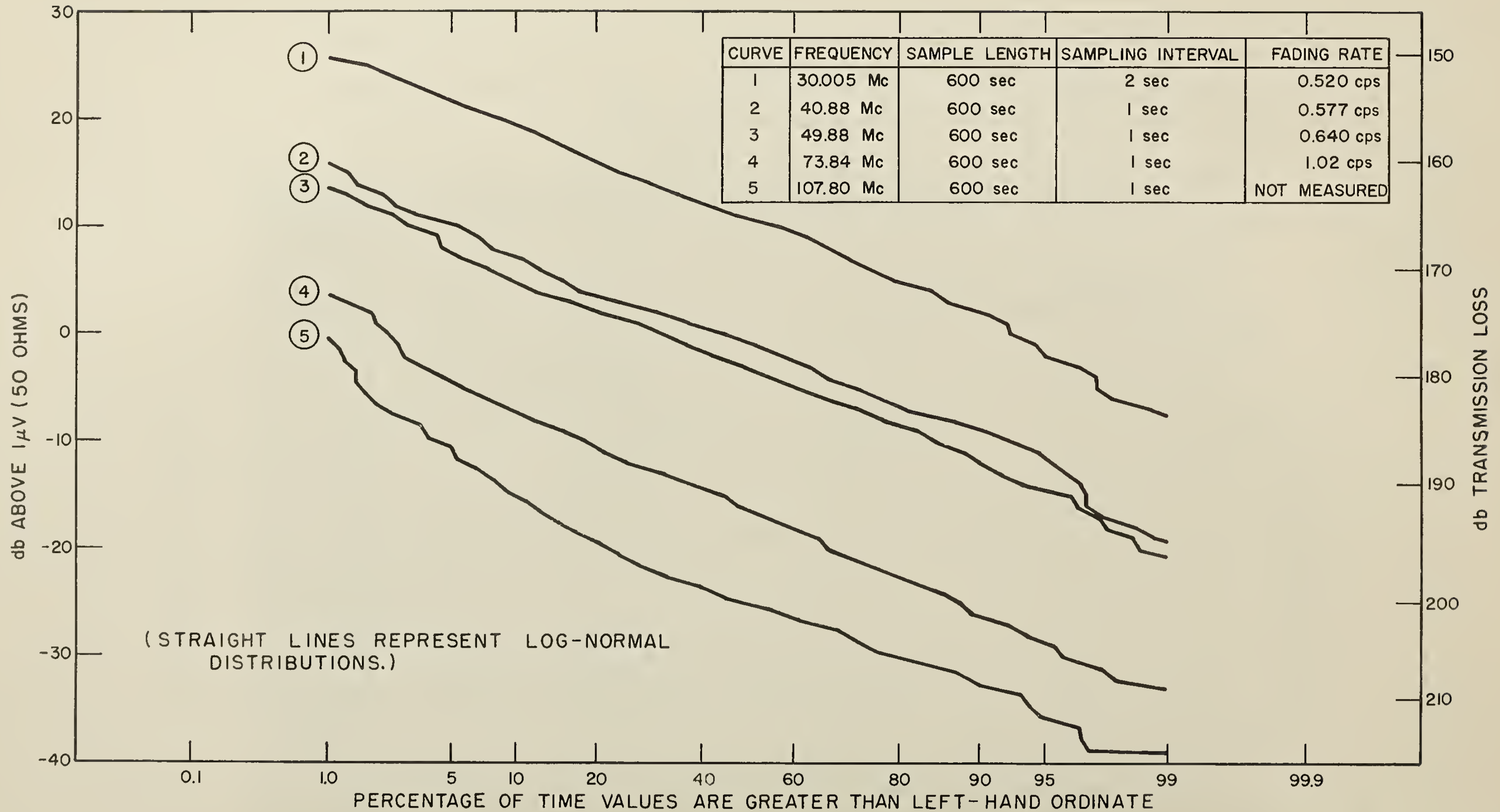
AMPLITUDE DISTRIBUTION OF SIGNAL INTENSITY VALUES RECEIVED
DURING PERIOD OF 1917-1925 HOURS 105° W TIME, JUNE 27, 1958

