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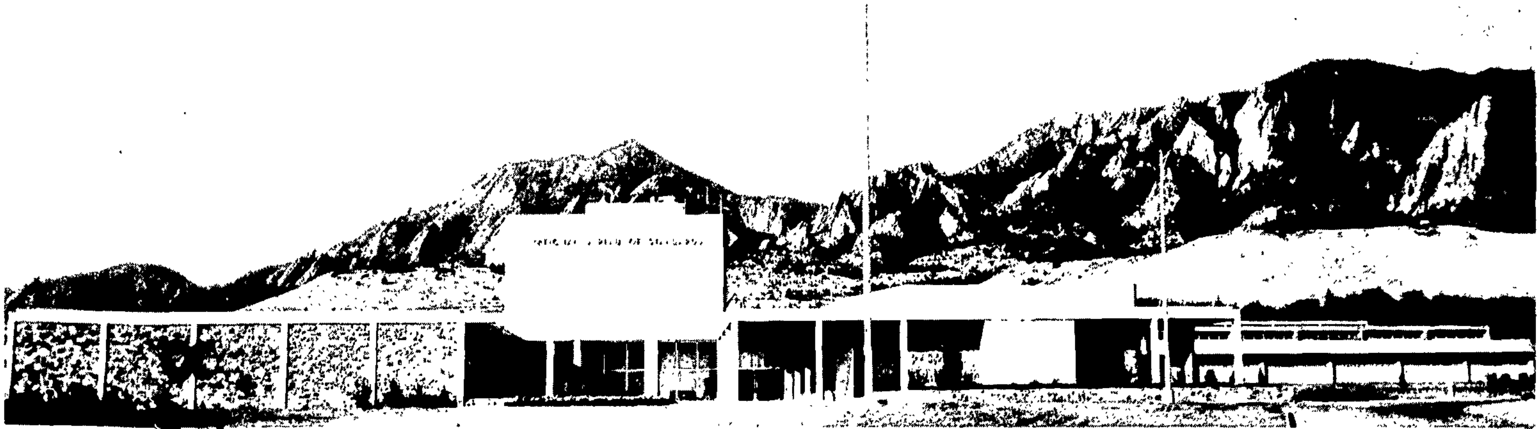

NBS REPORT

6742

Final Report on

EVALUATION OF AURORAL PROPAGATION FACTORS: TRANSMISSION LOSS PHASE

Part I

SYSTEM-LOSS BEHAVIOR & PREDICTION ON SOME HIGH-FREQUENCY ARCTIC PATHS

by

R. Silberstein

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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
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Boulder, Colorado

NATIONAL BUREAU OF STANDARDS REPORT

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Table of Contents

Page

FOREWORD

The studies reported herein were carried out on behalf of the U.S. Air Force, under support extended by the Wright Air Development Division, Wright-Patterson Air Force Base, Ohio [Delivery Order (33-616) 58-16]. The work has been performed on National Bureau of Standards Project 85422.

Part II of this report, entitled "A Comparison of Arctic HF Transmission Loss Riometer Data" by C. G. Little and R. Silberstein, was printed under separate cover as NBS Report 6743.

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ABSTRACT

Studies of high-frequency transmission loss were made during 1959 and 1960 on a propagation path along the auroral zone, across the auroral zone and across part of the Polar Cap and curves of its diurnal behavior were drawn. Attempts made to obtain correction factors to apply to predictions of transmission loss by standard methods for non-auroral paths gave results for the cases studied but revealed great difficulty of interpretation because of lack of knowledge of moding and insufficiently precise knowledge of such parameters as equivalent reflection height.

Studies of transmission loss during disturbances showed a variety of effects. The effect of proton events upon a Polar Cap path were not as conspicuous as might be expected, partially because they occurred at times when auroral disturbances spread over the Cap.

1. OBJECTIVES

(1) To obtain dynamic range and frequency dependence of transmission loss on frequencies of 5 to 20 Mc/s over selected arctic paths.

(2) To study the relationship between vertical-incidence absorption and oblique-incidence absorption with a view to being able to predict the latter correctly from the former.

(3) To study the effects of disturbances on high-frequency oblique-incidence circuits, and also to compare the behavior of a Polar Cap path with auroral zone paths in this regard.

Results of research in the relationship of cosmic noise absorption observed with riometers on VHF to the attenuation of high-frequency radio signals in the arctic are reported in Part II of this report, under separate cover. However, a few riometer results are considered here where appropriate.

2. INTRODUCTION

2.1 General

This report is preceded by an Interim Engineering Report on Evaluation of Auroral Propagation Factors for Wright Air Development Projects 85441 and 85422 for the period 1 July - 31 October 1959 by J. W. Koch and R. Silberstein. Part II of that report deals specifically with Project 85422. Figure 6 of Part II and conclusions relative to observations of Polar Cap and auroral zone types of disturbances from the figure are in error in that an equipment outage at Boulder during August 1959 prevented recording of a large daytime disturbance. The report is no longer available.

