NBS

Technical Note No. 230

VHF IONOSPHERIC SCATTER SYSTEM LOSS MEASUREMENTS EUROPEAN-MEDITERRANEAN AREA

By

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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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** Located at Boulder, Colorado.

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was at the desired elevation angle of 3.2° (degrees) with its minimum above the main lobe many db below the maximum. The site was therefore considered very satisfactory.

The sites at Seville and Leghorn were on essentially level ground with the first Fresnel zones clear. These sites therefore were considered excellent.

The site at Tripoli did not appear to be as good as some of the others at first inspection. The site selected was on somewhat undulatory terrain with a down slope to the Mediterranean of very nearly 1°, as shown on figure 3. Nearly all of the first Fresnel zone was on this sloping terrain. The antenna towers were set up on the down slope with the antenna height reduced by three feet to obtain a main lobe beam at the required elevation angle. The beam elevation angle was then checked by flight tests and found to be correct within about 0.2°. The minimum above the main lobe was at least 24 db down, indicating that the site was excellent for the purposes of this test.

All antenna azimuths were determined to an accuracy of ± 0.1°.

The dimensions of the rhombic antennas are given in table 1 and figure 1. A 600 ohm open wire transmission line connected the rhombic antenna to a balun and stub system 6 feet above ground level at the back tower of the rhombic. The balun and stub system transformed the impedance to 50 ohms at the operating frequency. After initial adjustment regular checks were made to insure that the VSWR was low (it was usually less than 1.1) and that the system impedance was very near 50 ohms. A length of RG-17/U (50 ohm) cable, as short as practicable, connected the balun at the bottom of the antenna to the equipment housed in the trailer. The cable attenuation at each site was measured and appropriate corrections to the scaled signal and noise levels were applied to compensate for this attenuation.

2.2 Transmitters

Continuous wave transmissions were maintained throughout the test period using 2 kw transmitters. By means of stable frequency-control equipment the transmitter frequency could be maintained within 2 c/s per day and usually within 1 c/s per day when all equipment was functioning properly. Regular carrier breaks for the purpose of measuring background noise were controlled by a pendulum clock which was regulated to within three seconds per day.

The transmitter power indicator was calibrated at regular intervals using a wattmeter operating at 50 ohm impedance, and routine checks were made using a reflectometer which indicated the forward power, back power, and VSWR. Power was usually maintained to within a few percent of 2 kilowatts. Where output levels were appreciably different, as during periods of transmitter adjustment, such levels were noted for correction of the scaled signal strength data.

Primary power was not available at the two transmitter sites. The transmitters were powered from 20 KVA diesel units operating at 60 c/s.

2.3 Receivers

The receivers used were constructed by the National Bureau of Standards and had previously been used for similar measurements in the U.S. A precision, crystal-controlled local oscillator was used in conjunction with these receivers to provide signal conversion directly to the 1000 c/s IF. Image rejection of greater than 25 db was achieved.

Noise figures of about 3.7 decibels were maintained and checked by means of a noise generator. The nominal receiver bandwidths were 80 c/s at Leghorn for the entire test period, and 40 c/s at Weymouth, except during March 8-31 and July 4-31 when a 250 c/s bandwidth was used because the transmitter frequency was not stable enough to use the 40 c/s bandwidth. The recording time constant was 12 seconds.

The receiving stations were operated on commercial 50 c/s AC power. The receivers, signal generators, noise diode generators and other critical electronic equipments were operated with regulated voltage. During much of the several months of operation, frequency stability was very good, with the relative drift between the transmitters and receivers usually less than 1 cycle per second per day. For example, after transmitter stability problems had been cleared up in early July at Tripoli, the frequency adjustments required at the Leghorn receiving site to maintain precise tuning to the transmitter signal were less than 1 c/s per week for most of the time up to the September shutdown date.

2.4 Calibrations and bandwidths

Receiver calibrations were made using a crystal-controlled signal generator and techniques described by Finney and Smith [1960]. For recording purposes the zero decibel level was taken as one microvolt RMS open circuit voltage (E) across a 50-ohm (R) source, the impedance of the antenna during recording or the signal generator during calibration. Under these conditions, one microvolt represents an equivalent available power $E^2/4R$ which is 143 decibels below one watt and a system loss of 176 decibels relative to the 2 kw transmitter output. System loss is the ratio of the radio-frequency power input to the terminals of the transmitting antenna to the resultant radio-frequency signal power available at the terminals of the receiving antenna [Norton, 1959; CCIR, 1959]. System loss is usually expressed in decibels.

The lowest received signal (limited by galactic background noise) was about 216 decibels system loss. Full scale on the graphic recordings was 136 decibels. With this sensitivity the minimum galactic noise level was a few decibels above the receiver noise level. The calibration was essentially linear in decibels.

At Weymouth a second receiver with considerably attenuated input was used for recording signal levels up to a system loss of 86 decibels so that low system loss values due to sporadic-E layer propagation could be recorded.

In addition to the signal generator calibration, a noise generator was used to calibrate the lower portion of the records extending up to 20 decibels above KTB noise level. The use of the noise calibration makes the measurement of galactic background levels independent of the receiver bandwidth because both calibrating and observed sources produce random noise.

A relationship between the signal generator calibration and the effective noise bandwidth (see appendix) can be obtained from a procedure due to J. W. Koch [1960]. This relationship can also be used to find the galactic noise levels for any receiver bandwidth.

2.5 Recording and scaling

The signal and noise levels were recorded by the use of graphic recorders throughout the recording program. To facilitate scaling, notes were made on the records regarding VSWR, antenna condition, receiver tuning and other adjustments. Also noted were temperature, weather, sferics, precipitation and interference from known sources when observers were at the station. Calibrations were made daily and differences between successive calibrations were usually less than 1/2 db throughout the range. To minimize drift, temperature variations in the receiving trailers were limited to about 3°F by means of thermostats, fans and air conditioners.

Samples of the recordings are shown in figures 4 and 5. The records for May 28 and June 19 illustrate the normal scatter trace. The spikes on the record obtained on August 12 during the Persied meteor shower are due to scatter or reflection from ionization trails produced by individual meteors. The duration of the spikes ranges from less than ten seconds to about five minutes. Both the normal and extended range recordings are shown for June 16 during a prolonged period of high signal level sporadic-E propagation. Examples of signals assumed to be propagated via the troposphere are shown in the two records from the Tripoli-Leghorn path with occasional meteor spikes projecting above the slowly varying level. Meteorological conditions along the path have not been investigated during the periods of assumed tropospheric propagation.

The record for September 19 was for a day during which the signal levels were among the lowest observed. During this period the minimum signal level and the maximum galactic noise level occurred at the same time. Even at this time of poorest signal to noise ratio, the median signal was still 15 decibels above the noise background. The interference noted during the noise break at 1830 hours was probably due to local precipitation static. In contrast, the portion of the record near 1100 hours on May 28 represents one of the highest scatter signal levels observed, 163 decibels system loss (13 db/1μv). Day-to-day differences of scatter signal level as great as 20 db were recorded at the same hour of the day, the highest median system losses being observed during the spring-fall period.

The graphic recordings were scaled daily. Hourly medians centered on the half-hour and background noise levels during transmitter breaks were noted on the records in accordance with standard scaling procedures. When sporadic-E propagated signals were encountered, two medians were scaled, the first including the effect of sporadic-E and the second interpolated through as if sporadic-E had not occurred. The criterion for designating sporadic-E propagation in any hour was that sometime during the hour the signal increased abruptly to or beyond full scale (i.e., 136 decibels system loss) and sustained this level for at least one minute. To exclude unusually intense meteor burst signals the level also had to stay well above the normal scatter level continuously for at least 12 minutes. If the signal was noticeably above the normal scatter level during the hour preceding or following an hour in which sporadic-E propagation occurred, the signal was judged to be influenced by sporadic-E propagation even though it did not reach full scale during that hour.

Interpolation of the scatter-signal amplitude through sporadic-E was made only for intervals of up to two hours. When sporadic-E propagated signals lasted more than two hours the interpolation was not made.

The 5-minute medians of sporadic-E propagated signals and the interference levels during transmitter breaks were scaled from the Weymouth records and analyzed.

The data were tabulated on weekly data sheets in the field. The records and tabulations were checked and further analyzed in the laboratory. The transmitter logs were examined and appropriate corrections were applied to the received field intensity for any periods when the transmitter levels were either above or below the standard 2 kw output.

No data were discarded except for a few hours when the receiver and transmitter were obviously out of tune and there was no way of correcting the errors introduced thereby.

3. RESULTS AND COMPARISONS

3.1 Diurnal variations and cumulative distributions

The results of the European-Mediterranean signal measurements and, for comparison, those of the Long Branch, Illinois-Boulder, Colorado path are shown in figures 6 through 13. The data from which figures 6 through 9 and figures 12 and 13 were plotted is given in table VI. For each month the following graphs are presented:

A. The diurnal variation of the hourly median system loss exceeded during 90% (upper decile), 50% (median), and 10% (lower decile) of the days.

B. The cumulative distribution of all hourly median system losses. Note that the abscissa represents the percentage of all hours during which the system loss is <u>less</u> than the ordinate value. Therefore to find the system loss <u>exceeded</u> for a certain percentage (p) of all hours enter table VI or the graph with (100 - p) percent.

The curves on the graphs are identified in the keys on figures 6, 8, 10, and 12. System loss is defined in the first paragraph of section 2.4.

Figures 6 - 11 show also the combined data for the spring-fall months (March, April, and September) and for the summer months (May through August). No data are available for the Tripoli-Leghorn path for the month of March 1958, so the spring-fall data for that path are for April and September only. The results of comparisons between the various paths are given in figure 10, where the differences between the graphs of figures 6 through 9 have been plotted for both the diurnal variations and the cumulative distributions.

The system loss scales on all graphs decrease upwards which corresponds to an increase in signal strength. Thus the peaks of the diurnal variation graphs around midday represent high signal levels but low values of system loss. In figure 10 a positive difference indicates that the first path given at the top had the greater signal strength or smaller system loss.

The Long Branch-Boulder path is an east-west path. It is possible that east-west scatter signal levels may not be entirely comparable to north-south scatter signal levels. However, a comparison of this path with the nearly north-south paths in the European-Mediterranean area is both interesting and useful in that the data may contribute to an understanding of the effect of path orientation relative to the geomagnetic field. Signal behavior on the various paths can be seen by examining the diurnal plots and system loss distributions in figures 6 - 9. The plots of the differences between the various graphs in figure 10 are also useful for comparison. In this figure, the differences are magnified about 4 times; i. e., 8 decibels here occupy the space of 30 decibels on other figures.

The following salient features are noted:

1. The highest observed system losses on the Seville-Weymouth path are within one decibel of those observed on the Long Branch-Boulder path (see the cumulative distribution differences of figure 10). For the Tripoli-Leghorn path, the highest observed system losses are two to four decibels greater than those for the Long Branch-Boulder path. However, each of the rhombic antennas used on the Long Branch-Boulder path had one decibel more gain than those used on the European-Mediterranean paths.

2. An examination of the diurnal-difference plots, figure 10, shows that during the spring-fall months the Seville-Weymouth path system losses are about 1 - 6 decibels above the Long Branch-Boulder median system losses, while the Tripoli-Leghorn path median system losses are about 1 - 7 decibels above the Long Branch-Boulder path median system losses. For the lower deciles the differences are generally smaller than those for the median especially during the morning and evening hours.
The marked differences between the Long Branch-Boulder path median system losses and those of the two European-Mediterranean paths during the period 1400-2100 hours will be discussed under 7 below.

3. For the summer months (figure 10) the system losses on the Long Branch-Boulder path are again below those for the other two paths but the diurnal differences are generally smaller for the Seville-Weymouth path and generally greater for the Tripoli-Leghorn path. The diurnal variation of the differences is also less than in the spring-fall case.

4. The nighttime system losses show somewhat different characteristics in that the European-Mediterranean signals do not decrease quite so rapidly after the evening maximum system losses period occurring at about 2000 as may be noted on all the diurnal difference curves comparing the Long Branch-Boulder path with the European paths (figure 10).

5. A comparison of the Tripoli-Leghorn and the Seville-Weymouth path, figure 10, shows a smaller diurnal variation of the difference in the median system losses than the comparisons of the two European-Mediterranean paths with the Long Branch-Boulder path. Similarly, the difference in cumulative distributions vary less over the percentage range comparing the European-Mediterranean paths with each other.

6. Aside from the diurnal variation there is only a small degree of hour to hour correlation between the variations of signal levels over the various paths. A period of moderate enhancement of signal level on one path is not particularly likely to be accompanied by a similar change on another path.

7. There is no certainty that all of the months of data are entirely typical. For the European-Mediterranean paths nearly all the data appear to follow seasonal trends consistent with those for paths previously observed. However, during July on the Tripoli-Leghorn path the system losses were about 3 db high. During most of this month the transmitting rhombic antenna had about 11 feet of sag compared to the normal 5 - 6 feet in the other antennas. The received signal strengths for the days immediately before the sag was reduced were compared with the data after the sag was reduced. No discernible variation was observed.

On the Long Branch-Boulder path the September medians show the expected diurnal variation, except that the evening hours do not show the usual system loss increase. For this path, data are also available for September 1959. The median plot of these data shows the expected evening system loss maximum. Thus it appears that the September 1958 data for the Long Branch-Boulder path are not entirely typical; the system losses for 1700-2400 hours seem abnormally low. If this is so, the differences between the European and the U.S. path signal levels during the period 1400-2100 hours noted in paragraph 2 above would be reduced.

8. The one marked difference between the Long Branch-Boulder and the European-Mediterranean data is in the relative occurrence of sporadic-E propagated signals. The occurrence

of sporadic-E propagated signals in the European-Mediterranean area is markedly greater than for the continental USA. This difference will be discussed in greater detail in the next section.

Figure 11 shows histograms of the diurnal variation in percentage occurrence of signals propagated by sporadic-E with a system loss of less than 156 decibels (greater than +20 db/1µv) for all paths. This level was chosen because it is about 6 db above the highest normal scatter signal level observed on the European-Mediterranean paths. It is about equal to the highest scatter signal levels observed on the Long Branch-Boulder path.

The greatest difference between the Long Branch-Boulder and the European-Mediterranean paths occurred during the month of June. The average percent of occurrence of sporadic-E propagated signal levels (equal to or greater than the criterion selected) for the month of June was as follows:

Long Branch-Boulder path	0.6%
Seville-Weymouth path	12.7%
Tripoli-Leghorn path	11.8%

The difference was not so marked for the other months of the period of comparison, but both European-Mediterranean paths show a substantial excess of sporadic-E propagated signals over the Long Branch-Boulder path for all months. The difference in occurrence of sporadic-E signals between the two European-Mediterranean paths was small.

At Weymouth a second receiver operating at greatly reduced sensitivity was used. With this receiver the full range of sporadic-E signal levels could be recorded. This permitted a more complete analysis of the sporadic-E signals for the Seville-Weymouth path. During all periods of sporadic-E propagation, 5-minute median system loss levels were measured for the time intervals 0-5, 5-10, ... 55-60 minutes after each hour. In figure 13 the cumulative distributions of these 5-minute medians are shown for the months May through September, separately and combined. In figure 12, the diurnal variation of the system loss of the sporadic-E signals is plotted as though all the 5-minute medians within any hour were centered on the half-hour.

The minimum observed 5-minute median system loss of sporadic-E propagated signals was 89 decibels or 11 db greater than the calculated inverse-distance system loss, assuming a lossless ionospheric reflection and fully realized rhombic to rhombic gain. Momentary signal levels only about 6 db greater than the inverse-distance system loss were recorded.

During August on the Tripoli-Leghorn path there was a total of 201 hours during which the recorded signal was higher than the usual ionospheric scatter signal and lower than most sporadic-E propagated signals. Also the variations of the recorded trace were much slower (see figure 6). No information on the short term signal variations was obtained since a time constant of 12 seconds was used throughout. This signal was assumed to be caused by tropospheric propagation resulting from favorable meteorological conditions over the Mediterranean resulting in ducting. Near the end of August this signal dominated the records continuously for several days. Thus it is likely that this type of signal will sometimes be a useful mode of propagation at 50 Mc/s for this path. It would probably not have been observed at much lower frequencies. During September the assumed tropospherically-propagated signal was observed for only a few hours. It was not observed on the Seville-Weymouth path nor at any other time on the Tripoli-Leghorn path.

3.2 Contribution of meteoric ionization

It has long been recognized that part of the observed scatter signal is the result of ionization due to micrometeorites [Bailey, et al., 1955; Eshleman, et al., 1955; Meadows, 1958]. This is in addition to the easily observed ionization produced by larger meteors. For example, in May, a month of greater meteor activity compared to April, there is a relatively greater signal enhancement at 0800 near the peak of meteor occurrence than at 2000 hours, near the minimum of meteor occurrence. This is shown in table II below.

Table II

System loss at 2000-2100 exceeds loss at 0800-0900 hours

	April	May
Seville-Weymouth	5 decibels	10 decibels
Long Branch-Boulder	9 decibels	12 decibels
Tripoli-Leghorn	7 decibels	12 decibels

3.3 Comparisons with earlier published results

The results obtained by Isted [1958] at 48 Mc/s on a path from Gibraltar to the United Kingdom in March, April, and May of 1955 have been compared with the NBS results for the corresponding months of 1958. Data on the paths, antennas, and calibration systems are presented in table III. The data for the Isted system were obtained from the literature [Bain, 1958; Crow, et al., 1956; Fitch and Ruddlesden, 1958; Isted, 1958; Kitchen and Millington, 1958; Meadows, 1958; Shinn, 1958; and Williams, 1958].