FIGURE 21



AMPLITUDE DISTRIBUTION OF SIGNAL INTENSITY VALUES RECEIVED DURING PERIOD OF 1917-1925 HOURS 105° W TIME, JUNE 27, 1958

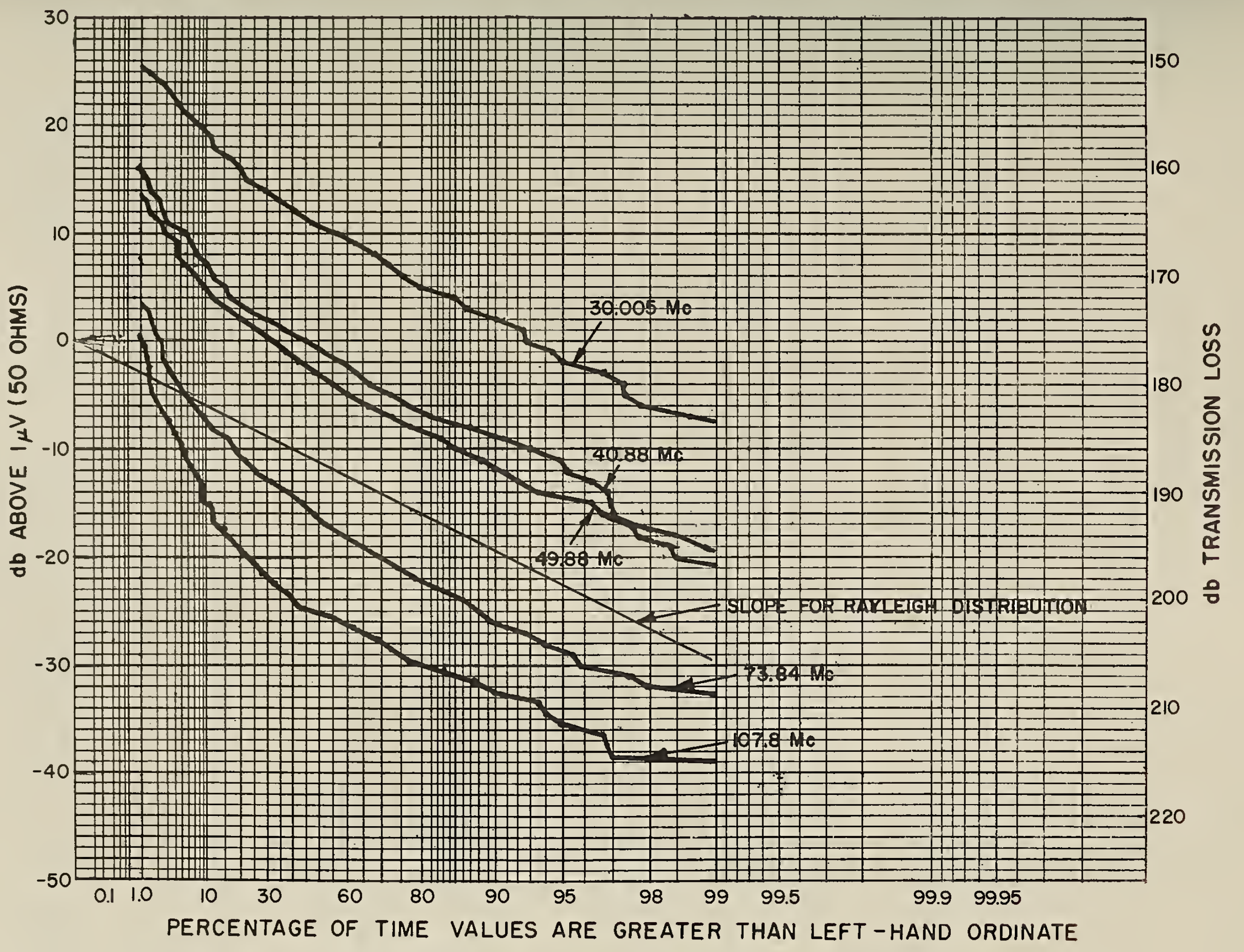
FIGURE 22



CURVE	FREQUENCY	SAMPLE LENGTH	SAMPLING INTERVAL	FADING RATE
1	30.005 Mc	600 sec	2 sec	0.520 cps
2	40.88 Mc	600 sec	1 sec	0.577 cps
3	49.88 Mc	600 sec	1 sec	0.640 cps
4	73.84 Mc	600 sec	1 sec	1.02 cps
5	107.80 Mc	600 sec	1 sec	NOT MEASURED

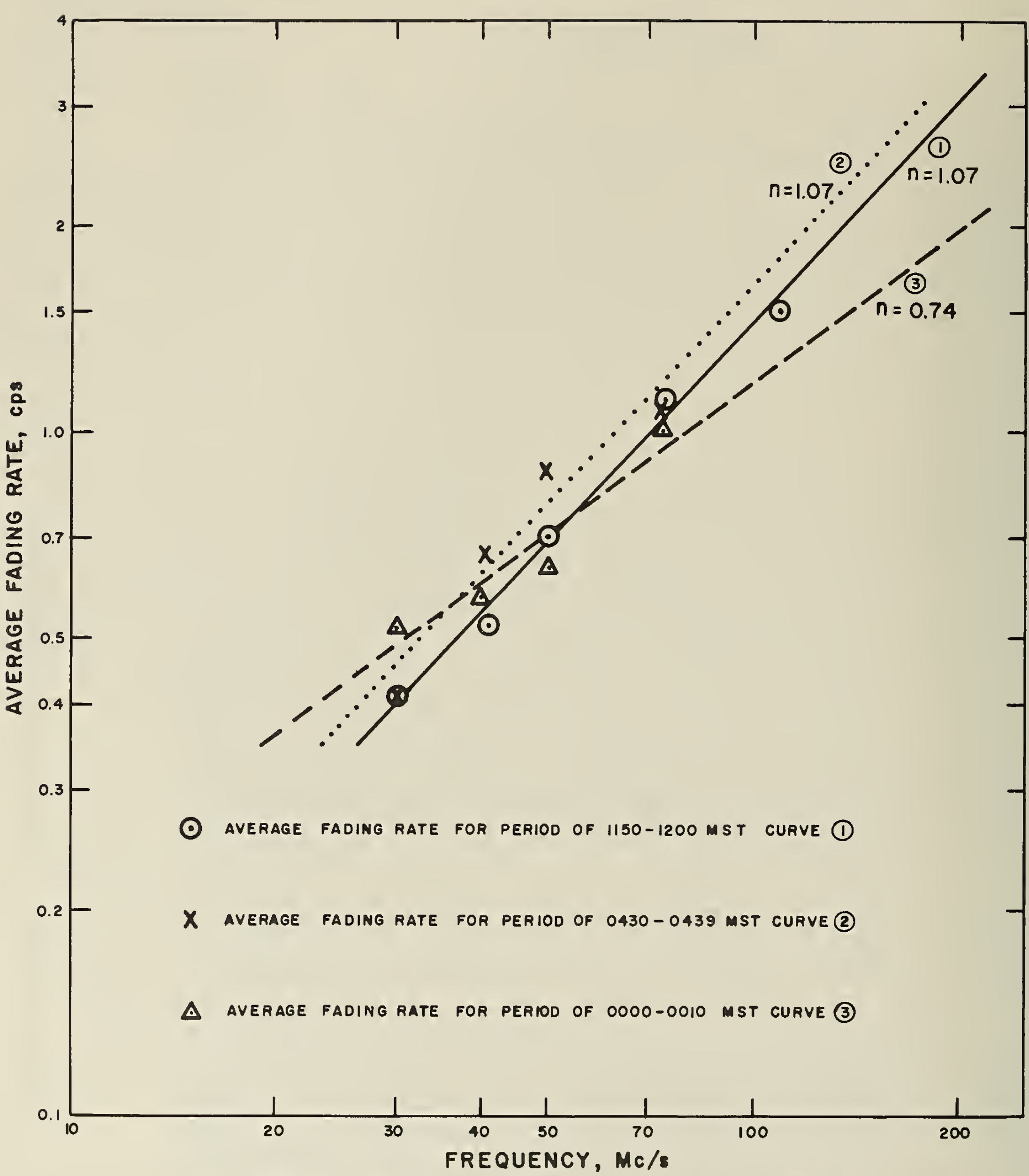
AMPLITUDE DISTRIBUTION OF SIGNAL INTENSITY VALUES RECEIVED
DURING PERIOD OF 0000-0010 HOURS 105° W TIME JUNE 28,1958

FIGURE 23



AMPLITUDE DISTRIBUTION OF SIGNAL INTENSITY VALUES RECEIVED DURING PERIOD OF 0000-0010 HOURS 105° W TIME JUNE 28, 1958

FIGURE 24



FADING RATE vs. FREQUENCY FROM RECORDS MADE JUNE 27-28, 1958

FIGURE 25

the noon period, are small compared to the other two curves. For this reason, it may be that the assumption of a constant exponent is justifiable only in cases where the signal is not appreciably affected by meteor bursts.

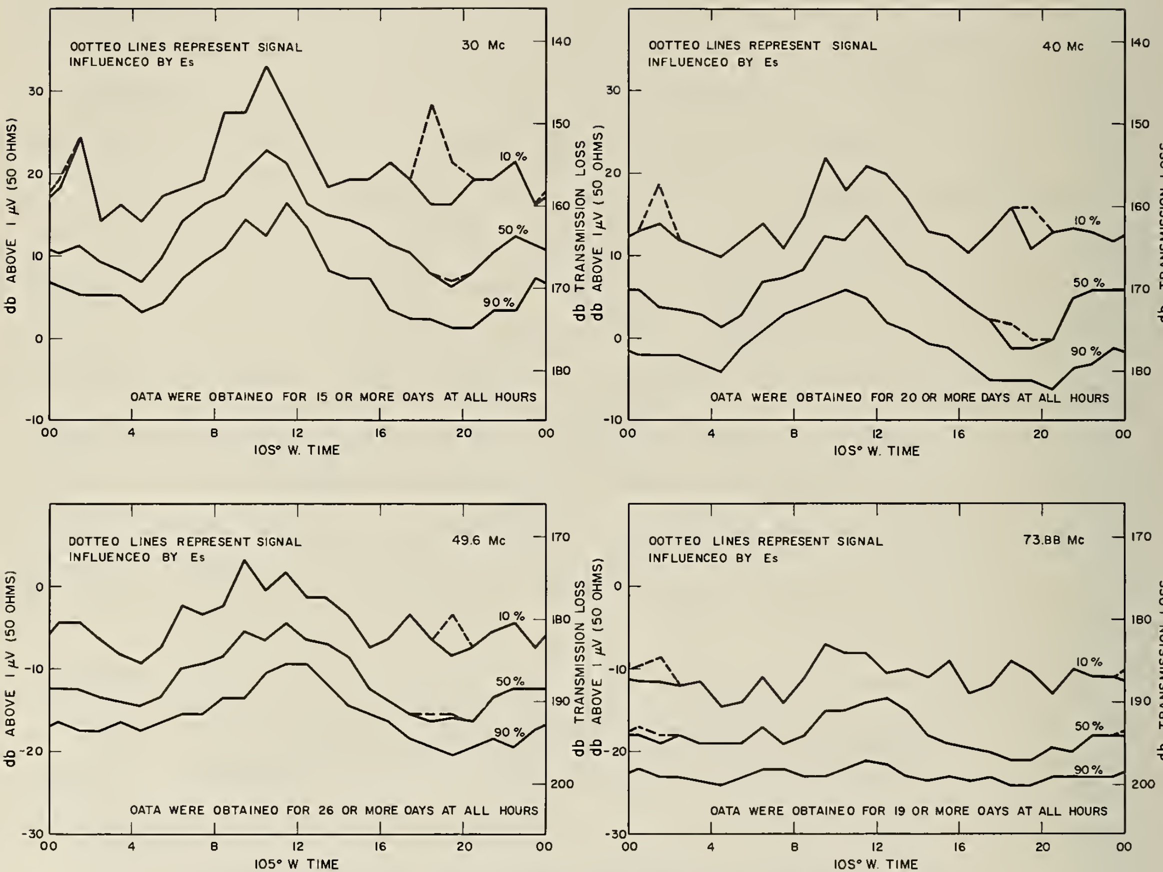
5. SUMMARY OF MEDIAN VALUES OF RECEIVED SIGNALS

Figures 26 to 35 are plots of the hourly median and upper and lower decile values of signals received during the period of September, 1957 through June, 1958. The signal intensity values are based on open-circuit antenna voltages for antenna impedances of 50 ohms. It is well known that scatter signals have their lowest values at the equinoxes and highest values in the summer. However, the data in these figures together with the low exponents for June (figure 5) show that this seasonal effect is frequency-dependent. The 30 Mc signal has much less of this seasonal variation than does the 108 Mc signal. The effect of absorption is one factor tending to hold the signal levels down on the lower frequencies. The data presented under "SID Behavior" suggests a correlation between low-frequency absorption and high-frequency enhancement, and the frequency dependence in the seasonal variation is just another evidence of such a correlation.

The dotted lines on figures 26 to 35 represent the values of signal intensity including the effects of any sporadic E propagation that occurred. Sporadic E effects were greatest in July; they were considerable in October, December, April, May and June. Minor sporadic E effects appear in the figures for September, November, January and February. None at all are seen in March.

In nearly all cases, the curves of figures 26 to 35 reach a minimum in the vicinity of 1900 hours MST. As was shown in figure 5, this is the period of lowest meteor-burst activity.

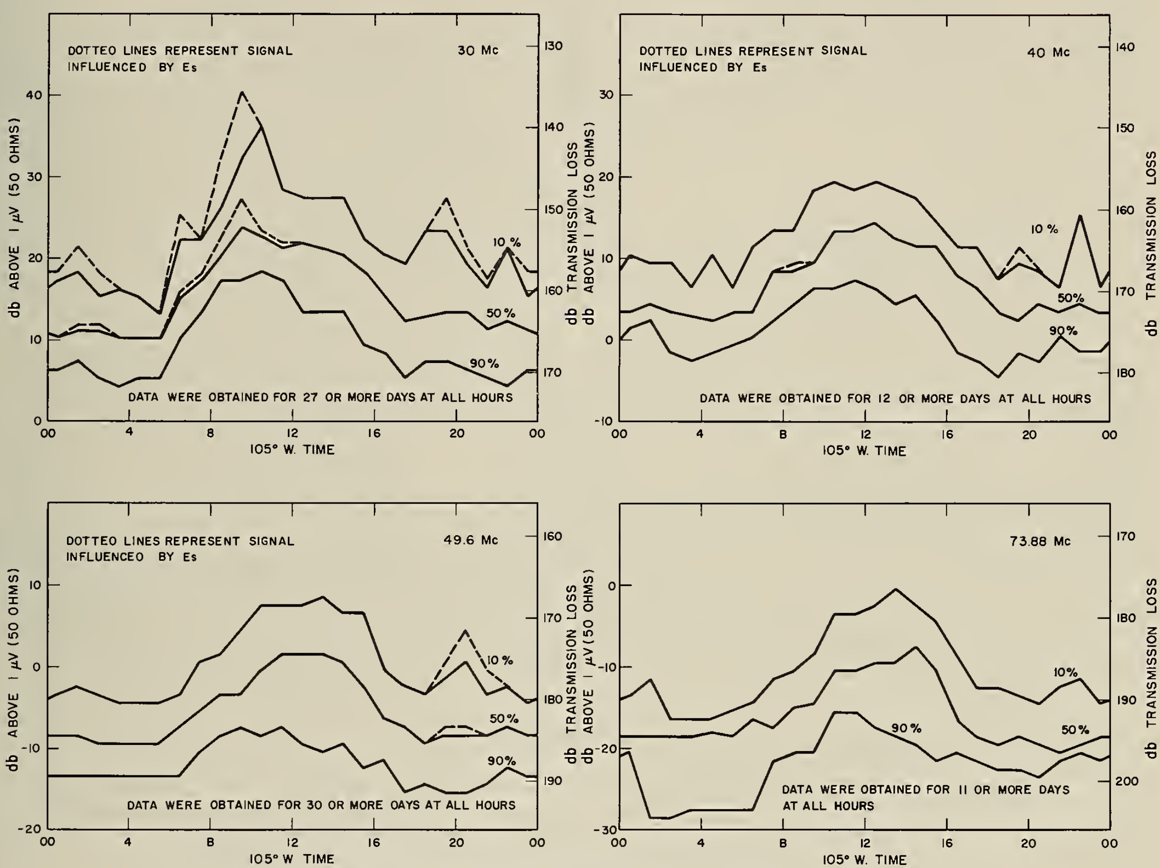
Within a given month the general signal level may rise or fall by several decibels. For this reason some of the curves in figures 26-35 that are based on only a few days' data concentrated in a particular part of the month do not represent the true median values for the month. However, the straight-line frequency dependence relationship found to



VALUES OF RECEIVED SIGNAL INTENSITY EQUALED OR EXCEEDED 10%, 50%, AND 90% OF THE TIME FOR THE MONTH OF SEPTEMBER, 1957. (ALL VALUES ADJUSTED TO 2 KILOWATTS TRANSMITTER POWER)