At the bottom of table III the decibel levels for equal available powers are shown in each of the scales used in recording. The reference levels used are Isted's 1 microvolt across 70 ohms matched load and the NBS results referred to 1 microvolt open circuit voltage across the 50 ohm antenna terminals. These data are shown in ghe graph of figure 14 in system loss.

TABLE III

COMPARISON DATA

Isted: 1955, Gibraltar-East Hanningfield (March, April, May)
NBS: 1958, Seville, Spain - Weymouth, England (March, April, May)

Patb	Gibraltar-East Hanningfield	Seville-Weymouth
Frequency	48 Mc/s	49.8 Mc/s
Transmitter Coordinates	36°08'N, 05°19'W	37°09'N, 05°35'W
Receiver Coordinates	51°41'N, 00°34'E	50°38'N, 02°22'W
Midpoint Coordinates	43°54'N, 02°22'W	43°54'N, 04°09'W
Path Length	1110 miles, 1786 km	944 miles, 1520 km
Transmitting Antennas:	4 x 4 curtain with reflectors	Long wire rhombic
Gain relative to half-wave dipole	16 db	18 db
Half-power horizontal beamwidth	20°	6°
Receiving Antennas:	1 x 8 vertical stack of half-wave dipoles with reflectors	Long wire rhombic
Gain relative to half-wave dipole	12 db	18 db
Half-power beamwidth	84°	6°
Combined Antenna Gains:		
Theoretical relative to dipole	28 db	36 db
Average realized relative to dipole	17 db [Shinn, 1958]	18 to 25 db [Bailey, et al, 1955]
Desired lobe elevations and antenna heigbts for path lengths [Merrill, 1962]		
Lobe Alignment Equivalent	2.9°, 115 ft.	5.0°; 66 ft.
Optimum for maximum power transfer	2.3°, 145 ft.	3.8°, 85 ft.
Lobe Alignment:	1.8°, 175 ft.	3.2°; 103 ft.
Lobe elevations for antenna heights used (assuming sea foreground) [Merrill, 1962]		
Transmitter: 1st lobe	0.4°, 700 ft.	3.2°, 103 ft.
2nd lobe	1.2°	
3rd lobe	2.1°	
4th lobe	3.0°	
Receiver: 1st lobe	4.2°, 80 ft. to center of stack	3.2°, 103 ft.
Power to Transmitting Antenna, P_t	30 to 40 kw	2 kw
Receiver Calibration Scales	Decibels relative to 1µv across 70 ohms, <u>matched load</u> conditions	Decibels relative to 1 µv <u>open circuit</u> antenna voltage, 50 ohm antenna
Formula for power available, P_a, to a matched load, voltage as specified above:	$P_a = E^2/R = E^2/70$	$P_a = E^2/4R = E^2/200$

COMPARISON OF VARIOUS SCALES USED

	db above 1 watt	db above 1µv across 70 ohm matched (Isted)	db above 1µv open circuit 50 ohm antenna (NBS)	System loss Isted (40 kw)	System loss NBS (2 kw)
P_t: To transmitting antenna					
Isted (40 kw)	46.0				
NBS (2 kw)	33.0				
P_a: Available to receiver matched to antenna					
	-138.5	0	4.5	184.5	171.5
	-143.0	-4.5	0	189.0	176.0

The NBS data are replotted from the monthly-median diurnal variations given in earlier figures. The Isted data are taken from a smoothed curve drawn through the monthly mean values of thirty-minute medians [Isted, 1958]. The NBS data are based on substantially continuous records while the Isted data are based on an average of 16 daily record samples per month. Only three or four of these are nighttime records.

A change in Isted's receiving antennas, from a single dipole and reflector to a stack of 8 dipoles and reflectors made in mid-March, was compensated by adding 8 db to the data obtained with a dipole [Isted, 1958]. Because no transmissions were made from Gibraltar at certain hours in March and April, lack of data made interpolation necessary; the interpolated points are shown as solid circles on the plots. Where some of the thirty-minute medians exceeded the recorder range, the monthly mean is plotted with an upward-pointing arrow. Note that the system loss scale is different on the graph for May in figure 14 than for March and April. An indication of the overall system-loss differences is given in table IV. System loss values were taken from the monthly cumulative distribution curves.

Table IV

	March			April			May		
System Loss	Isted	NBS	Diff.	Isted	NBS	Diff.	Isted	NBS	Diff.
Exceeded 90% of month	194	178	16	190	180	10	~ 175	169	~ 6
Exceeded 50% of month	197	185	12	196	186	10	184	180	4
Exceeded 10% of month	202	189	13	202	190	12	189	187	2

It is at once apparent from the graphs that there are marked differences in the shape of the diurnal variation curves -- and less marked differences in the general levels (the Isted antenna had a combined theoretical plane-wave gain some 8 db less than that of the NBS rhombics; see table III). The authors of this report believe that these discrepancies can be explained on the basis of great differences in the effective antenna patterns, particularly that of the Gibraltar transmitting antenna which, because of geographical conditions beyond economic control, had to be placed considerably higher than desired above a hilly foreground.

In general, it is felt that the Isted experiments favored scattering from off-path meteor trails, while the NBS experiments were directed toward a smaller common volume along the great circle path between transmitter and receiver. The effects of differing antenna characteristics on the diurnal variations are discussed by Smith [1959]. In what follows, frequent references will be made to reports of the tests as presented at the Symposium on Long-Distance Propagation Above 30 Mc/s, which was held in London in January 1958 by the Institution of Electrical Engineers.

The antennas used by NBS were long-wire rhombics having a half-power beamwidth of 6°, with the center of the lobe directed at a point 85 kilometers above the path midpoint. This lobe alignment was determined from data given by Merrill [1960, 1962]. The flat terrain or sea at both ends of the path assured that the correct lobe elevations were actually achieved. In the case of the Weymouth site, the lobe elevation was verified by means of a target transmitter in an airplane. The information in the reports [Merrill, 1960, 1962] were also used to obtain the lobe elevations given in table III for the Isted antennas.

The desired lobe elevations are based on the actual path length of 1786 kilometers. The four lobe elevations for the transmitting antenna at Gibraltar are based on the 700-foot height given by Meadows [1958], and an assumed smooth, spherical earth foreground (the actual foreground will be discussed shortly).

Since no information could be found in the symposium reports regarding the elevation of the receiving antenna lobe, the midpoint of the 1 x 8 stack of dipoles was estimated to be 80 feet high from a photograph of the antenna in which some other dimensions were known. The resulting elevation of the first lobe was found to be 4.2°. Even the top-most dipole of the stack, at about 125 feet, was barely above the lobe-alignment equivalent height of 115 feet, as determined from Merrill's [1960] report. Thus it is difficult to understand how the receiving antenna could have illuminated the common volume at a height of 85 kilometers. It seems likely that meteor-trail heights around 100 km would have been favored.

From diagrams and descriptions in some of the symposium papers [Isted, 1958; Meadows, 1958; Kitchen and Millington, 1958; Fitch and Ruddlesden, 1958; Williams, 1958, and Bain, 1958], the situation at the Gibraltar site was as follows: Five-hundred-foot high hills, about four miles in front of the antenna, would have intercepted ground reflections at elevations of less than about 3°. At 23 miles, another ridge some 3000 feet high intercepted all radiation below an elevation of about 1°. Fitch and Ruddlesden [1958] indicate that at best, if some lobes had been formed, the illumination of the ionosphere would have been striated with an overall result 3 db greater than for a free space antenna which may even be optimistic in view of lack of coherence between direct and ground reflected signals. For a scaled antenna at 37.3 Mc/s, the horizontal direction of the major lobe, as measured by Crow, et al. [1956] appears to have been several degrees to the west of the great circle path to East Hanningfield, the receiving site. The horizontal half-power beamwidth of the array used at Gibraltar was given as 20°, though no measured azimuthal pattern at 48 Mc/s was given.

At Slough, some 50 miles west of East Hanningfield, Bain [1958] measured the diurnal variation of the mean bearing of signals at 37.3 Mc/s received from Gibraltar and found that it deviated to the west an average of 7° during the night and 0° during the day. At Winkfield, near Slough, Meadows [1958] confirmed Bain's result by measuring the direction of arrival of reflections from meteor trails of the 37.3 Mc/s signal from Gibraltar.

Meadows also found that the number of reflections arriving per degree of elevation was approximately constant over the range 1 - 5° and fell rapidly in the region of 6 - 7°. This implies (from path geometry considerations) apparent reflection heights around 100 km. He discusses the underlying reasons for the above observations in terms of the motion of the earth in its orbit and its daily rotation. These results agree with the studies of other workers [Smith, 1959; Bailey, 1955].

Measurements on a north-south path by Hagfors [1962] show that at midday most of the meteor bursts are received from the eastern side of the path whereas around midnight the majority of the bursts are from the west side of the path. At both times a minimum in the number of bursts was seen along the great circle path.

Since the Isted path was 18% longer than the NBS path an estimate of the increase of system loss for the longer path should be made in order to compare the results with the NBS measurements. The distance dependence as shown [JTAC, 1960] for optimum-height ideally-sited antennas of the type used by NBS, indicates a system loss about 3 decibels greater for the longer path. It is probable that the system loss is greater for antennas of larger beamwidth or with multiple lobes.

The differences between the Isted results and the NBS results may now be explained on the basis of the above observations. The narrow-beam NBS antennas directed toward a comparatively small scattering volume above the path midpoint would discriminate somewhat against meteors, but, at the same time, the diurnal variations would show a strong solar influence [Bailey, et al, 1955]. Isted's [1958] broadbeam antennas, with the transmitting antenna major lobe directed somewhat to the west of the great circle path and the receiving antenna pattern directed above the 85-kilometer height, would be principally influenced by meteoric ionization. Therefore, an increase in the number of meteors should have caused a greater increase in the Isted signal levels than in the NBS signal levels.

The response of Isted's [1958] system to the increased influx of meteors during May is evident in figure 14, in which the meteoric maximum around 0800 is more pronounced than in March or April. In going from April to May the increases in Isted's signals, at the times of day of both maximum and minimum meteoric activity, were far larger than for any of the three NBS paths described under section 3.2. In fact, in May the general level of the diurnal curve for the Isted signals is much closer to the NBS curve, especially during the night when the effect of meteoric ionization is greatest.

Table IV indicates that the monthly median system loss was 4 to 12 db greater for Isted's system. This must, according to the definition of system loss [Norton, 1959], be explicable by differences in the antenna systems and the associated terrain, assuming comparable ionospheric conditions. Several decibels of this difference could be accounted for by the poor foreground at Gibraltar and another 1 to 3 db by the greater path length. It is indicated [Bailey, et al., 1955] that any remaining differences in system loss are well within the differences in realized gains expected for such different antenna systems. The Isted group realized an average gain of 17 db relative to half-wave dipoles for their antennas [Shinn, 1958]. While no actual measurements of realized gain were made on the NBS system, figure 56 of the report by Bailey, Bateman and Kirby [1955] gives cumulative distributions of realized gains for similar antenna systems, the median values ranging from 18 to 25 db. The same reference shows that the diurnal variation of realized gain is much greater for rhombic antenna systems than for wide beam Yagi antenna systems, the rhombics having a broad maximum during daylight hours. This would explain why the greatest differences in system loss, figure 14, occur during the late morning and afternoon hours when meteoric ionization is low. At this same time, the realized gain of the rhombic system is greatest because solar radiation is most effective in ionizing the 85-kilometer scattering region. According to a study made by Ellyett and Leighton [1958], it is also possible that midday scatter signal levels were 2 to 3 db lower during the sunspot-minimum year of 1955 than near the sunspot maximum in 1958.

In view of all the above considerations, the NBS and Isted results seem more compatible than was first believed.

3.4 Galactic noise and terrestrial interference

In ionospheric scatter systems using low-noise receivers, the galactic background is the lowest observable noise level in the absence of interference from terrestrial sources. The diurnal variation of galactic noise actually observed at a given site is predictable from the antenna pattern, its elevation and azimuth, and the time of day. As the antenna beam rotates with the earth it scans the heavens in the direction of increasing right ascension and at a constant declination. Whenever the beam passes through the plane of the galaxy the background noise shows a peak. For a given time of observation the right ascension seen by the main lobe increases about four minutes each day because of the earth's revolution about the sun. One method of predicting the diurnal variation is to use a set of galactic charts [Menzel, 1960].

Figures 15 and 16 are mass plots of the measured background noise levels for one month at Weymouth and Leghorn. The effect of any interference during the transmitter breaks has been eliminated by interpolation where possible. The data in terms of decibels above KTB are plotted against right ascension, which was determined from the direction of the antenna beam and the time of observation.

The declination in celestial coordinates of the main lobe at Weymouth was 35.3° south of the celestial equator while at Leghorn it was 39.5° south. The center of the radio galaxy is in the constellation Sagittarius at about 30° south, which accounts for the slightly higher levels seen by the Weymouth antenna. The maxima near right ascension 0900 and 1700 hours correspond to the passage of the plane of the galaxy (Milky Way) through the antenna lobe -- the larger maximum being nearer the galactic center. The 3 or 4 db spread in the galactic noise levels is due to varying ionospheric absorption at the low elevation angle of the antenna beam. The measured levels are about 3 db below the levels estimated from galactic charts using a 6° half-power beamwidth probably because the directivity gain corresponding to this half-power beamwidth is 21 db, while the measured power gain of the rhombics is only 18 db. The difference between directivity gain and power gain is equal to antenna copper losses and nearby ground losses as well as the loss in the terminating resistors. The last, when computed for these antennas, was found to be 2.8 db [Schelkunoff and Friis, 1952].

While galactic noise-level measurements were not made at the transmitting sites, the antennas were pointed to northerly declinations well away from Sagittarius so that had one placed receivers at those sites the maximum noise levels encountered would have been 3 to 5 decibels below the levels seen at the receiving sites. See also section 2.4 for application of galactic noise data to practical systems.

Interference during transmitter breaks was observed only rarely, and then almost always at levels well below the scatter or sporadic-E propagated signal. Some analysis was thought desirable to determine the most probable origins of the interference and the effect of sporadic-E propagation.

The maximum interference levels during the two-minute transmitter breaks were scaled from the Weymouth records for the period May 1st through September 26th, except July 4 - 31 when the bandwidth was 250 c/s instead of the regular 40 c/s. Only those levels which exceeded the expected galactic noise by more than 2 db were scaled. Known instances of local ignition, sferics and precipitation static were eliminated in scaling. The remaining interference was probably from the following sources:

1. Manmade noise from ignition, power lines, or electrical apparatus.

2. Radio or radar transmitters on or near the signal frequency or its subharmonics.
3. Sferics or precipitation static.
4. Some of the above types propagated to the receiving site by sporadic-E.

During the period studied, there were 5586 usable transmitter breaks including 419 cases of recognizable interference which exceeded the galactic level by more than 2 db. The peak level was always measured even though it lasted for only a fraction of the two-minute break in most cases. Both the interference and the transmitter breaks were classified according to whether or not sporadic-E propagation of the scatter signal occurred within one hour. A mass plot of the data was made which preserved the distinction between the two classes. The results are summarized in figure 17 (see key on opposite page).

Figure 17A shows the diurnal variation of all interference for the peak levels exceeded during 1%, 2%, and 5% of the transmitter breaks. The diurnal variation of galactic noise is shown in figure 17A as it would appear on September 30 when the maximum occurs at 1800. The entire diurnal curve of the galactic background shifts toward earlier hours at the rate of about two hours per month. Thus, for example, on October 30 the maximum would occur at 1600 and on July 30 at 2200 hours.

In figure 17B the cumulative distributions of all the interference and of the galactic noise observed in a 40 c/s passband are plotted separately.

Most of the interference occurred during local working hours, and the pronounced minimum at midday suggests that its origin is principally local man-made noise. The antenna beam was directed out over Ringstead Bay and just to the east of Portland Harbor, an active naval base. Occasionally ignition noise was heard when boats were in the beam. There was a small seashore community one-third of a mile east of the site and agricultural tractors were operated in the vicinity.

For figure 17C and D the two classes of interference were analyzed separately, each based on its own population of transmitter breaks. These figures demonstrate a tendency for the strongest interfering signals to occur when sporadic-E propagation conditions exist. In both graphs, the highest interference levels ever observed are indicated by small squares along with the peak levels exceeded during 2%, 5%, and 10% of the transmitter breaks. The noon-hour minimum is most definite under sporadic-E conditions, which probably eliminates distant radio transmitters and natural phenomena as the major sources of the interference. On such a north-south path, along which the noon-hour recess from work may occur simultaneously at many points, man-made noise could have been the most likely source of the interference.

An indication of the relative unimportance of interference at the Weymouth site is given by including selected ionospheric scatter levels on the graphs in figures 17B, C, and D (see key).

No detailed study of the interference at the Leghorn site was made. However, an inspection of the records indicated that the frequency of occurrence and amplitude of interference were certainly no worse than at Weymouth. This is somewhat reassuring since the antenna beam was pointed almost directly toward Leghorn some 7 to 10 miles distant. There was no observable noise directly attributable to the electric railway systems in the area. During severe storms, the noise level was somewhat higher than for Weymouth, which may have been due to the effect of strong winds and rain on local power lines. During heavy rainstorms at both sites, precipitation static and interference from nearby lightning discharges sometimes produced noise levels equal to or a few decibels above the scatter signal. While these noise levels will affect the error rate of a scatter system their occurrence is quite rare and some techniques are available for reducing the level of precipitation-static.