RECEIVED SIGNAL INTENSITY

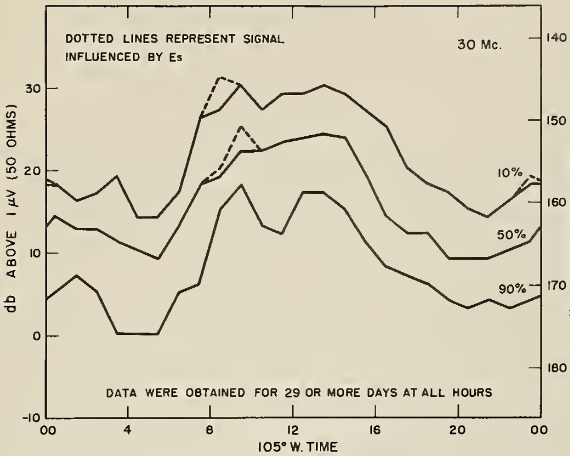
FIGURE 26

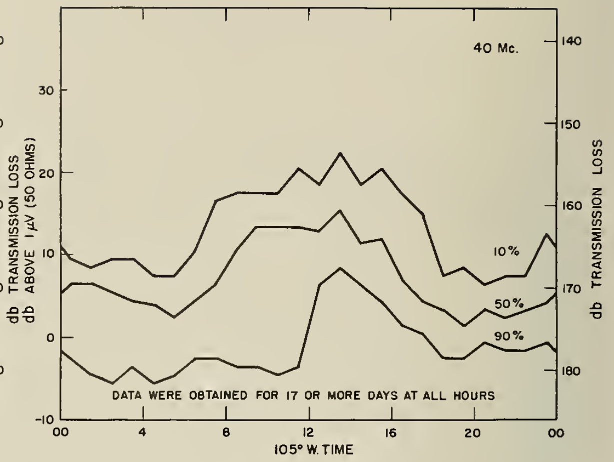


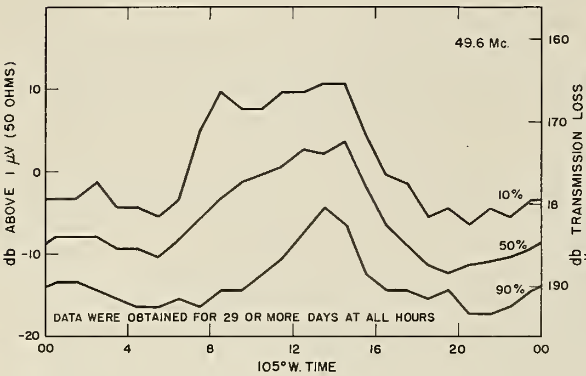
VALUES OF RECEIVED SIGNAL INTENSITY EQUALED OR EXCEEDED 10%, 50%, AND 90% OF THE TIME
FOR THE MONTH OF OCTOBER, 1957. (ALL VALUES ADJUSTED TO 2 KILOWATTS TRANSMITTER POWER)

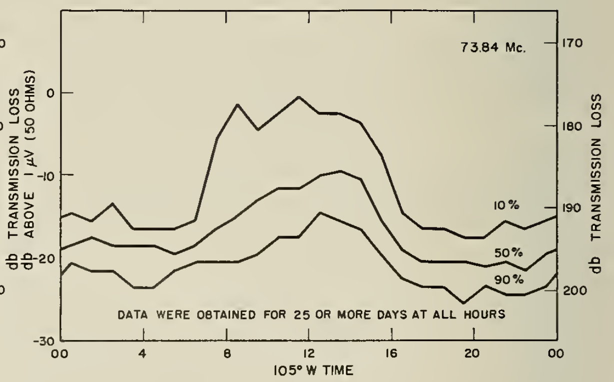
RECEIVED SIGNAL INTENSITY

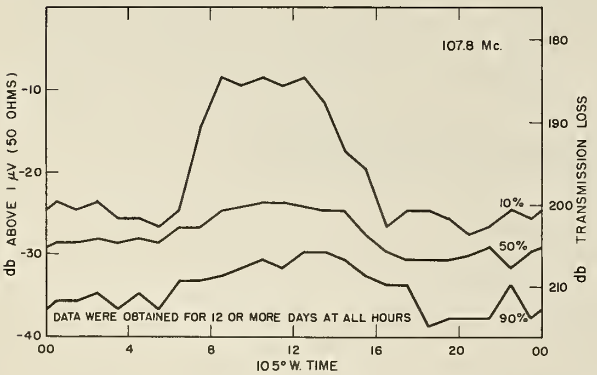
FIGURE 27







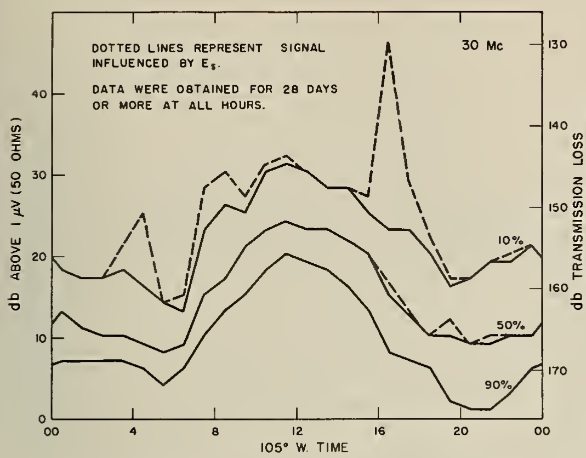


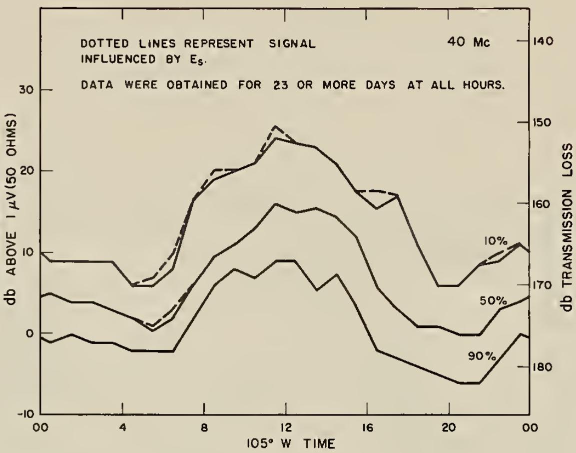


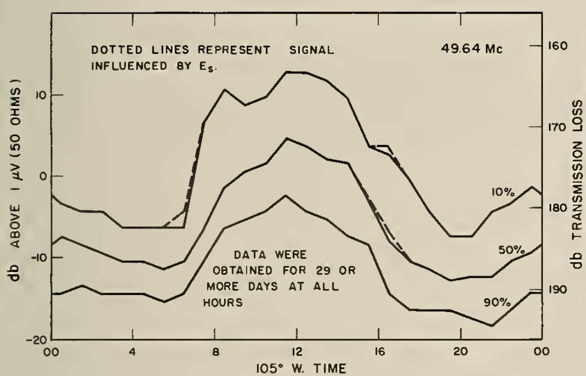
VALUES OF RECEIVEO SIGNAL INTENSITY EQUALEO OR EXCEEDED 10%, 50%, AND 90% OF THE TIME FOR THE MONTH OF NOVEMBER, 1957. (VALUES AOJUSTED TO 2 Kw. TRANSMITTER POWER)