4. CONCLUSIONS

The experimental systems and techniques used on two ionospheric forward-scatter paths at 50 Mc/s in the European-Mediterranean area have been described.

The results of measurements are described in detail in graphs and text material. A summary of system loss values taken from the cumulative distributions appears in table V below.

Table V

Summary of System Loss Values
in Decibels for Three Paths

Season	Percent of Hours*	Seville-Weymouth	Long Branch-Boulder	Tripoli-Leghorn
Spring-Fall	50%	185	182	186
Spring-Fall	90%	190	188	181
Spring-Fall	99%	192	192	195
Summer	50%	180	177	183
Summer	90%	186	184	190
Summer	99%	190	189	193

* System loss is equal to or less than the specified value for these percentages of time.

It is evident that the Seville-Weymouth values are statistically comparable with those for the Long Branch-Boulder path, recognizing that the former path is longer (see table I and [JTAC, 1960]). This is true in spite of the differences in path orientation. On the other hand, the relatively greater system loss values for the Tripoli-Leghorn path which is of comparable length would suggest some influence of the geomagnetic location of the scattering region, system loss being greater as one goes farther south.

Sporadic-E propagated signals were observed much more frequently in the European-Mediterranean area than in the United States. During June sporadic-E was in evidence 25 times as long in the European-Mediterranean area. The ionospheric scatter signal levels observed on the two European-Mediterranean paths are not greatly different from levels measured in the USA. The unusual variations and low signal levels observed in 1955 by Isted [1958] on 48 Mc/s transmitted from Gibraltar to England, have been explained on the basis of antenna patterns which favored off-path and higher-level scattering by meteoric ionization. Galactic noise levels at both receiving sites have been presented, together with an analysis of the interference observed at the receiving site in England. The observed galactic noise levels are in good agreement with predictable levels.

5. ACKNOWLEDGMENTS

The accomplishment of these experiments is due in large measure to our NBS colleagues who manned the field stations and kept transmitters and receivers operating 24 hours a day with remarkably few outages. The work of Milton W. Woodward, who with great resourcefulness kept a single, early model of the transmitter on the

air at Moron, Spain, is especially commendable. Valuable assistance was provided at all stations by airmen and non-commissioned officers assigned by the U.S. Air Force, 1823rd AACS Group. Logistical and financial matters were ably handled by the American Embassies and the U.S. Air Force. The help and encouragement so cheerfully given by Mr. C. F. Sutton of the British Air Ministry are greatly appreciated.

6. LIST OF FIGURES

7. LIST OF TABLES

8. REFERENCES

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APPENDIX

The relationship between signal generator calibration and the effective noise bandwidth [Koch, 1960] is obtained as follows:

1. Using a noise generator source of fairly high level, the receiver noise power output equals the product of the receiver integrated power gain over the pass band and the source noise power per unit bandwidth.
2. Using a signal generator source, the receiver power output equals the product of the power gain at the center of the pass band and the signal generator power.
3. If these two output powers are made equal a simple relation exists between the power gain at the center of the pass band and the integrated power gain. The effective noise bandwidth can then be readily calculated.

The effective noise bandwidth, B, is defined as the rectangular pass band which has the same maximum gain and passes the same noise power as the actual pass band.

$$B = \frac{1}{G} \int G_f \, df \qquad \text{[Goldman, 1948]}$$

where G = power gain at the center of the pass band

G_f = power gain as a function of frequency.

Using a noise generator source, the receiver noise power output is:

$$P_{out} = (F + 1)\, KT \int G_f \, df$$

where F = noise figure reading of the noise generator.

With a signal generator source tuned to the center of the pass band, and the signal generator output, P_{sg}, adjusted for the same receiver power output as before,

$$P_{out} = P_{sg} G.$$

Then,

$$P_{sg} G = (F + 1) KT \int G_f \, df$$

and

$$\frac{P_{sg}}{(F + 1) KT} = \frac{1}{G} \int G_f \, df = B$$

or

$$10 \log_{10} B = 10 \log_{10} P_{sg} - 10 \log_{10} (F + 1) KT$$

which can be rewritten

$$10 \log_{10} B = -10 \log_{10} KT - 10 \log_{10} (F + 1)$$

$$+ 10 \log_{10} P_{sg}.$$

If the power is expressed in decibels above one watt (dbw) and the noise figure in terms of decibels above KTB,

$$10 \log_{10} KT = 204 \text{ dbw} \quad \text{with } B = 1 \text{ Hz}$$

when T = 288.37°K.

If we write

$N = 10 \log_{10} (F + 1)$ expressed in db above KTB

and $S = 10 \log_{10} P_{sg}$ expressed in dbw

we obtain $10 \log_{10} B = 204 - N + S$

or $B = \text{Antilog}_{10} \dfrac{204 - (N - S)}{10}$.

The value of (N - S) for each of the nominal bandwidths utilized was obtained by plotting a number of the noise calibrations against the corresponding signal calibrations. The corresponding effective noise bandwidths are given in Table VII. The values of (N - S) for effective noise bandwidths of 100, 1000, and 2000 c/s are also given.

Table VII

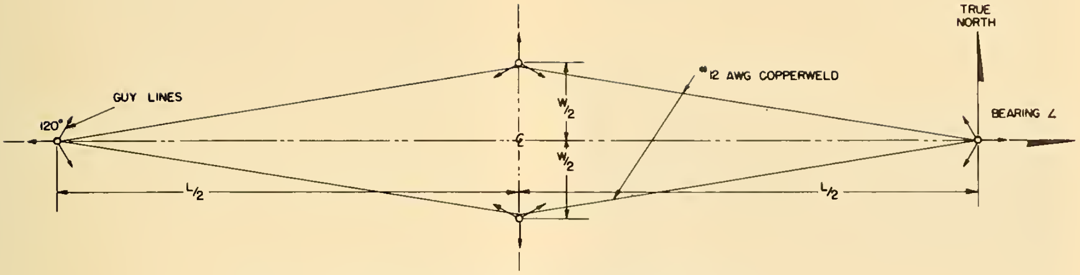
Nominal 3-db bandwidths	(N - S)	Effective noise bandwidths
c/s	db	c/s
40	188 ± 1	40 ± 10
80	181 ± 1	200 ± 50
250	179 ± 1	315 ± 80
	184	100
	174	1000
	171	2000

The probable errors in bandwidth in Table VII correspond to the errors in the determination of (N - S). The effective noise bandwidths probably differ from the nominal bandwidths because the 1000 c/s filters in the receivers which determined the bandwidths were broadened by increasing the filter circuit resistances, thus causing the skirts to widen rapidly.

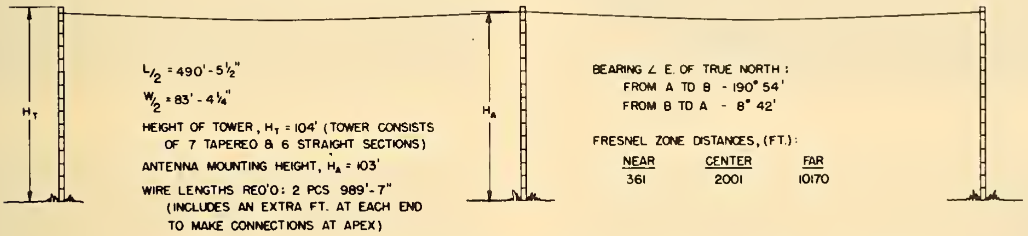
The above expression can be rewritten in the form

$$N - S = 204 - 10 \log B.$$

This formula is a convenient means of converting the galactic noise levels, N, of figures 15 and 16 into equivalent signal levels, S, when the noise bandwidth is known. The galactic noise levels of figures 15 and 16 are representative of the levels obtained using long-wire rhombic antennas pointed at the indicated declinations. See also section 3.4.



PLAN VIEW OF RHOMBIC ANTENNAS



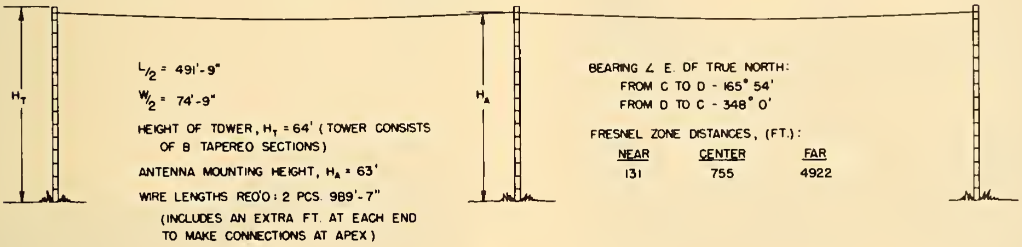
$L/2$ = 490'-5½"
$W/2$ = 83'-4¼"
HEIGHT OF TOWER, H_T = 104' (TOWER CONSISTS OF 7 TAPERED & 6 STRAIGHT SECTIONS)
ANTENNA MOUNTING HEIGHT, H_A = 103'
WIRE LENGTHS REQ'D: 2 PCS 989'-7" (INCLUDES AN EXTRA FT. AT EACH END TO MAKE CONNECTIONS AT APEX)

BEARING ∠ E. OF TRUE NORTH:
FROM A TO B - 190° 54'
FROM B TO A - 8° 42'

FRESNEL ZONE DISTANCES, (FT.):

NEAR	CENTER	FAR
361	2001	10170

TOWER & ANTENNA HEIGHTS FOR SEVILLE-WEYMOUTH PATH



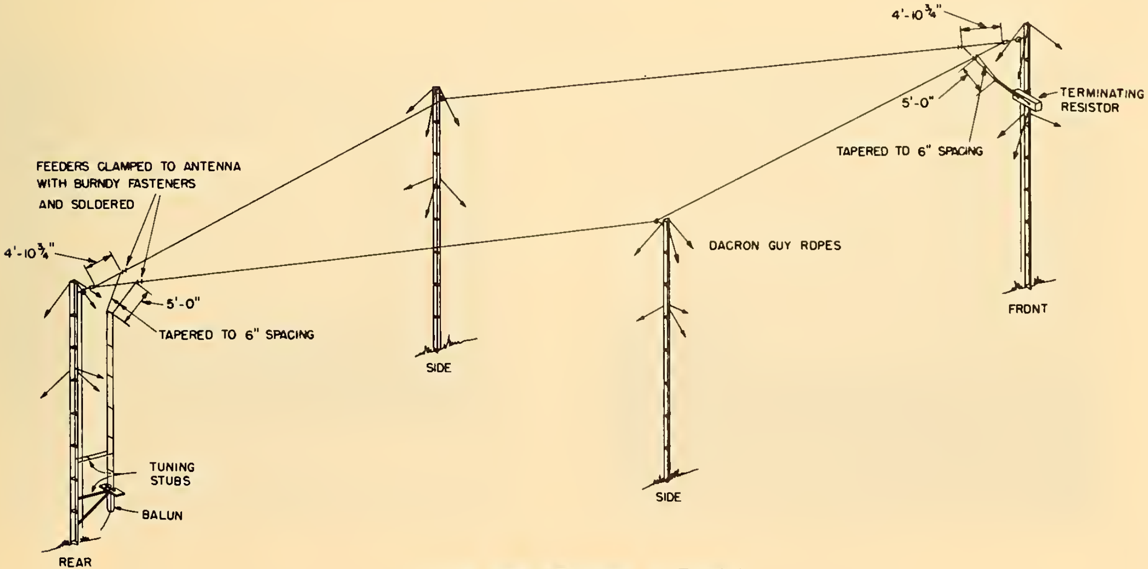
$L/2$ = 491'-9"
$W/2$ = 74'-9"
HEIGHT OF TOWER, H_T = 64' (TOWER CONSISTS OF 8 TAPERED SECTIONS)
ANTENNA MOUNTING HEIGHT, H_A = 63'
WIRE LENGTHS REQ'D: 2 PCS. 989'-7" (INCLUDES AN EXTRA FT. AT EACH END TO MAKE CONNECTIONS AT APEX)

BEARING ∠ E. OF TRUE NORTH:
FROM C TO D - 165° 54'
FROM D TO C - 348° 0'

FRESNEL ZONE DISTANCES, (FT.):

NEAR	CENTER	FAR
131	755	4922

TOWER & ANTENNA HEIGHTS FOR TRIPOLI-LEGHORN PATH

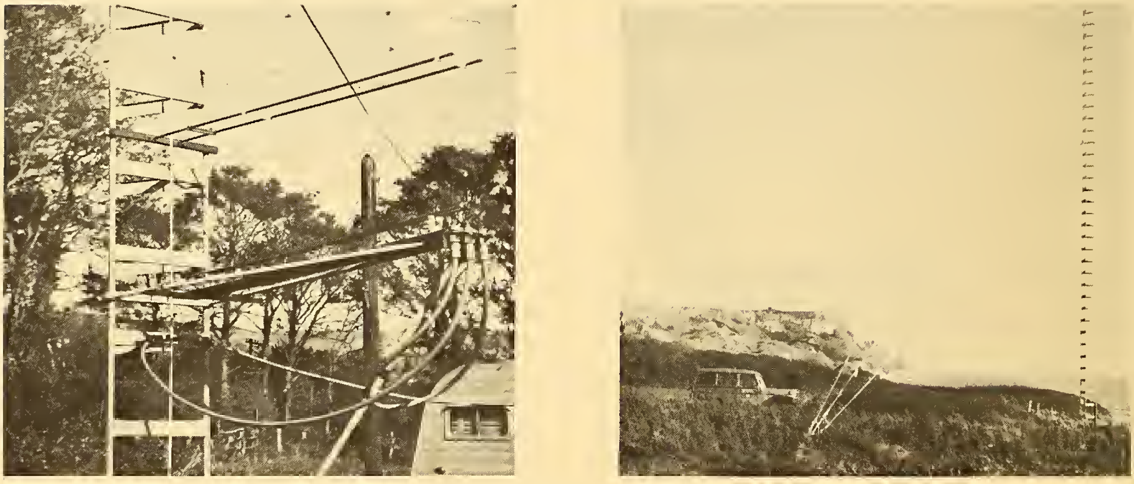


LONG WIRE RHOMBIC ANTENNA

Figure 1. Details of rhombic antennas

-SEVILLE SITE-

-WEYMOUTH SITE-



-TRIPOLI SITE-

Figure 2. Photographs of sites

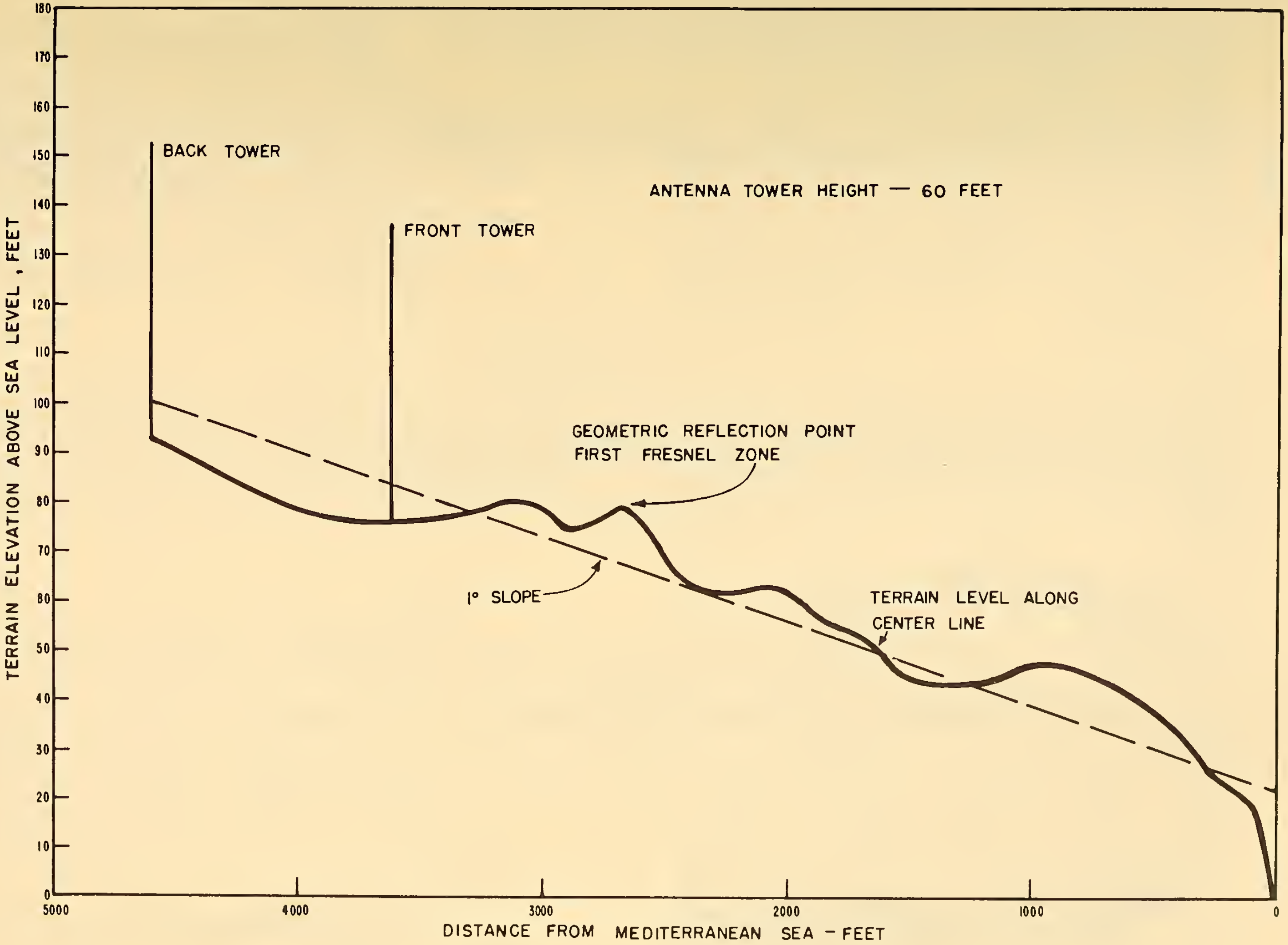
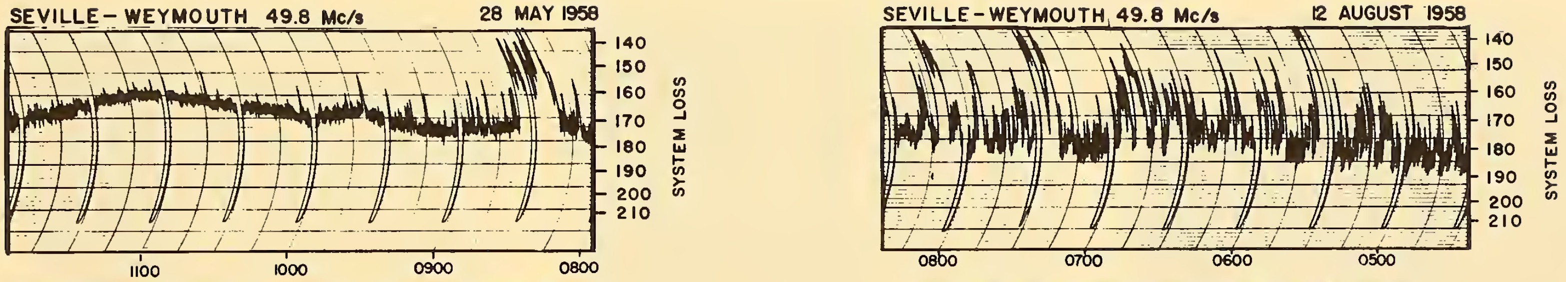


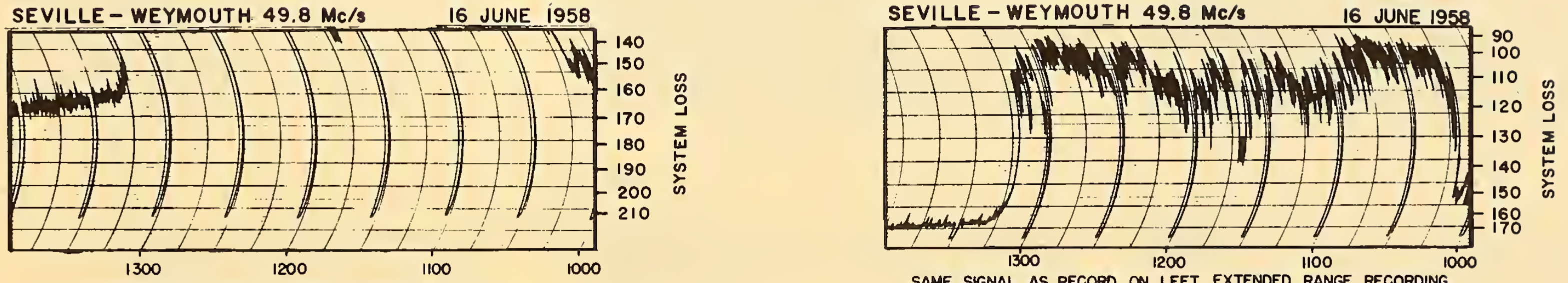
Figure 3. Terrain profile of Libya site


SEVILLE - WEYMOUTH 49.8 Mc/s 28 MAY 1958

SHORT INTERVAL E_s SIGNAL FOLLOWED BY NORMAL DAYTIME TRACE

SEVILLE - WEYMOUTH 49.8 Mc/s 12 AUGUST 1958

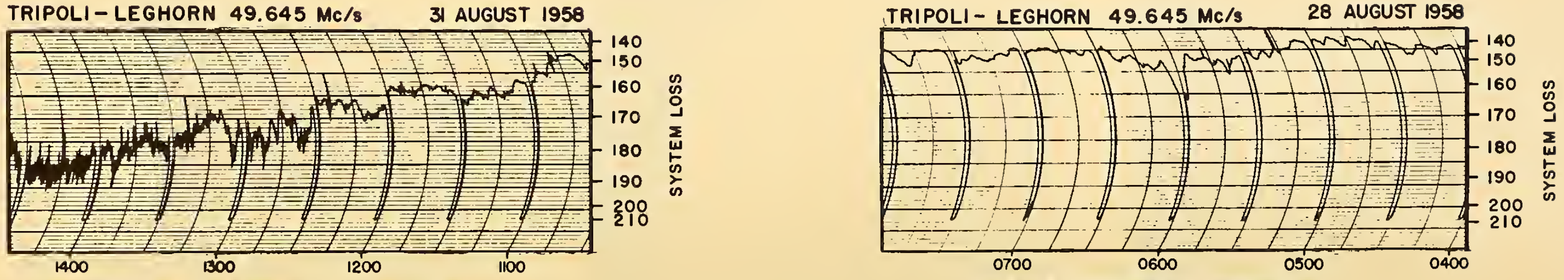
SPIKY RECORD OBTAINED DURING PERSEID METEOR SHOWER


SEVILLE - WEYMOUTH 49.8 Mc/s 16 JUNE 1958

E_s TRANSMISSION (NORMAL SCATTER RECORD AFTER 1320)

SEVILLE - WEYMOUTH 49.8 Mc/s 16 JUNE 1958

SAME SIGNAL AS RECORD ON LEFT, EXTENDED RANGE RECORDING


TRIPOLI - LEGHORN 49.645 Mc/s 31 AUGUST 1958

TRANSITION FROM TROPOSPHERIC TO NORMAL PROPAGATION

TRIPOLI - LEGHORN 49.645 Mc/s 28 AUGUST 1958

PROBABLE TROPOSPHERIC PROPAGATION

Figure 4. Sample recordings (6 - 5-hour records)

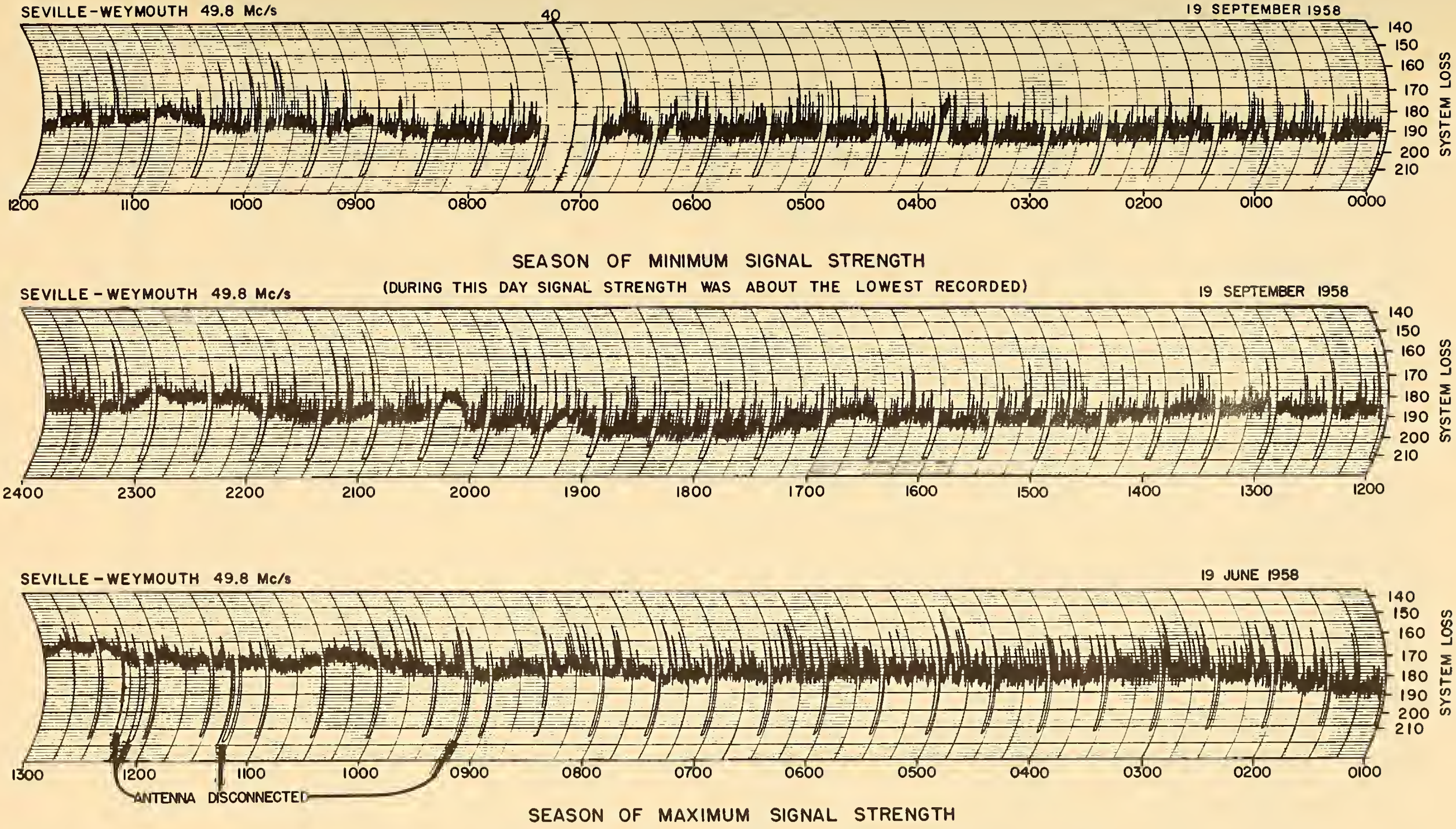


Figure 5. Sample recordings (3 - 12-hour records)