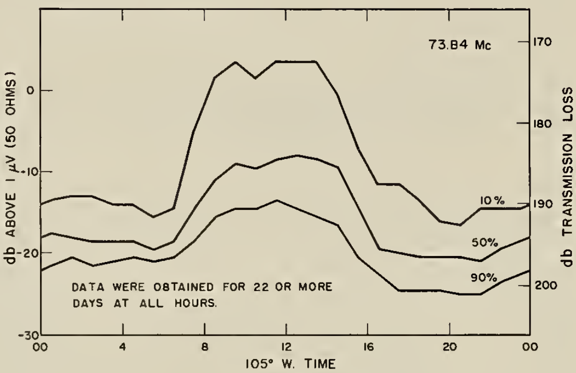
RECEIVED SIGNAL INTENSITY

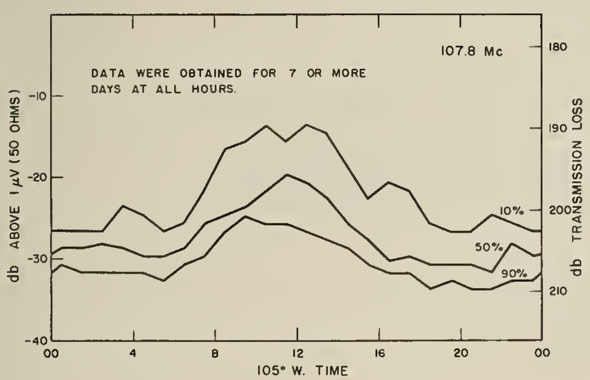
FIGURE 28









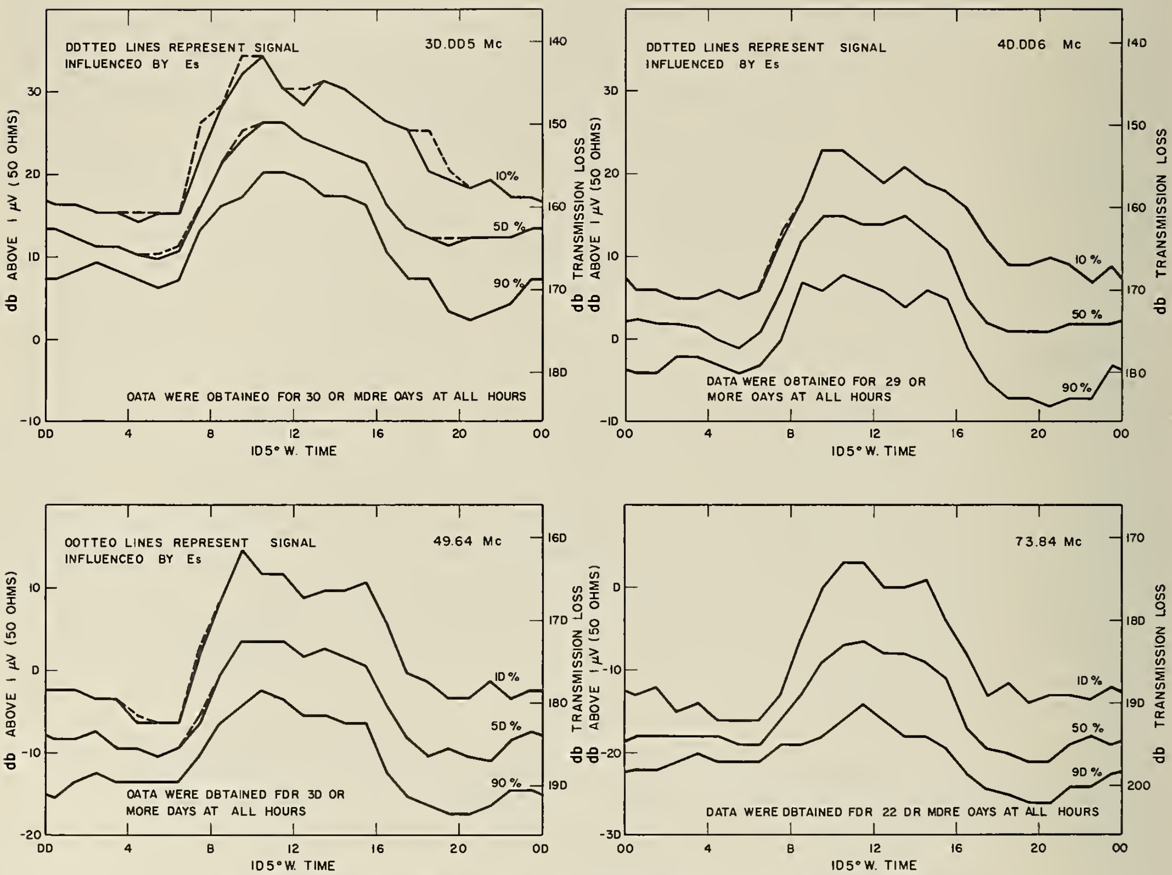


VALUES OF RECEIVED SIGNAL INTENSITY EQUALED OR EXCEEDED 10%, 50%, AND 90% OF THE TIME FOR THE MONTH OF DECEMBER 1957.

(VALUES ADJUSTED TO 2 Kw TRANSMITTER POWER)