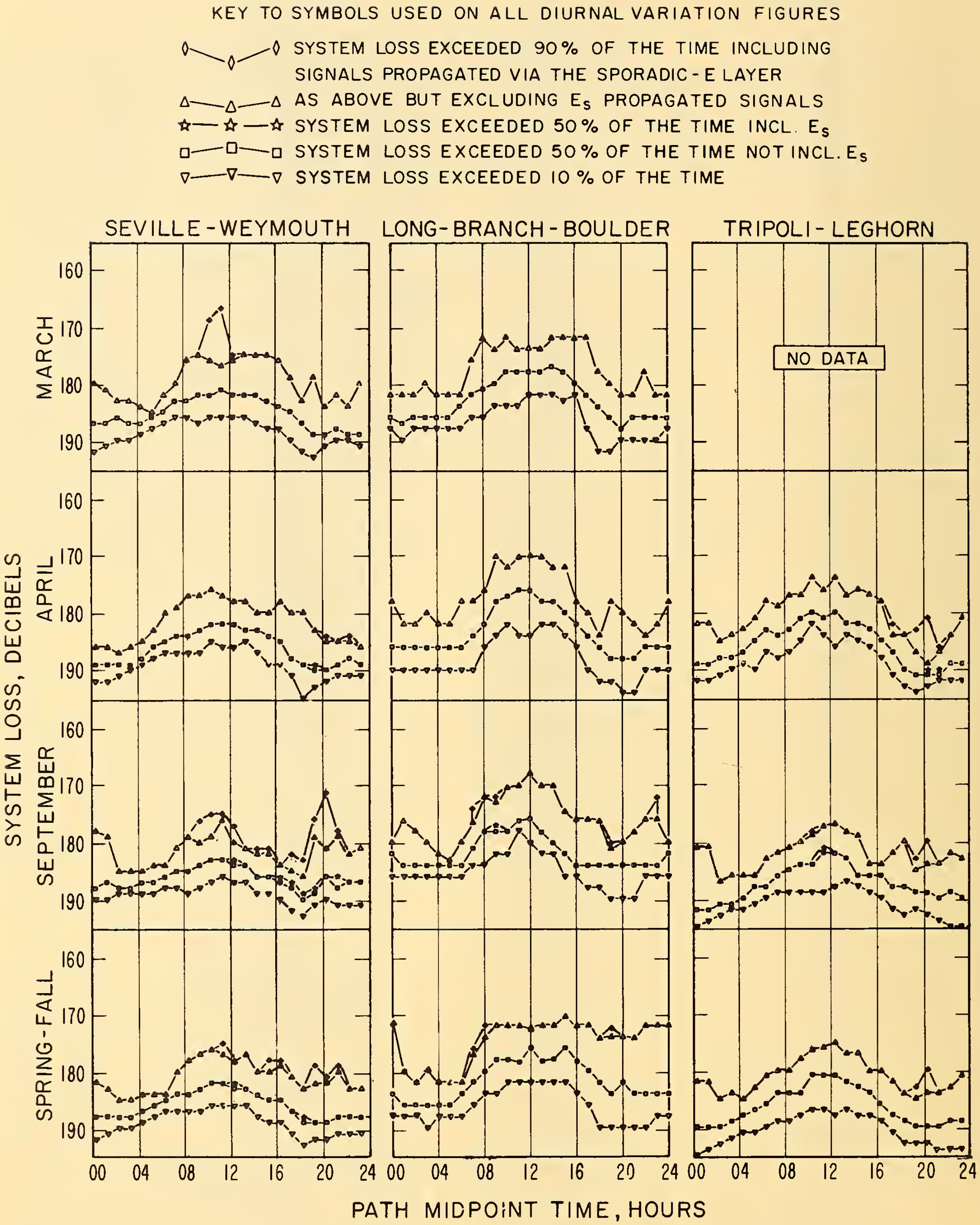


Figure 6. Diurnal variation during spring-fall months

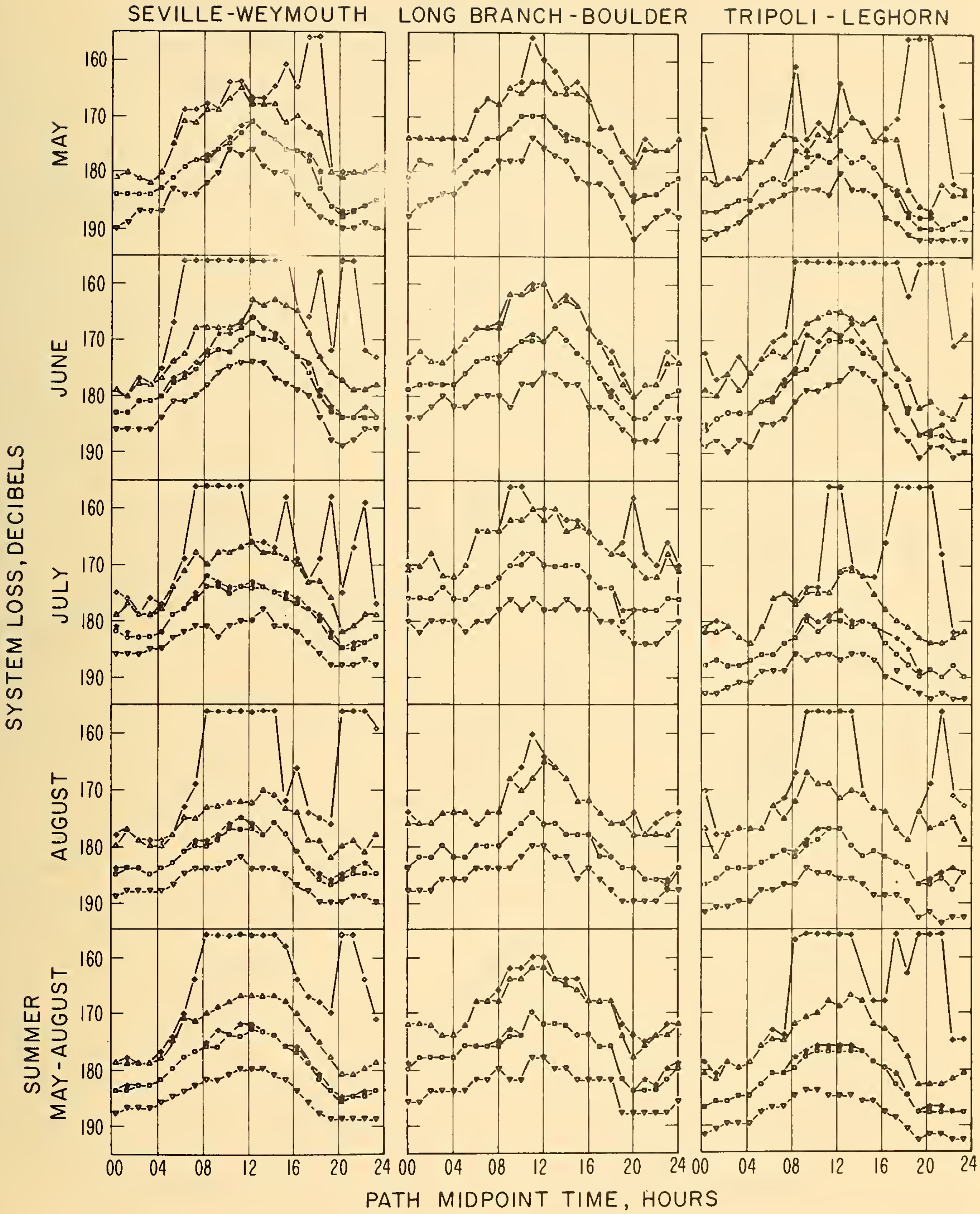


Figure 7. Diurnal variation during summer months

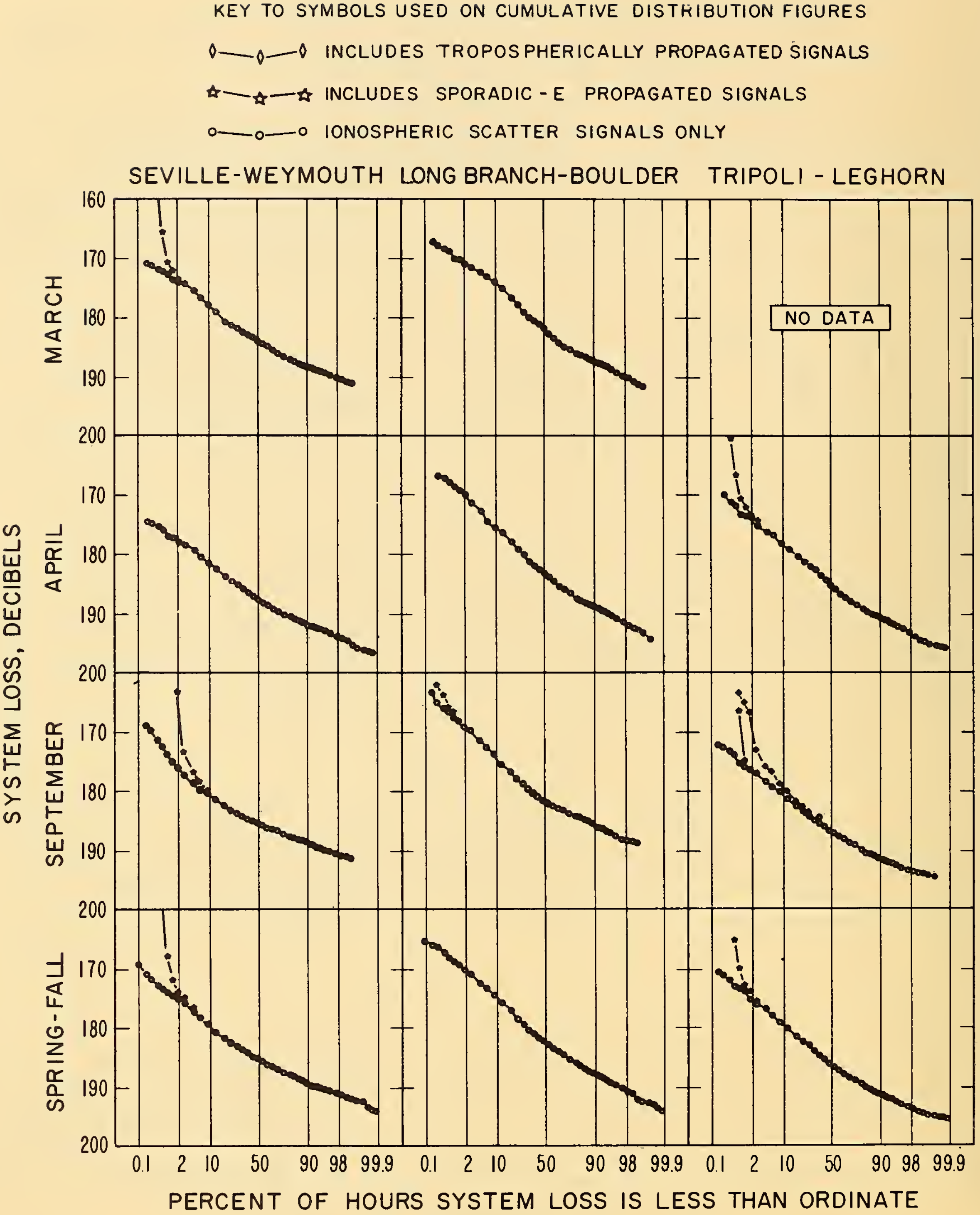


Figure 8. Cumulative distribution for spring-fall months

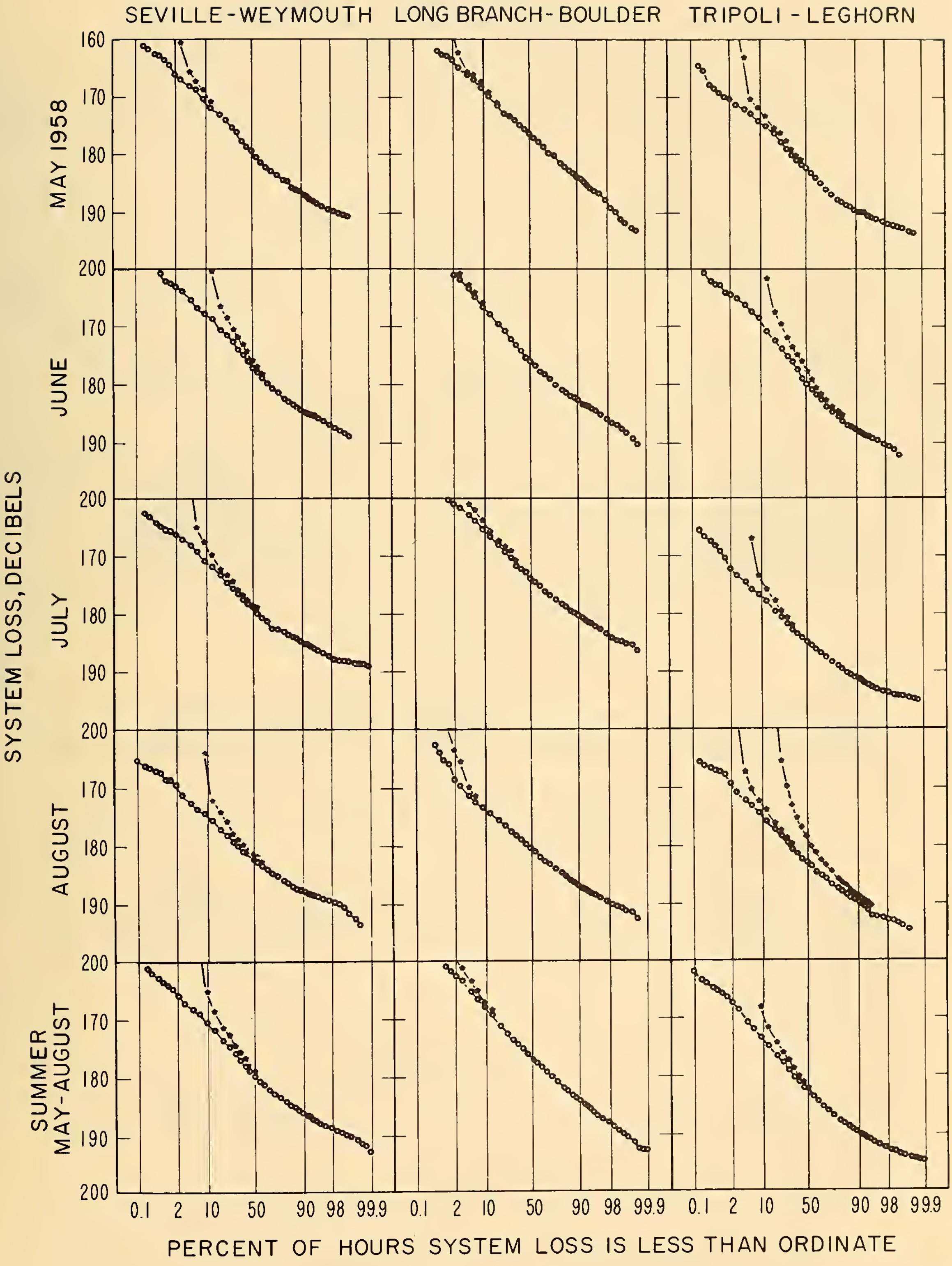


Figure 9. Cumulative distribution for summer months

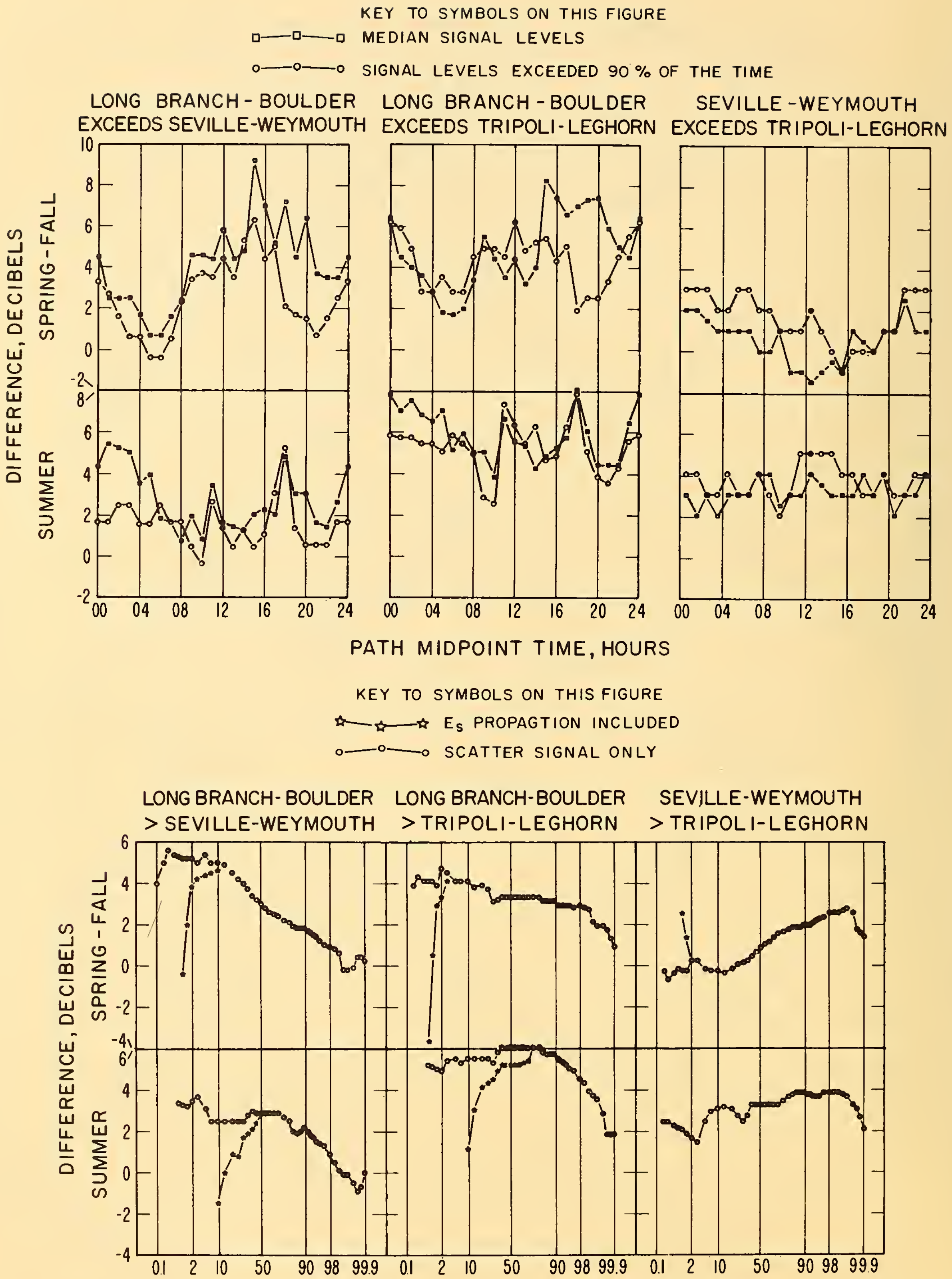


Figure 10. Differences between observed system losses (3 paths for summer months and spring-fall)

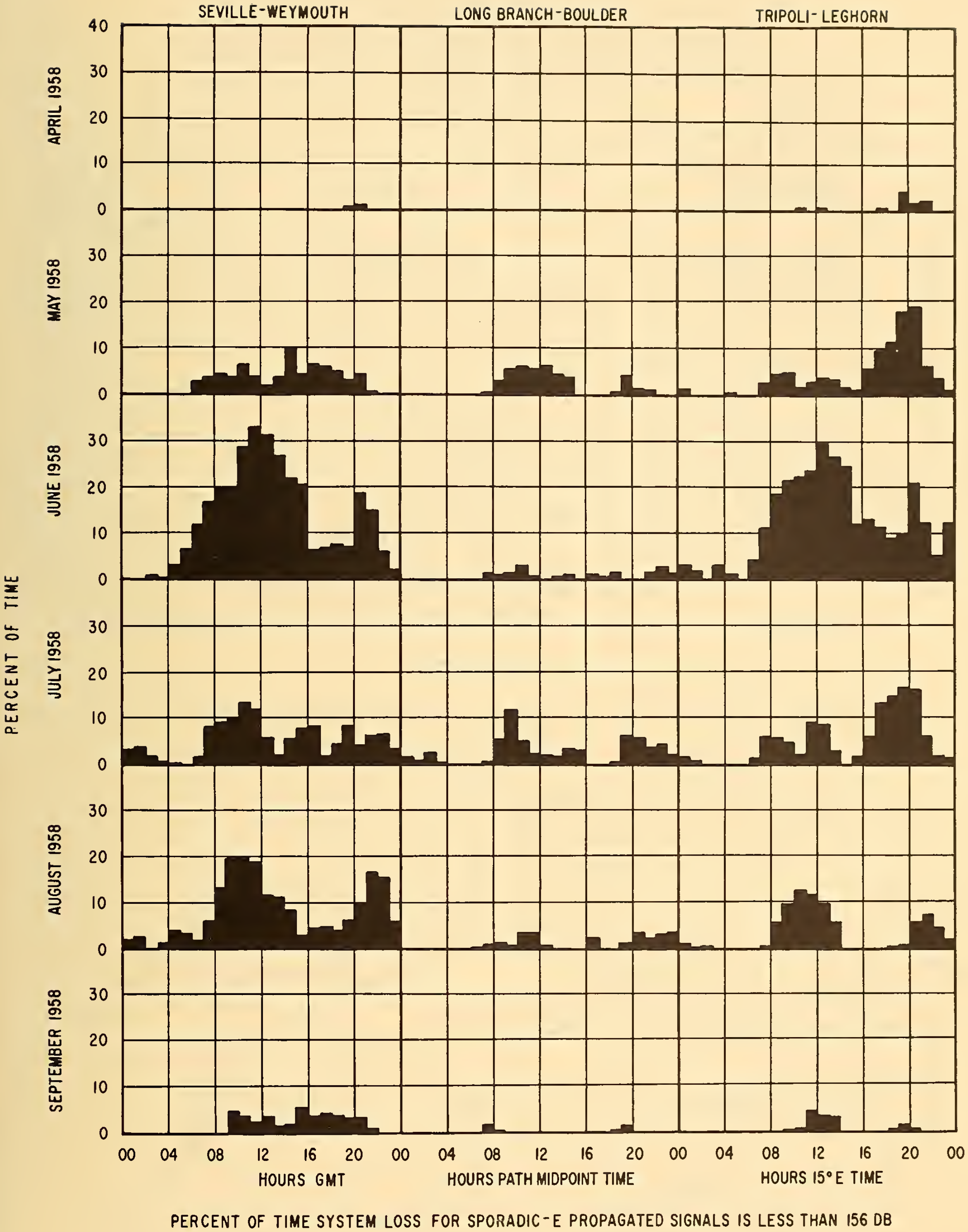


Figure 11. Percent of time sporadic-E propagated signal was present

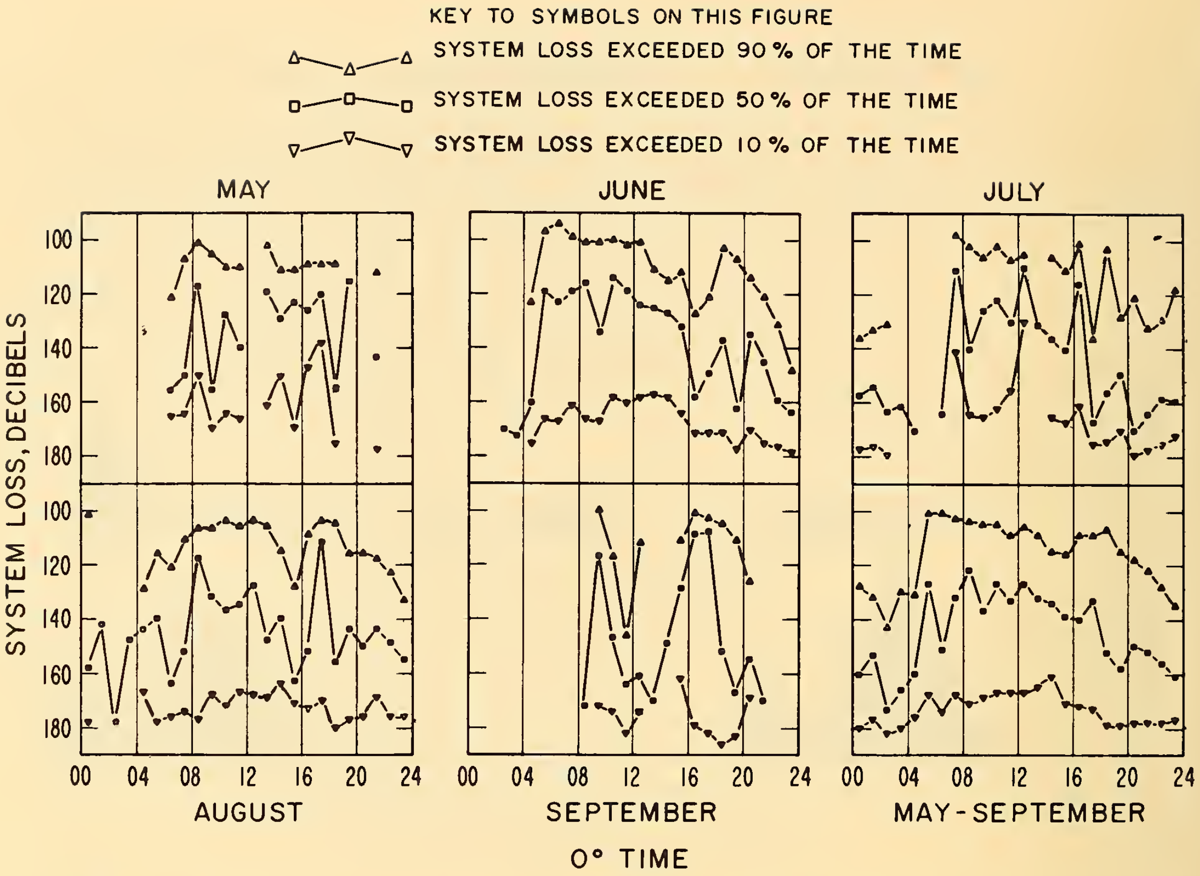


Figure 12. Diurnal variation of sporadic-E signals at Weymouth

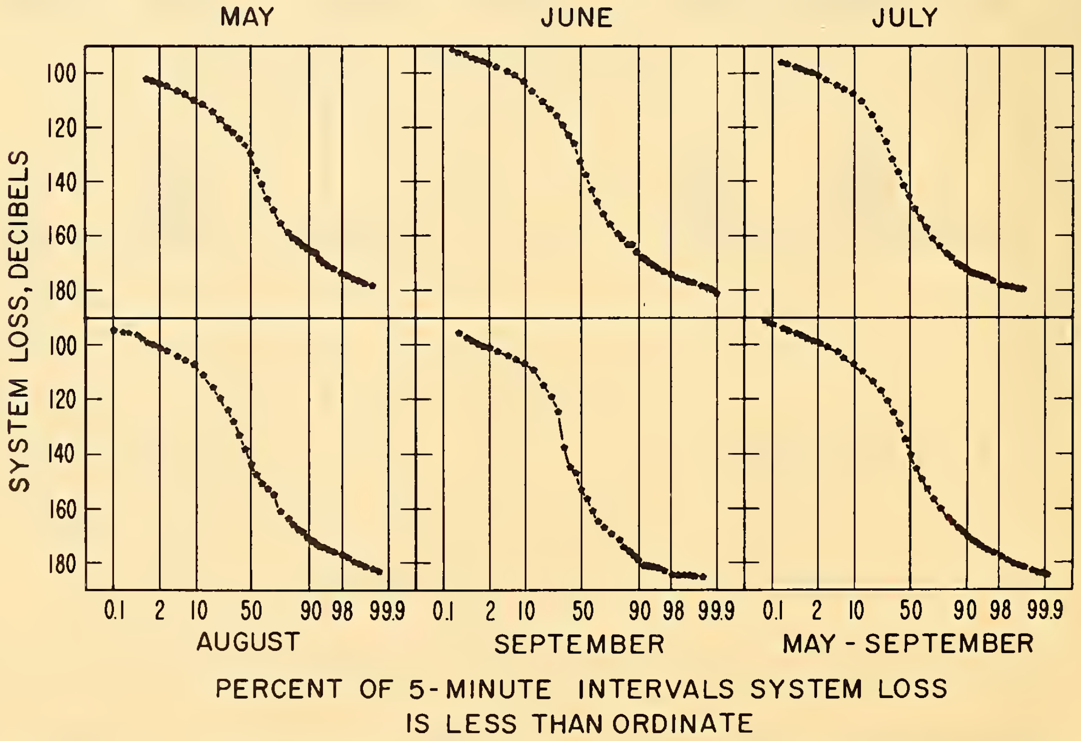


Figure 13. Cumulative distribution of sporadic-E signals at Weymouth

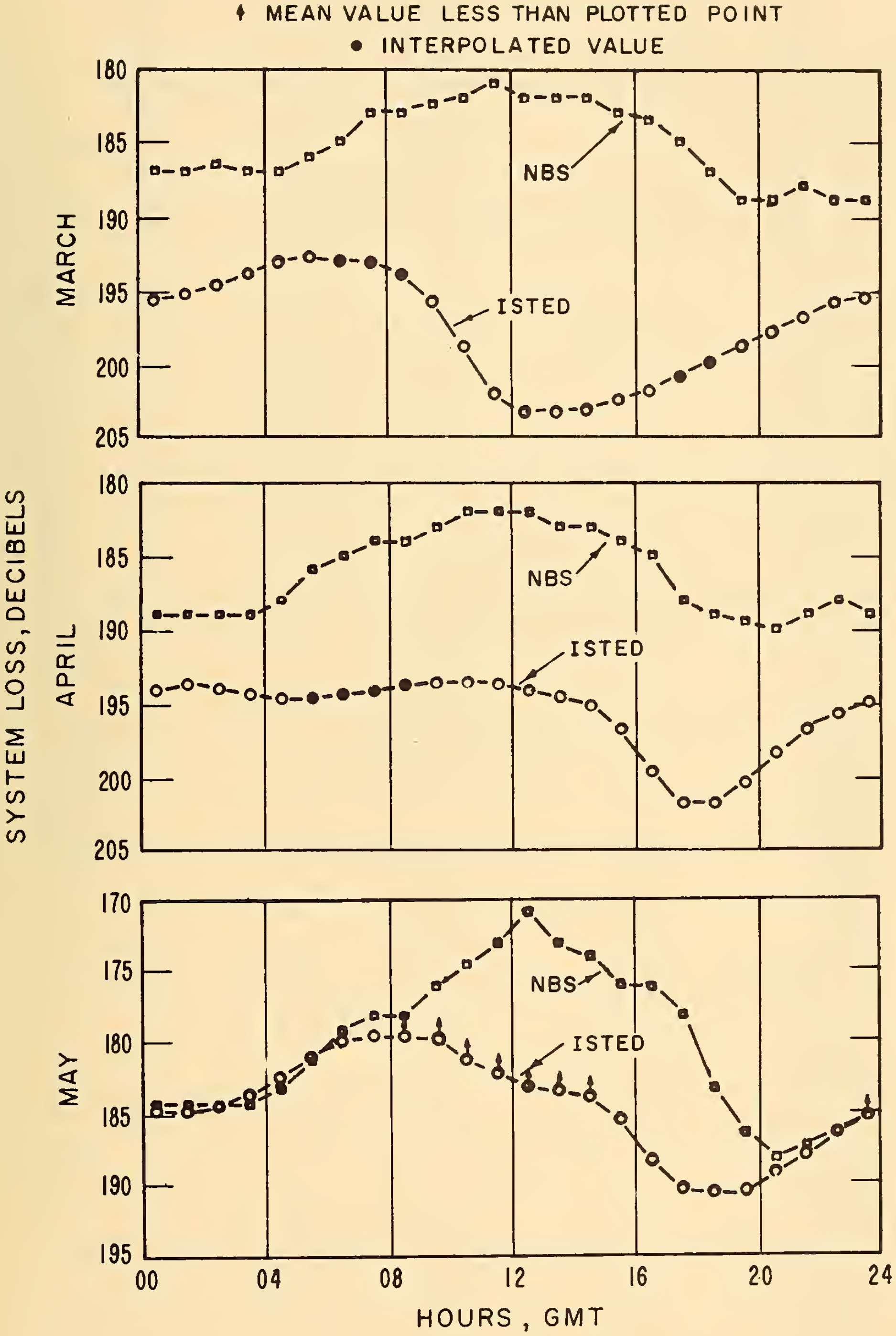


Figure 14. Comparison with Isted 1955 results

MASS PLOT OF LEVELS OBSERVED DURING HOURLY TWO-MINUTE TRANSMITTER BREAKS DURING THE MONTH OF AUGUST 1958. VERTICAL SCALE CALIBRATED BY USING 50 OHM COAXIAL DIODE NOISE GENERATOR. HORIZONTAL SCALE IS RIGHT ASCENSION OF MAIN LOBE OF RHOMBIC RECEIVING ANTENNA. DECLINATION IS -35° 22'.

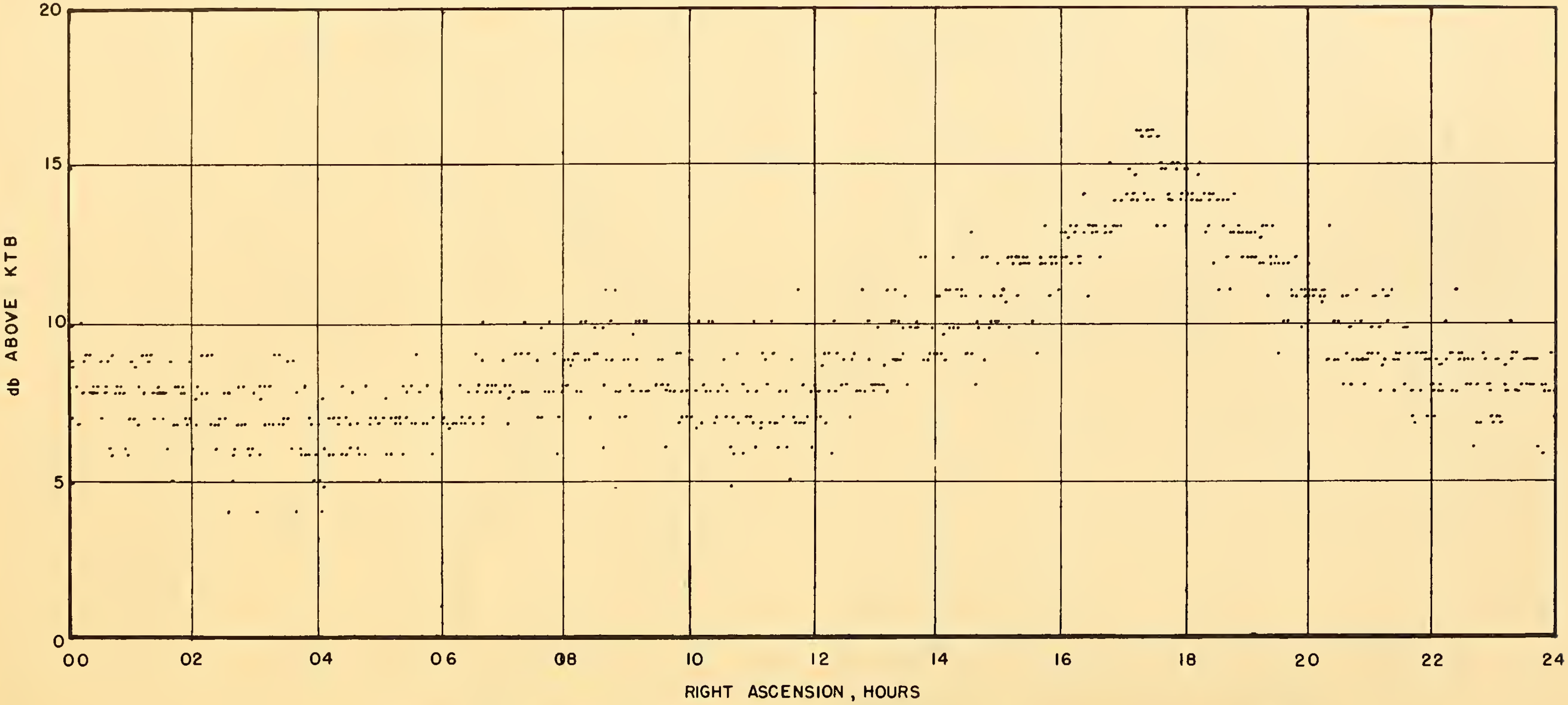
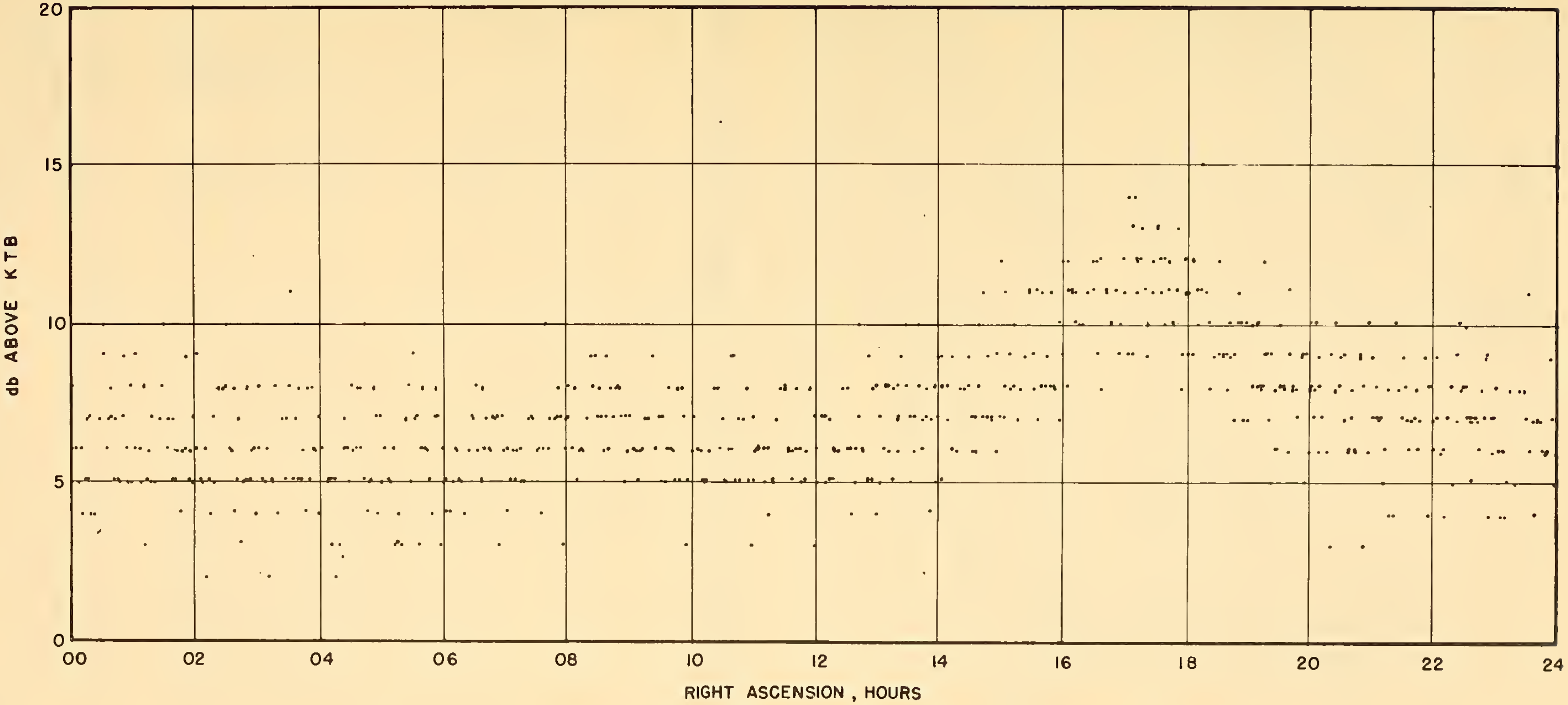
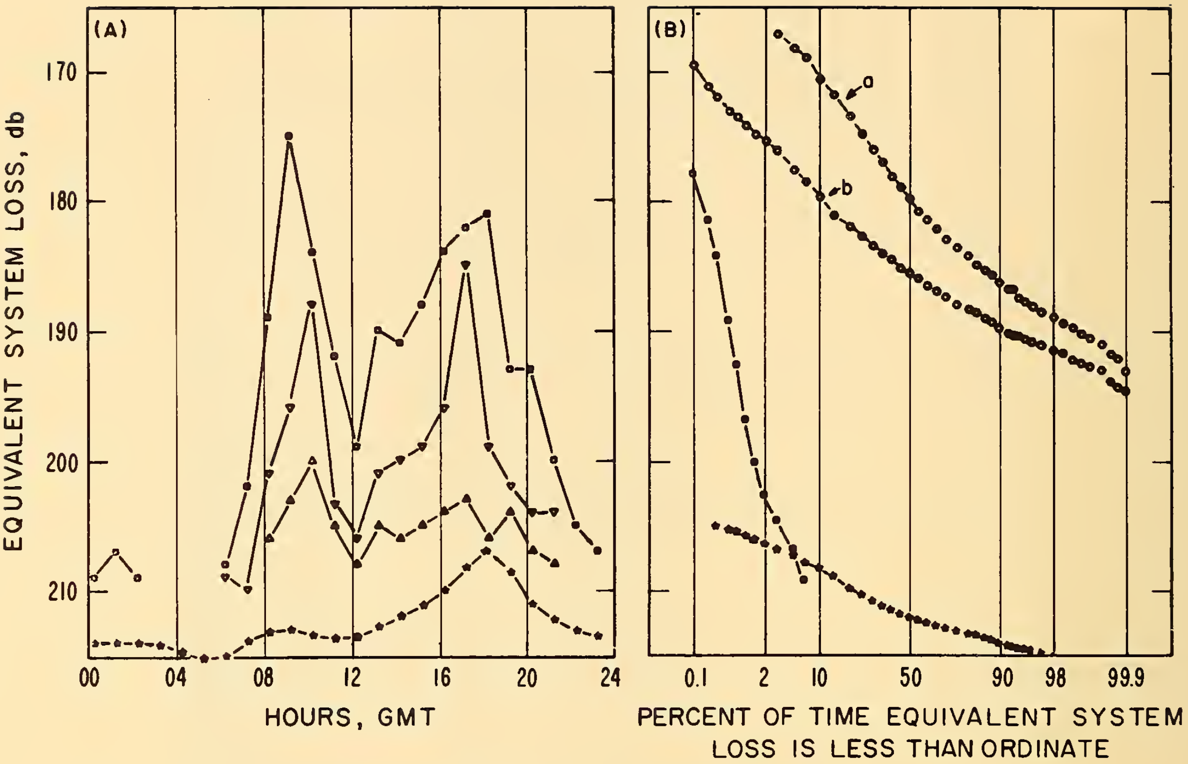


Figure 15. Observed galactic noise levels, Weymouth, England



MASS PLOT OF LEVELS OBSERVED DURING HOURLY TWO-MINUTE TRANSMITTER BREAKS DURING THE MONTH OF AUGUST 1958. VERTICAL SCALE CALIBRATED BY USING 50 OHM COAXIAL DIODE NOISE GENERATOR. HORIZONTAL SCALE IS RIGHT ASCENSION OF MAIN LOBE OF RHOMBIC RECEIVING ANTENNA. DECLINATION IS -39° 30'.