RECEIVED SIGNAL INTENSITY

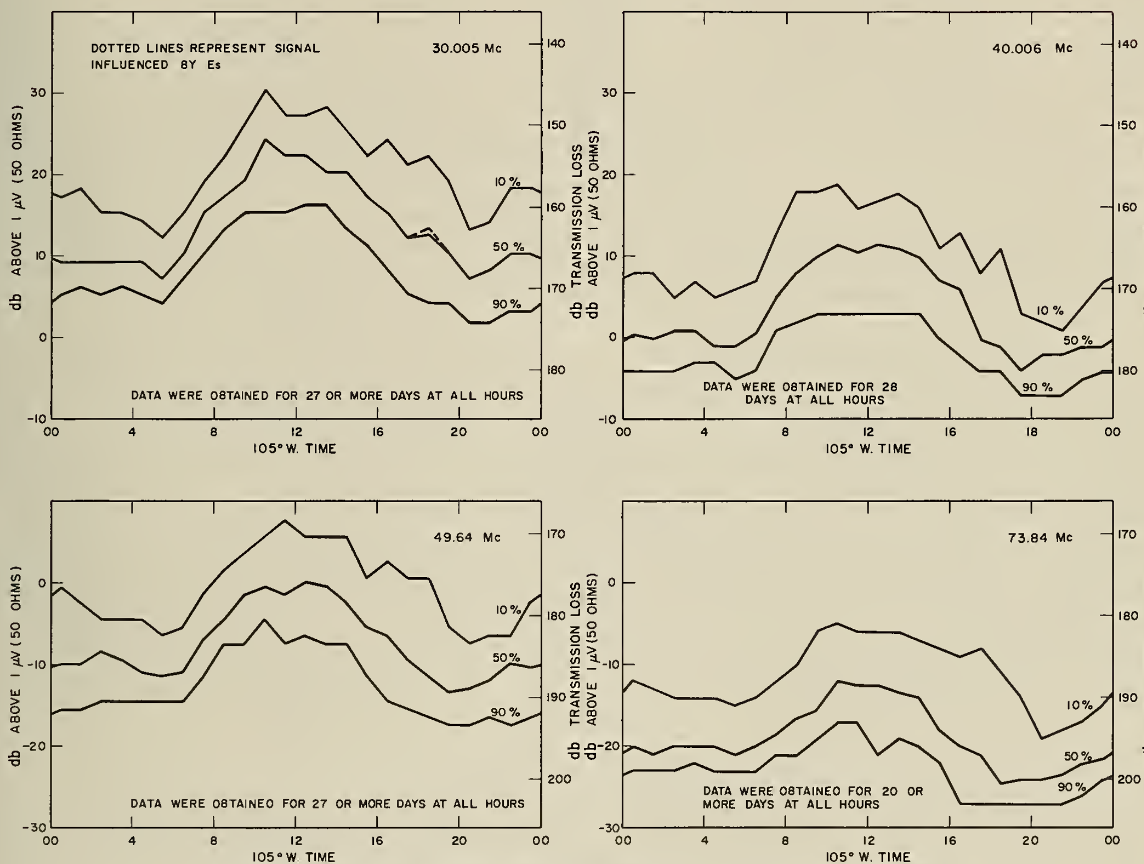
FIGURE 29



VALUES OF RECEIVED SIGNAL INTENSITY EQUALED OR EXCEEDED 10 %, 50 %, AND 90 % OF THE TIME FOR THE MONTH OF JANUARY, 1958. (ALL VALUES ADJUSTED TO 2 KILOWATTS TRANSMITTER POWER)

RECEIVED SIGNAL INTENSITY

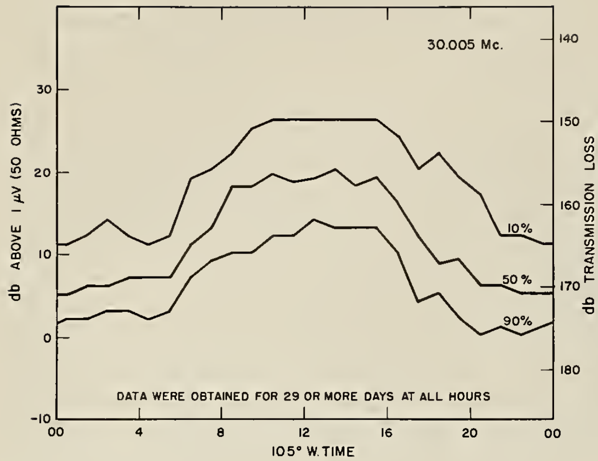
FIGURE 30

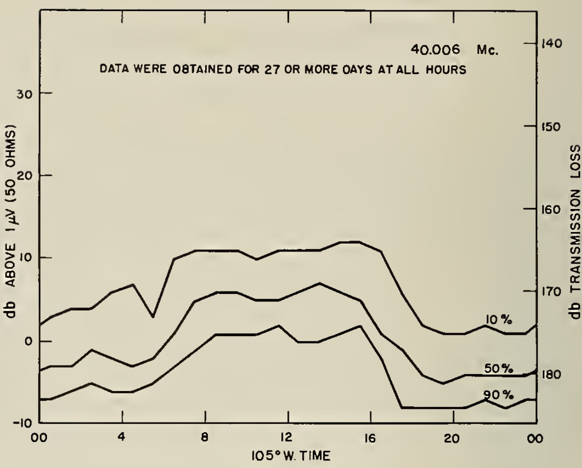


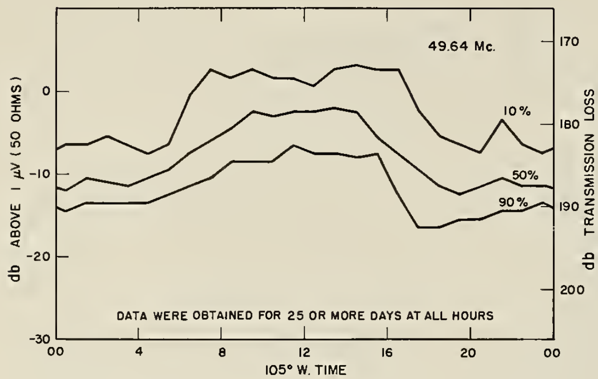
VALUES OF RECEIVED SIGNAL INTENSITY EQUALED OR EXCEEDED 10%, 50%, AND 90% OF THE TIME FOR THE MONTH OF FEBRUARY, 1958. (ALL VALUES ADJUSTED TO 2 KILOWATT TRANSMITTER POWER)

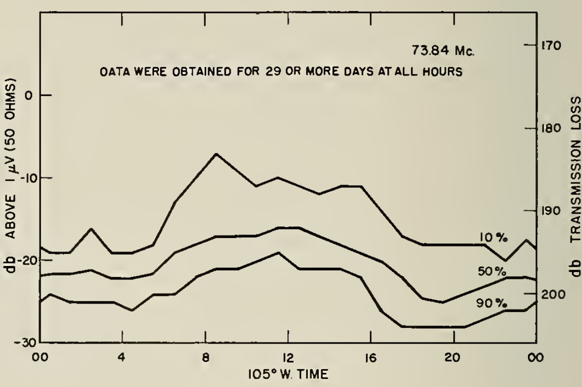
RECEIVED SIGNAL INTENSITY

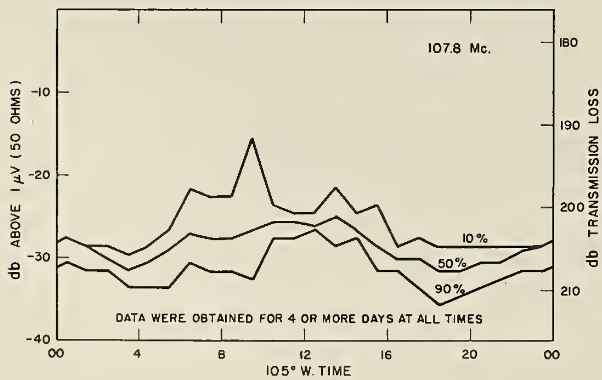
FIGURE 31







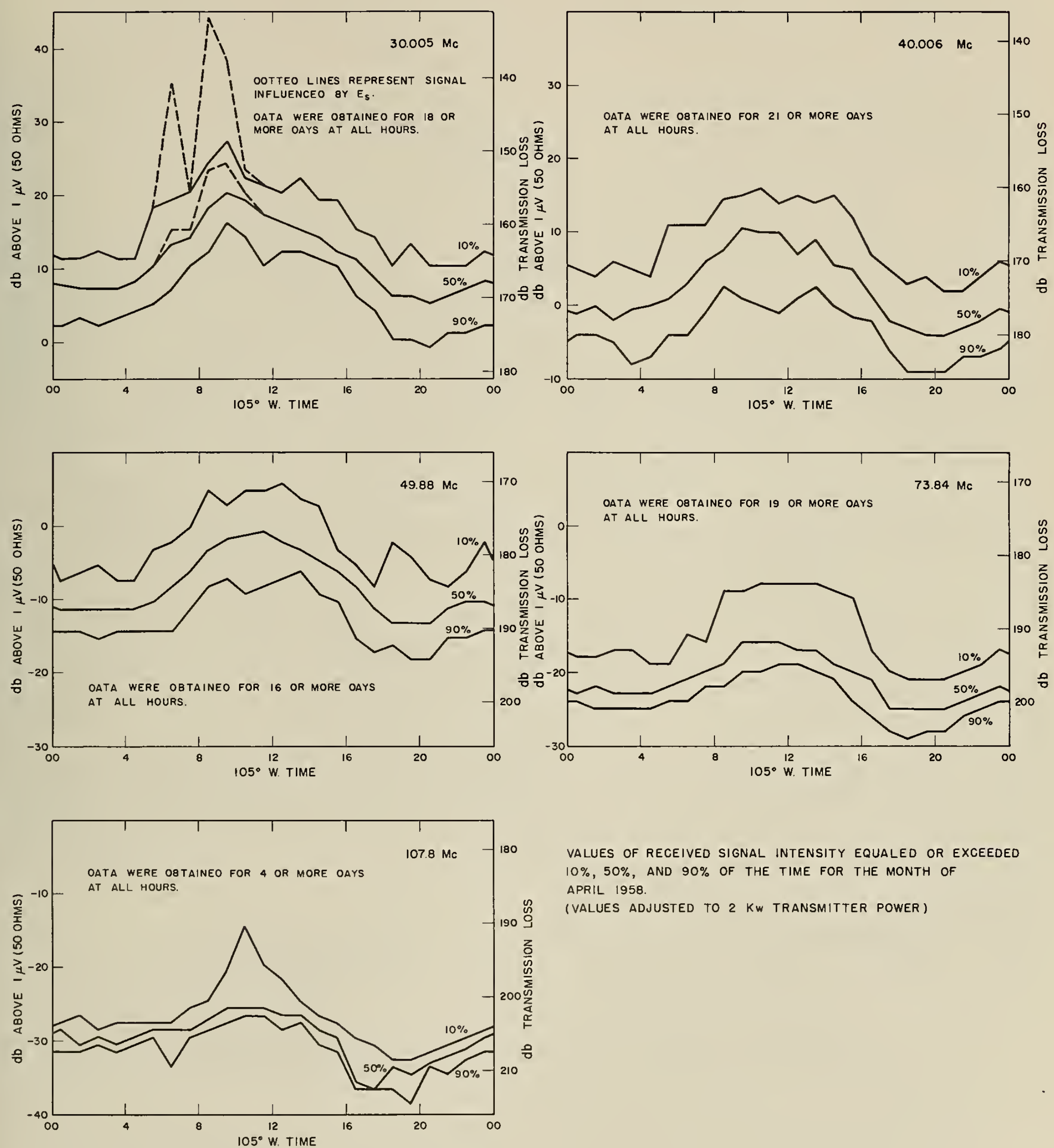




VALUES OF RECEIVED SIGNAL INTENSITY EQUALED OR EXCEEDED 10%, 50%, AND 90% OF THE TIME FOR THE MONTH OF MARCH, 1958. (VALUES ADJUSTED TO 2 Kw TRANSMITTER POWER)

RECEIVED SIGNAL INTENSITY

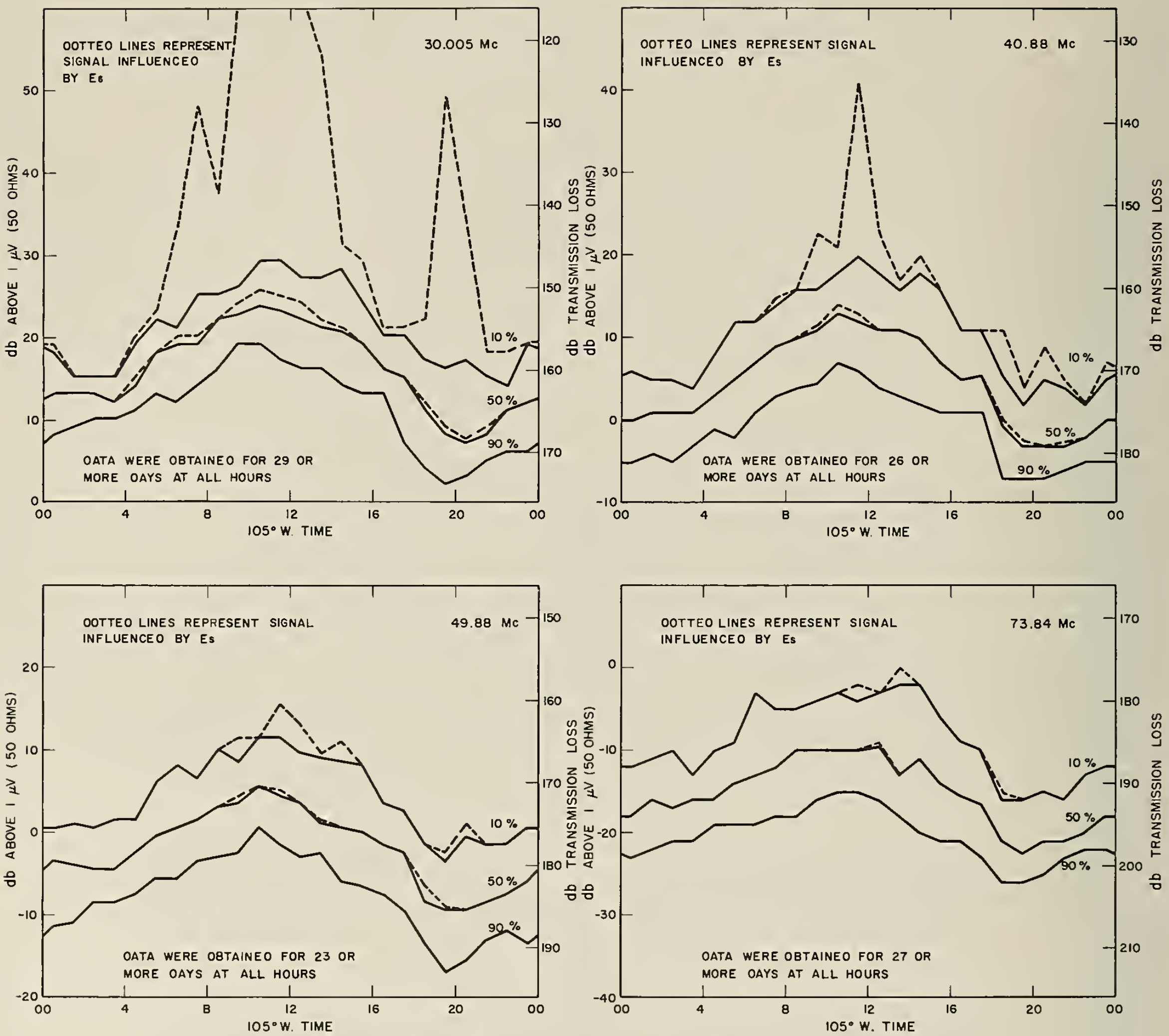
FIGURE 32



VALUES OF RECEIVED SIGNAL INTENSITY EQUALED OR EXCEEDED 10%, 50%, AND 90% OF THE TIME FOR THE MONTH OF APRIL 1958.
(VALUES ADJUSTED TO 2 Kw TRANSMITTER POWER)