Figure 16. Observed galactic noise levels, Leghorn, Italy



NO E_s OBSERVED DURING HOUR

OBSERVED DURING PERIODS OF E_s

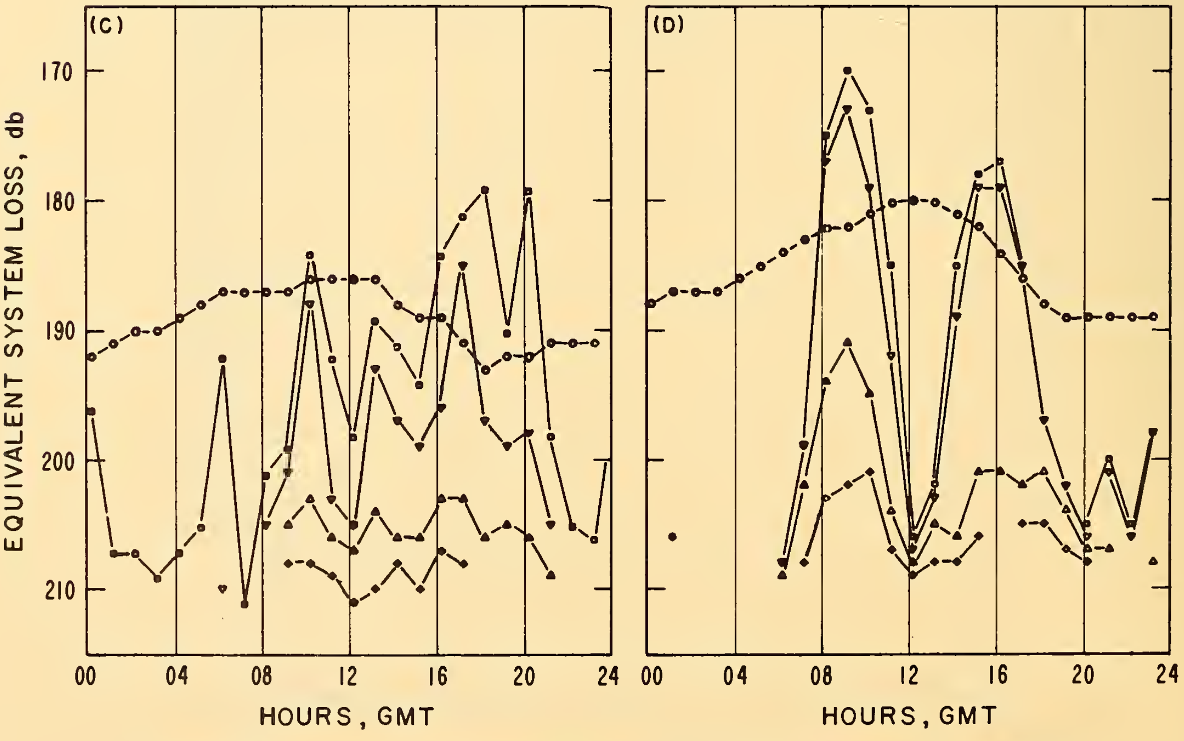


Figure 17. Interference observed at Weymouth, England

KEY FOR FIGURE 17

A.

□—□—□	PEAK INTERFERENCE LEVEL EXCEEDED DURING 1% OF TRANSMITTER BREAKS (BOTH CLASSES)
▽—▽—▽	PEAK INTERFERENCE LEVEL EXCEEDED DURING 2% OF TRANSMITTER BREAKS (BOTH CLASSES)
△—△—△	PEAK INTERFERENCE LEVEL EXCEEDED DURING 5% OF TRANSMITTER BREAKS (BOTH CLASSES)
☆—☆—☆	GALACTIC NOISE EXCEEDED 10% OF THE TIME. DIURNAL CURVE FOR SEPTEMBER 30.

B.

○—○—○	(a) IONOSPHERIC SCATTER SIGNAL (SUMMER 1958)
○—○—○	(b) IONOSPHERIC SCATTER SIGNAL (SPRING - FALL 1958)
□—□—□	PEAK INTERFERENCE LEVEL (BOTH CLASSES)
☆—☆—☆	GALACTIC NOISE LEVEL

C.

□—□—□	HIGHEST INTERFERENCE LEVEL OBSERVED DURING ANY TRANSMITTER BREAK
▽—▽—▽	PEAK INTERFERENCE LEVEL EXCEEDED DURING 2% OF TRANSMITTER BREAKS
○—○—○	IONOSPHERIC SCATTER SYSTEM LOSS EXCEEDED 10% OF THE TIME (SPRING-FALL 1958)
△—△—△	PEAK INTERFERENCE LEVEL EXCEEDED DURING 5% OF TRANSMITTER BREAKS
◇—◇—◇	PEAK INTERFERENCE LEVEL EXCEEDED DURING 10% OF TRANSMITTER BREAKS

D.

□—□—□	HIGHEST INTERFERENCE LEVEL OBSERVED DURING ANY TRANSMITTER BREAK
▽—▽—▽	PEAK INTERFERENCE LEVEL EXCEEDED DURING 2% OF TRANSMITTER BREAKS
○—○—○	IONOSPHERIC SCATTER SYSTEM LOSS EXCEEDED 10% OF THE TIME (SUMMER 1958)
△—△—△	PEAK INTERFERENCE LEVEL EXCEEDED DURING 5% OF TRANSMITTER BREAKS
◇—◇—◇	PEAK INTERFERENCE LEVEL EXCEEDED DURING 10% OF TRANSMITTER BREAKS

TABLE VI

(OATA FOR FIGURE 6)

SYSTEM LOSS - SPRING-FALL MONTHS

PATH FREQUENCY TIME CORRECTION	YEAR MONTH	TYPE	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
			TIME IN HOURS																							
SEVILLE-WEYMOUTH 49.800 Mc/s 14 MINUTES	1958 MARCH	90% E_s											169	167	175											
		90%	180	181	183	183	184	185	182	180	176	175	178	177	176	175	175	175	178	179	183	179	184	182	184	180
		50% E_s																								
		50%	187	187	186	187	187	188	185	183	183	182	182	181	182	182	182	183	184	185	187	189	189	188	189	189
		10 %	192	191	190	190	189	188	187	186	186	187	186	188	188	188	187	188	188	190	192	193	191	190	190	191
SEVILLE-WEYMOUTH 49.800 Mc/s 14 MINUTES	1958 APRIL	90% E_s																					184		184	
		90%	186	188	187	186	185	183	180	189	177	177	176	177	178	178	180	180	178	180	180	183	185	185	185	188
		50% E_s																				189				
		50%	189	189	189	189	188	188	185	184	184	183	182	182	182	183	183	184	185	188	189	190	190	189	188	189
		10%	192	192	191	190	189	188	187	187	187	187	185	186	188	185	187	189	189	191	195	193	192	191	191	191
SEVILLE-WEYMOUTH 49.800 Mc/s 14 MINUTES	1958 SEPTEMBER	90% E_s										178	175	175	177		181	181		182	183	178	171	178		
		90%	178	179	185	185	185	184	184	181	179	180	179	178	180	181	182	182	184	185	188	179	161	179	182	181
		50% E_s													185				186	187	189	188		188		
		50%	188	187	188	188	187	187	186	185	185	184	183	183	184	184	186	188	187	188	190	189	186	188	187	187
		10 %	190	190	189	189	189	189	188	188	189	188	187	188	187	187	189	189	190	192	193	191	190	191	191	191
SEVILLE-WEYMOUTH 49.800 Mc/s 14 MINUTES	1958 SPRING-FALL	90% E_s												175				178	178			179	181	179		
		90%	182	183	185	185	184	184	184	180	178	177	178	177	178	177	180	180	179	181	183	182	182	180	183	183
		50% E_s													182						188					
		50%	188	188	188	188	187	186	185	184	184	183	182	182	183	183	164	185	185	187	189	189	189	188	188	188
		10 %	192	191	190	190	189	188	187	187	187	187	188	188	188	188	188	189	189	191	193	192	192	191	191	191
LONG BRANCH-BOULDER 49.880 Mc/s 0 MINUTES	1958 MARCH	90% E_s																								
		90%	182	182	182	180	182	182	182	176	172	174	172	174	174	174	172	172	172	172	178	180	182	182	178	182
		50% E_s																								
		50 %	188	187	186	188	188	188	184	182	181	180	178	178	178	178	177	178	180	182	184	188	188	188	188	188
		10 %	188	190	188	188	188	188	188	188	186	184	184	184	182	182	182	183	182	188	192	192	190	190	190	190
LONG BRANCH-BOULDER 49.880 Mc/s 0 MINUTES	1958 APRIL	90% E_s																								
		90%	178	182	182	180	182	182	178	178	176	170	172	170	170	170	172	172	178	180	184	178	180	182	184	182
		50% E_s																								
		50%	186	188	186	186	186	188	186	184	182	178	177	178	178	178	178	180	182	184	188	188	188	188	188	186
		10%	190	190	190	190	190	190	190	190	188	184	182	184	184	182	182	184	188	190	192	192	194	194	190	190
LONG BRANCH-BOULDER 49.880 Mc/s 0 MINUTES	1958 SEPTEMBER	90% E_s								174		172										180				172
		90%	180	178	178	180	182	183	180	176	172	173	170	170	168	170	170	174	178	178	176	181	180	178	178	176
		50% E_s										177														
		50%	182	184	184	184	184	184	184	181	178	178	178	178	178	178	180	182	184	184	184	184	184	184	184	184
		10 %	188	188	188	186	186	188	186	188	184	182	182	178	180	182	182	188	188	188	188	190	190	190	188	188
LONG BRANCH-BOULDER 49.880 Mc/s 0 MINUTES	1958 SPRING-FALL	90% E_s								178	172											172				
		90%	172	180	182	180	182	182	182	177	174	172	172	172	172	172	172	170	172	172	174	174	174	174	172	172
		50% E_s																								
		50%	184	188	186	188	188	186	184	182	180	178	178	178	178	178	178	176	178	180	182	184	182	184	184	184
		10 %	188	188	188	190	188	188	188	188	184	184	182	182	182	182	182	182	184	188	190	190	190	190	190	188

NOTE: THESE TABLES GIVE THE VALUE OF HOURLY MEDIAN SYSTEM LOSS EXCEEDED DURING THE PERCENTAGE OF TIME SHOWN IN THE COLUMN HEADED TYPE. WHEN THE PERCENTAGE IS FOLLOWED BY "E_s" THE TABULAR VALUE INCLUDES THE EFFECT OF SIGNALS PROPAGATED BY THE SPORADIC-E LAYER. WHEN THE CORRECTION IS ADDED TO THE HOUR SHOWN IN THE COLUMN HEADING THE RESULT IS PATH MIDPOINT TIME.

TABLE VI

(DATA FOR FIGURES 6 AND 7)

SYSTEM LOSS – SPRING-FALL MONTHS

PATH FREQUENCY TIME CORRECTION	YEAR MONTH	TYPE	TIME IN HOURS																							
			00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
TRIPOLI-LEGHORN 49.645 Mc/s 18 MINUTES	1958 MARCH	90% E_s																								
		90%																								
		50% E_s											NO DATA													
		50%																								
		10%																								
TRIPOLI-LEGHORN 49.645 Mc/s 18 MINUTES	1958 APRIL	90% E_s																		182		183	181	186		
		90%	182	182	185	184	183	181	178	179	177	177	174	176	174	177	176	177	178	184	184	187	189	187	184	181
		50% E_s																					190	190		
		50%	189	189	188	188	187	185	183	184	183	181	180	181	180	182	162	183	185	187	190	191	191	191	189	189
		10%	192	192	191	190	189	190	187	188	187	185	182	184	186	184	185	186	188	191	193	194	193	192	192	192
TRIPOLI-LEGHORN 49.645Mc/s 18 MINUTES	1958 SEPTEMBER	90% E_s											178									183	180			
		90%	181	181	187	186	186	186	183	182	181	180	179	177	177	178	179	184	164	182	180	185	184	184	182	183
		50% E_s												181												
		50%	192	192	191	191	190	188	188	186	185	184	184	182	182	183	186	186	186	188	188	189	189	190	189	190
		10%	195	194	193	192	192	191	190	189	189	189	189	189	188	187	168	189	190	192	193	192	193	194	195	195
TRIPOLI-LEGHORN 49.645Mc/s 18 MINUTES	1958 SPRING-FALL	90% E_s																				183	180			
		90%	182	182	185	184	185	183	181	180	180	178	176	176	175	177	177	180	180	182	164	185	184	184	183	181
		50% E_s																								
		50%	190	190	190	189	188	187	186	184	184	184	181	181	181	182	183	184	186	188	189	190	190	190	189	189
		10%	195	194	193	192	191	191	190	189	189	188	187	187	186	167	168	188	189	191	193	193	193	194	194	194

SYSTEM LOSS – SUMMER MONTHS

SEVILLE-WEYMOUTH 49.800 Mc/s 14 MINUTES	1958 MAY	90% E_s							169	169	168		164	164	167	167	185	161	165	151	154		160			
		90%	181	180	181	182	180	175	171	171	169	169	167	165	168	168	168	171	170	172	173	180	181	180	180	179
		50% E_s									177		174	172						177	180		187			
		50%	164	184	184	184	183	181	179	178	176	176	175	173	171	173	174	176	176	178	183	186	188	167	186	185
		10%	190	189	187	187	187	183	184	184	182	160	178	177	176	179	180	180	184	186	188	189	190	190	189	190
SEVILLE-WEYMOUTH 49.800 Mc/s 14 MINUTES	1958 JUNE	90% E_s			177		175	167	124	117	115	139	107	112	109	124	124	131		166	158	172	124	137	172	173
		90%	179	180	178	178	177	174	172	168	168	168	168	167	163	164	163	164	165	169	173	176	177	179	179	178
		50% E_s						177	176	174	172	169	169	168	166	166	169			174	179	182			182	
		50%	183	163	181	181	180	173	177	175	173	172	172	170	169	170	170	171	173	176	180	183	184	184	184	184
		10%	186	186	186	186	184	181	181	180	178	176	175	174	174	174	177	178	179	180	184	188	189	188	186	186
SEVILLE-WEYMOUTH 49.800 Mc/s 14 MINUTES	1958 JULY	90% E_s	175	176		178	177		169	141	149	136	136	141		166	167	158	169		169	158	175	167	159	177
		90%	179	177	179	179	178	174	171	168	170	168	168	167	166	168	168	169	170	173	173	176	182	181	179	179
		50% E_s	181	182						175	172	173	174		173			175	176		179	182		184		
		50%	182	183	183	183	182	179	178	176	174	174	175	174	174	174	175	176	177	178	180	183	185	185	184	183
		10%	186	186	166	185	165	183	182	181	181	183	181	180	180	178	181	181	182	184	186	188	188	188	187	188
SEVILLE-WEYMOUTH 49.800Mc/s 14 MINUTES	1958 AUGUST	90% E_s	178			179	179		173	169	114	121	108	121	131	137	149	172	166	174	175	176	155	144	134	159
		90%	180	177	179	180	180	178	175	175	173	173	172	172	172	170	171	173	174	179	179	182	180	179	181	178
		50% E_s	184							179	179	176	178	175	176						185	186	185	184	183	
		50%	165	184	164	185	184	183	181	180	180	179	177	177	177	178	178	178	181	184	186	167	186	185	185	185
		10%	189	188	188	188	188	187	185	184	184	184	163	182	184	184	164	185	187	188	190	190	190	189	189	190
SEVILLE-WEYMOUTH 49.800Mc/s 14 MINUTES	1958 SUMMER	90% E_s		178			177	174	170	164	140	148	121	127	152	137	149	158	164	167	168	170	155	154	164	171
		90%	179	179	179	179	178	175	171	171	170	169	168	167	167	167	167	168	170	173	175	178	181	181	180	179
		50% E_s		183							175	173		172	172				176		181		185		184	
		50%	164	184	183	183	182	180	178	177	176	176	174	174	173	173	174	176	177	179	182	184	186	185	165	184
		10%	188	187	187	187	186	185	184	183	182	182	181	180	180	180	181	182	164	186	188	189	189	189	189	189

TABLE VI

(DATA FOR FIGURE 7)

SYSTEM LOSS - SUMMER MONTHS

PATH FREQUENCY TIME CORRECTION	YEAR MONTH	TYPE	TIME IN HOURS 00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
LONG BRANCH-BOULDER 49.880 Mc/s 0 MINUTES	1958 MAY	90% E_s											164	146	160	162	165	164					176	174		
		90%	174	174	174	174	174	174	169	167	166	165	166	164	164	166	166	166	167	172	172	176	179	176	176	176
		50% E_s															175						184			
		50%	181	178	179	180	180	178	176	174	174	172	170	170	170	172	174	174	175	176	178	182	185	184	184	182
		10%	188	166	185	164	164	182	180	180	178	178	176	174	166	177	178	161	162	182	184	188	192	190	188	187
LONG BRANCH-BOULDER 49.880 Mc/s 0 MINUTES	1958 JUNE	90% E_s									167			160			162				172	176				172
		90%	174	172	174	174	172	170	168	168	168	162	162	161	160	164	163	164	168	170	174	178	180	176	178	174
		50% E_s									173			169							179					
		50%	179	178	178	178	178	176	174	173	174	172	170	170	170	168	170	172	174	177	160	182	164	184	182	160
		10%	184	164	162	180	182	182	180	180	180	162	178	178	176	176	178	178	182	162	164	186	168	188	186	164
LONG BRANCH-BOULDER 49.880 Mc/s 0 MINUTES	1958 JULY	90% E_s	170									140	154		160		162	162				166	158	168	170	166
		90%	171	170	166	172	172	170	164	164	164	162	162	160	162	160	164	163	164	166	168	166	170	172	172	168
		50% E_s											166									176				
		50%	176	176	176	174	176	176	174	174	172	170	170	168	170	170	170	170	172	174	174	180	178	176	178	176
		10%	160	182	180	180	160	182	180	180	178	176	178	176	178	178	176	178	178	180	180	182	184	184	184	182
LONG BRANCH-BOULDER 49.880 Mc/s 0 MINUTES	1958 AUGUST	90% E_s	174										168	160	164								174		176	174
		90%	176	176	176	174	174	174	176	174	174	168	170	166	165	166	168	172	172	174	176	176	178	176	178	178
		50% E_s																		180						188
		50%	184	182	182	180	182	182	180	180	160	178	176	174	176	176	178	178	178	162	182	184	164	186	186	187
		10%	188	168	188	186	166	166	184	184	184	184	182	180	180	182	182	186	184	166	188	190	190	190	190	188
LONG BRANCH-BOULDER 49.880 Mc/s 0 MINUTES	1958 SUMMER	90% E_s									166	162	162	180	160		164	164				172	174	175		172
		90%	172	172	172	174	174	172	168	168	168	164	164	162	162	164	165	166	168	168	168	174	176	176	174	174
		50% E_s	179								175	175												182	183	180
		50%	180	178	178	176	178	176	176	176	176	174	174	170	172	172	172	174	174	176	176	182	184	184	184	182
		10%	186	186	184	184	184	184	182	182	180	182	182	178	176	180	160	182	182	182	182	188	168	188	188	166
TRIPOLI-LEGHORN 49.645 Mc/s 18 MINUTES	1958 MAY	90% E_s	172								161	174	171	173	164				172	170	134	134	139	168	182	183
		90%	181	182	181	181	178	178	175	173	174	176	173	174	172	170	171	174	174	174	183	166	167	182	184	184
		50% E_s									176	177								185	187	188	168			
		50%	187	187	186	185	185	182	181	182	180	179	177	178	176	178	177	179	182	184	188	190	190	190	189	168
		10%	192	191	190	189	187	186	165	164	163	163	163	184	180	183	183	184	188	189	191	192	192	192	192	192
TRIPOLI-LEGHORN 49.645 Mc/s 18 MINUTES	1958 JUNE	90% E_s	172	177		173			170	169	134	134	134	141	140	134	134	150	134	134	162	134	134	143	171	169
		90%	179	160	178	179	178	173	172	173	170	167	168	165	165	166	167	166	170	175	177	182	181	183	184	160
		50% E_s	185						180	177	175	169	170	168	169	167	170				182		186	185		
		50%	186	184	163	183	163	181	181	178	178	175	172	170	170	170	172	173	176	178	183	187	187	167	186	188
		10%	189	188	190	188	189	185	185	184	181	179	179	178	177	175	176	177	182	166	188	191	189	189	191	190
TRIPOLI-LEGHORN 49.645 Mc/s 18 MINUTES	1958 JULY	90% E_s	181	180							176	174	174	139	156	170		172	166	134	134	134	138	168	182	
		90%	182	182	181	183	184	181	176	175	177	175	175	175	171	171	172	175	178	180	181	183	164	184	183	162
		50% E_s										179	160	179	176	180				183	185	189				
		50%	168	187	188	188	187	186	186	184	183	180	182	160	180	181	180	181	164	186	188	190	189	190	188	190
		10%	193	193	192	191	191	189	189	189	186	187	188	186	167	186	186	187	190	189	192	193	194	193	194	194
TRIPOLI-LEGHORN 49 645 Mc/s 18 MINUTES	1958 AUGUST	90% E_s	170	178						171	167	134	134	134	134	153							169	145	171	173
		90%	177	182	176	177	177	177	173	175	172	167	169	169	171	170	171	173	174	177	179	174	177	176	175	179
		50% E_s									181	179	177										186	185	184	
		50%	187	186	184	184	184	183	182	181	182	180	179	177	177	180	182	181	182	183	184	187	187	186	188	185
		10%	192	191	191	190	190	188	188	187	187	164	185	185	186	186	187	189	189	189	190	193	192	194	193	193
TRIPOLI-LEGHORN 49.645 Mc/s 18 MINUTES	1958 SUMMER	90% E_s	179	181					173	174	157	144	152	141	149	152		168	168	134	163	134	139	153	175	175
		90%	181	182	179	180	179	176	175	175	172	171	170	168	169	167	168	172	173	175	178	183	183	183	182	181
		50% E_s									178	177	176	176	176	176				181			167	187		
		50%	187	186	186	185	185	183	161	181	180	178	177	177	177	177	177	179	180	163	185	188	188	188	188	188
		10%	192	191	190	190	190	168	187	187	165	164	164	185	185	185	186	186	188	189	191	193	192	192	193	193

TABLE VI

(DATA FOR FIGURES 8 AND 9)

PATH FREQUENCY	YEAR MONTH	DATA INCLUDED	SELECTED PERCENTAGES FROM CUMULATIVE DISTRIBUTIONS																							
			0.5	01	02	05	10	20	30	40	50	60	70	80	86	90	93	95	97	98	98.6	99.0	99.3	99.5	99.7	99.8
SEVILLE - WEYMOUTH 49.800 Mc/s	1958 MARCH	E_s	161	171	174	176																				
		SCATTER	172	173	175	176	178	181	182	184	184	186	187	188	189	189	190	190	190	191	191	192	192			
	1958 APRIL	E_s																								
		SCATTER	175	177	178	179	182	184	185	187	188	189	190	191	192	192	193	193	194	194	194	195	196	196	196	197
	1958 MAY	E_s	121	125	140	166	169	173																		
		SCATTER	163	164	166	168	171	173	176	178	180	182	183	185	186	187	188	188	189	190	190	191	191	191		
	1958 JUNE	E_s	99	101	106	118	146	166	170	173	176	180	180	182	184											
		SCATTER		162	163	166	168	170	173	175	177	179	181	183	184	165	185	186	186	187	188	188	189	189		
	1958 JULY	E_s	110	114	132	158	168	172	174	177	178	180	182													
		SCATTER	164	165	166	168	170	173	176	178	179	181	182	183	184	185	185	186	187	187	188	188	188	188	189	189
	1958 AUGUST	E_s	105	109	114	134	164	174	178	180	181	182	184													
		SCATTER	167	168	169	172	175	177	179	181	182	183	184	186	187	188	188	188	189	189	190	190	190	192	192	194
	1958 SEPTEMBER	E_s	108	168	174	177																				
		SCATTER	173	174	175	177	180	182	183	184	185	186	187	188	189	190	190	190	191	191	192	192	192	193	193	194
	1958 SPRING-FALL	E_s	148	168	174	177	179	182																		
		SCATTER	173	174	175	177	180	182	183	184	185	186	187	188	189	190	190	190	191	191	192	192	193	193	194	194
	1958 SUMMER	E_s	100	103	115	141	165	171	174	177	179	181														
		SCATTER	162	164	166	168	170	173	176	178	180	181	183	184	185	186	187	188	188	189	189	190	190	190	191	192
LONG BRANCH-BOULDER 49.880 Mc/s	1958 MARCH	E_s																								
		SCATTER	169	170	171	173	174	177	180	181	182	184	186	187	187	188	189	189	190	191	191	192	192	192		
	1958 APRIL	E_s																								
		SCATTER	167	168	170	173	175	178	180	182	185	185	186	188	188	189	190	190	191	192	192	193	193	194	194	
	1958 MAY	E_s	141	141	157	166	168	171	173	175																
		SCATTER		163	164	166	169	172	174	175	177	178	180	182	183	184	185	186	187	188	190	190	192	192	193	194
	1958 JUNE	E_s	154	157	160	163	166	170																		
		SCATTER			161	164	167	170	172	174	176	178	179	181	182	183	184	184	185	186	187	187	188	188	190	190
	1958 JULY	E_s	141	141	146	161	164	168	169	171	173	175														
		SCATTER		160	161	163	165	168	170	172	174	175	177	178	180	180	181	182	183	184	184	185	185	185	186	186
	1958 AUGUST	E_s	141	155	163	170	172	175																		
		SCATTER	162	165	168	171	173	175	177	179	180	182	183	184	186	187	188	188	189	190	190	190	191	191	192	192
	1958 SEPTEMBER	E_s	164	167	169																					
		SCATTER	166	168	169	172	174	177	179	181	182	183	184	185	185	186	187	187	188	189	189	189				
	1958 SPRING-FALL	E_s																								
		SCATTER	167	169	170	172	175	177	180	181	182	184	185	186	187	188	189	189	190	190	191	192	192	193	193	193
	1958 SUMMER	E_s	141	146	153	163	167	170	173																	
		SCATTER			162	165	168	171	173	175	177	178	180	182	183	184	185	186	187	188	189	189	190	190	192	192
TRIPOLI-LEGHORN 49.645 Mc/s	1958 MARCH	E_s													NO DATA											
		SCATTER																								
	1958 APRIL	E_s	160	170	173	176																				
		SCATTER	171	173	174	176	178	180	182	184	185	187	188	189	190	191	192	192	193	193	194	195	195	195	196	196
	1958 MAY	E_s	134	134	134	170	172	176	178	180	182	184														
		SCATTER	168	170	171	172	174	177	179	181	183	184	186	188	189	190	190	191	192	192	192	193	193	193	194	194
	1958 JUNE	E_s	134	134	134	134	150	168	172	175	178	181	183	185	187											
		SCATTER	162	163	164	166	169	172	175	178	180	182	184	186	187	188	189	189	190	190	191	191	192			
	1958 JULY	E_s	134	134	134	150	174	178	181	183	185															
		SCATTER	168	169	172	175	177	180	182	184	185	186	186	189	190	191	192	192	193	194	194	194	194	194	195	195
	1958 AUGUST	TROPO.	134	134	134	135	147	158	170	175	178	181	183	186	187	188	189	190	192							
		E_s	134	134	134	167	172	176	178	181	182	184														
		SCATTER	166	167	169	172	174	177	179	181	183	184	186	187	188	189	190	191	192	192	193	193	193	194	194	
	1958 SEPTEMBER	TROPO.	134	163	167	176	179	182	184	186																
		E_s	134	167	176	178	180																			
		SCATTER	174	176	177	179	160	183	185	186	187	188	189	190	191	192	192	193	194	194	194	194	195	195	195	
	1958 SPRING-FALL	E_s	157	170	174	177																				
		SCATTER	172	174	175	177	179	182	183	185	186	188	189	190	191	192	192	192	193	194	194	195	195	195	195	196
	1958 SUMMER	E_s	134	134	134	146	168	174	177	180	182	184														
		SCATTER	164	166	167	170	173	176	179	181	183	184	186	188	189	190	190	191	192	193	193	193	194	194	194	194

TABLE VI

(DATA FOR FIGURES 12 AND 13)

SYSTEM LOSS - SPORADIC-E SIGNALS ONLY

TIME IN HOURS (GMT)

PATH FREQUENCY	YEAR MONTH	TYPE	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
SEVILLE-WEYMOUTH 49.800 Mc/s	1958 APRIL	90%							122	108	102	106	111	111		103	112	112	110	110	110			113		
		50%							156	151	118	156	136	138		120	130	124	127	121	154	114		144		
		10%							166	165	151	170	165	167		162	151	170	148	139	176			178		
		COUNT*							18	21	18	29	32	20	3	15	36	38	19	19	24	12	3	17		
	1958 MAY	90%					124	98	95	100	102	102	101	103	102	112	116	113	128	122	104	108	115	122	132	149
		50%			171	173	161	120	124	120	117	135	115	120	125	126	128	133	159	150	138	163	136	146	160	164
		10%					176	167	168	162	167	168	159	161	159	158	159	165	172	172	172	178	171	176	177	179
		COUNT*			7	7	29	34	52	74	81	96	115	139	123	120	85	94	42	46	51	54	96	93	54	30
	1958 JUNE	90%	137	134	132					99	103	107	103	108	106		107	112	102	137	104	129	122	133	130	119
		50%	158	155	164	162	171		165	112	141	127	123	131	111	132	137	141	117	168	157	150	171	165	159	160
		10%	178	177	180					142	165	166	163	156	131		166	168	162	176	175	171	180	178	176	173
		COUNT*	34	30	16	8	6		12	31	49	49	60	55	21	11	26	41	33	14	37	58	42	65	55	25
	1958 JULY	90%	102				129	116	121	111	107	107	104	106	104	106	115	128	109	104	105	116	116	118	123	133
		50%	158	142	178	148	144	140	164	152	118	132	137	135	128	148	140	163	152	112	156	144	150	144	149	155
		10%	178				167	178	176	174	177	168	172	167	168	169	164	171	173	170	180	177	176	169	176	176
		COUNT*	19	12	8	8	18	18	21	48	82	100	113	100	48	66	56	35	33	20	26	34	66	90	96	63
	1958 AUGUST	90%										100	117	146	112			111	101	103	105	111	126			
		50%									172	117	147	164	161	170	149	129	109	108	152	167	155	170		
		10%										172	174	182	174			162	179	182	186	183	169			
		COUNT*									6	23	23	31	28	7	5	24	15	18	28	37	23	4		
	1958 SEPTEMBER	90%	128	132	143	130	131	101	101	103	104	105	105	109	106	109	115	116	109	109	107	115	118	122	128	135
		50%	160	153	173	166	160	127	151	132	122	137	127	133	127	132	134	139	140	133	152	158	150	152	156	161
		10%	180	177	182	180	176	168	174	168	171	169	167	167	167	165	161	171	172	173	179	179	178	178	178	177
		COUNT*	53	42	31	23	53	52	103	174	236	297	345	345	223	217	208	233	142	117	166	195	229	276	205	118

*NUMBER OF 5-MINUTE MEDIANS OBSERVED

SELECTED PERCENTAGES FROM CUMULATIVE DISTRIBUTIONS—SPORADIC-E SIGNALS ONLY.

	0.5	01	02	05	10	20	30	40	50	60	70	80	86	90	93	95	97	98	98.6	99.0	99.3	99.5	99.7	99.8
1958 APRIL		102	104	107	110	115	120	125	130	141	151	159	163	165	167	170	173	174	175	177	177	178	179	
MAY	94	96	97	100	104	110	116	123	133	144	152	160	164	167	170	172	174	175	176	177	178	178	179	180
JUNE	98	100	102	105	108	116	126	137	146	154	162	167	171	173	175	176	177	180	180	181				
JULY	96	99	100	104	107	115	124	133	144	151	155	164	168	171	174	175	176	178	178	180	181	182	183	184
AUGUST	97	100	101	104	107	115	125	145	153	161	168	172	176	180	182	182	184	185	185	185	186	186	186	
1958 SEPTEMBER	96	98	100	103	107	114	121	129	141	150	157	164	168	171	173	175	177	178	180	181	182	186	186	

DEPARTMENT OF COMMERCE ★ NATIONAL BUREAU OF STANDARDS ★