RECEIVED SIGNAL INTENSITY

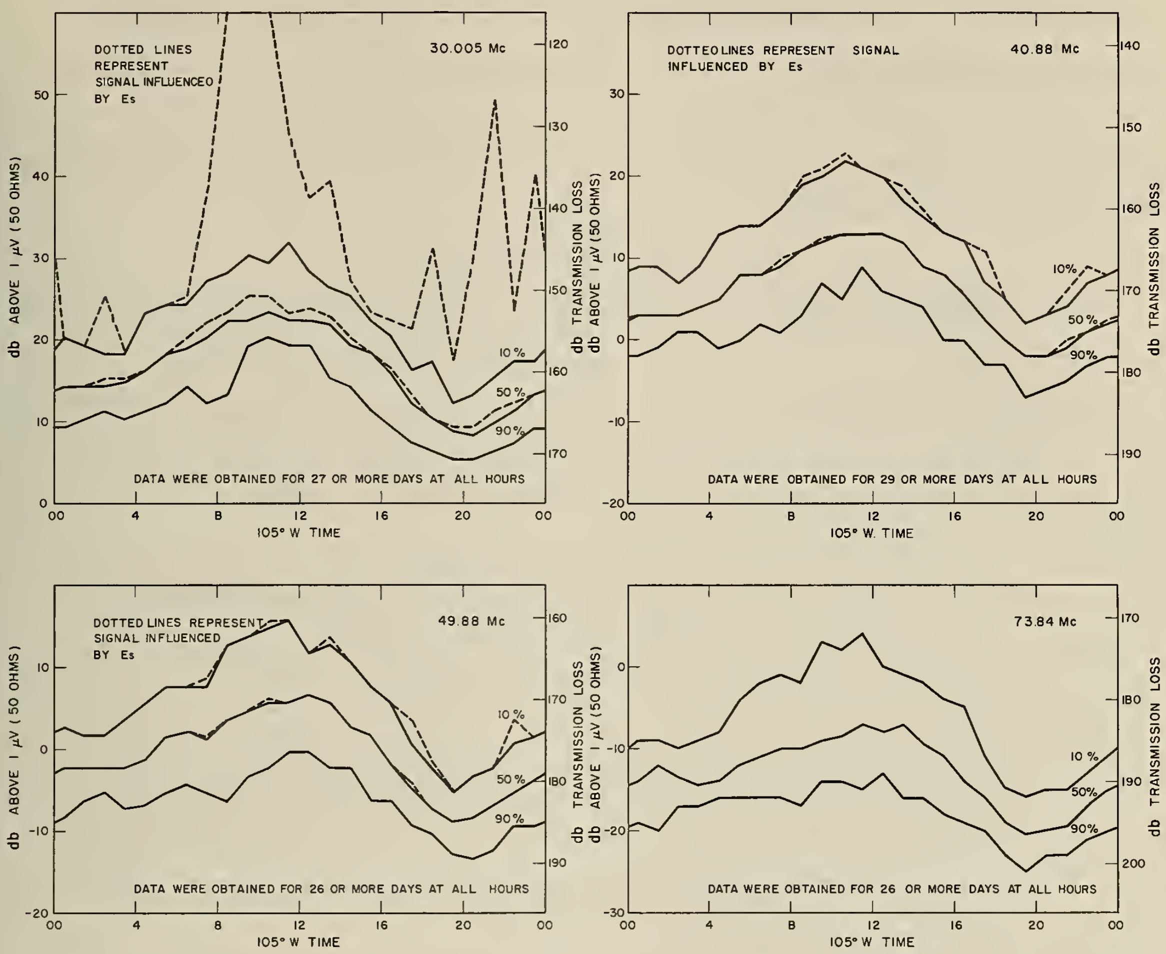
FIGURE 33

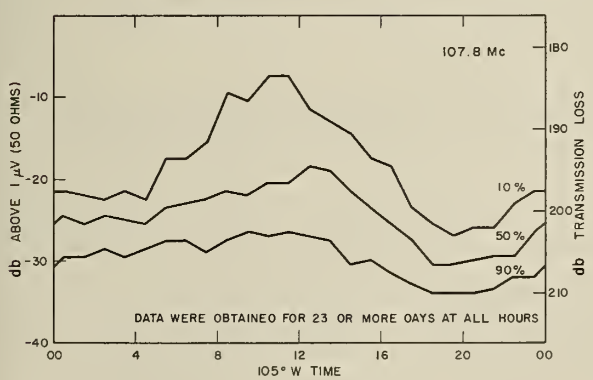


VALUES OF RECEIVED SIGNAL INTENSITY EQUALED OR EXCEEDED 10%, 50%, AND 90% OF THE TIME
FOR THE MONTH OF MAY, 1958 (ALL VALUES ADJUSTED TO 2 KILOWATTS TRANSMITTER POWER)

RECEIVED SIGNAL INTENSITY

FIGURE 34





VALUES OF RECEIVED SIGNAL INTENSITY EOUALED OR EXCEEDED 10%, 50%, 9ND 90% OF THE TIME FOR THE MONTH OF JUNE, 1958. (ALL VALUES ADJUSTED TO 2 Kw TRANSMITTER POWER)

RECEIVED SIGNAL INTENSITY

FIGURE 35

hold in figures 1-4 may be used to determine median values that more nearly represent the month at any given hour. The median values of signal on frequencies where large samples were obtained may be plotted on semi-log coordinates (db vs. frequency) and a straight line drawn through the points and the probable median values for other frequencies may be read off the graph.

6. DISCUSSION AND CONCLUSIONS

The value of n_o may vary from about 6 to 8 during periods of strong scatter signals and may reach values somewhat less than 5 during periods of weak scatter signal and strong meteoric activity. Meteoric activity is one powerful factor that influences these changes, but evidently is not the only one. The value of n_o varies diurnally and from month to month.

Other important results of this study are summarized below:

1. Signal intensity changes during SID's differ in direction according to the frequency of the signal.
2. Amplitude distributions are of a different type for periods of relatively low and relatively high meteoric influence.
3. The value of n_o varies throughout the day in accordance with the relative importance of meteoric and non-meteoric components of the signal.
4. The frequency-dependence analysis of signals from strong meteor bursts gives low values of n_o.
5. Magnetic disturbance was observed in one instance to produce signal-intensity behavior similar to that characteristic of SID's.

There is evidence from the SID data and from seasonal variations in exponent that cases of high absorption at HF will tend to be accompanied by abnormally high signals at VHF. 5 Mc recordings are now being made simultaneously with the other frequencies to test for such a correlation.

7. ACKNOWLEDGMENT

The observations and measurements reported herein were carried out with the assistance of Messrs. R. P. Fitzpatrick, C. H. Johnson, D. L. Ross and J. L. Green. Discussions with A. D. Wheelon and K. L. Bowles have been helpful.

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9. LIST OF FIGURES

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NATIONAL BUREAU OF STANDARDS
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