The report is also preceded by NBS Report No. 6703[1], Interim Report, Transmission-Loss Phase, Evaluation of Auroral Propagation Factors (1 Nov. 1959 - 29 Feb. 1960) by R. Silberstein. A correction sheet was issued along with this report.

The more important material in the two reports is reviewed here. Some of the data and text appear again in revised and corrected form.

2.2 The Problem

Errors and complete failure of radio communication systems may be due to the incidence of fading characteristics incompatible with the modulation systems employed but perhaps the more usual circumstance encountered on high-frequency radio circuits is the attenuation of the signal until external noise and interference control the behavior of the receiving system. The overall purpose of any project such as this one is to learn about and minimize the sources of error, so as to enable reliable communications at the highest possible speed.

2.3 System Loss & Transmission Loss

In a simple wire circuit the attenuation factor is known and in a good cable does not vary with the weather, so that the overall attenuation of the signal from the receiver to the transmitter can be computed as a fixed quantity. Considering the ratio of the power received to the power transmitted it may be said that there is a "transmission loss" which is a fixed quantity[2]. By contrast, in a radio circuit the transmission loss is a highly variable quantity which must be expressed in terms of statistical distributions for different periods of the day for a particular month.

Transmission loss at high frequency is caused by several factors[3,4,5].

Throughout this report the term system loss will be used in describing the data instead of transmission loss, both being defined in Reference 2. System loss includes ohmic losses in the antenna. Since these losses are probably very small for the antennas used, it may be assumed that the transmission loss does not differ very much from the reported system loss, so that in describing propagation phenomena in the text system loss data are taken to represent transmission loss.

2.3.1 Geometrical Factors

With antennas in free space the received power and hence the transmission loss is a fixed quanity proportional to the inverse distance squared. In the case of point-to-point transmission with an ionospheric reflector the wave-path geometry is modified by the curvature of the earth and the ionosphere as well as the electron distribution curve to include some focusing and defocusing. As the maximum usable frequency is approached another type of focusing takes place.

Because a given operating frequency has a skip distance determined by the amount and height distribution of ionization, propagation may be via various "modes", each contributing to the total received power. This moding may change from hour to hour and day to day as ionization conditions change. Irregularities and motions in the ionosphere may cause focusing and defocusing, either in the reflecting region or in a lower layer through which the wave passes. These changes will cause amplitude fluctuations as the vector combination of all waves arriving at the receiver changes. Tilts of the layers, either systematic or varying because of motion of the ionosphere, may cause asymetric trajectories in the great circle and lateral deviation of the radio waves.

2.3.2 MUF Failure

When the ionization in a reflecting layer becomes low enough, because of normal diurnal trends or because of a radio disturbance, a given mode will fail and its contribution to the total signal will cease. When all possible modes have failed there is no more signal.

Lateral deviation of radio waves, associated with horizontal irregularities and their motion, is also an important attribute of signals which continue to be propagated as weaker modes after failure of the MUF for the great circle path. Such modes are sometimes scattered from the ground and, more rarely, even from ionospheric irregularities.

2.3.3 Shielding or Blanketing

Shielding or blanketing[6] of F2-layer propagation can occur during daytime when normal E-layer ionization is sufficiently high and at any time when sporadic-E ionization is high. Frequently the shielding layer provides a propagation mode, but this is not necessarily the case. Shielding is often only partial and F2-layer signals at a distant point may vary in amplitude inversely as the amplitude of the scattered E-layer signal received closer to the transmitter.

2.3.4 Absorption

By absorption is meant the abstraction of power from the wave by collision between the vibrating electrons and ions. Most absorption occurs in the D region - where the gases are relatively dense and the chances of collision are large - and some occurs in the E region. When the wave passes through a region close to the critical frequency or, to a lesser degree, close to the MUF, there may be appreciable absorption because, even if the collisional rate is low, the wave spends more time in the layer. This type of absorption is called deviative; the more usual type is said to be non-deviative.

At the higher frequencies attenuation of the waves is roughly inversely proportional to the square of the operating frequency.

2.3.5 Radio Disturbances

2.3.5.1 General

Radio disturbances or blackouts are the most striking feature of high-frequency arctic propagation. In the following the relation of auroral and non-auroral disturbances is indicated.

2.3.5.2 Short Wave Fadeout

Short wave fadeouts (SWF) (of which the sudden ionospheric disturbance, SID, is a special case) occurring on the sunlit side of the globe, are a result of ultraviolet radiation from hydrogen flares on the sun. This was formerly called a Type I disturbance.

2.3.5.3 Auroral Disturbance

A regular auroral-type radio disturbance (formerly called Type II) is the result of negatively-charged particles streaming into the earth's atmosphere. The disturbance usually starts at night and is usually accompanied by visual aurora and a geomagnetic disturbance. D region ionization increases, increasing the absorption of radio waves while the F2 ionization appears to decrease by reducing the MUF. Radio circuits may therefore suffer loss of signals because of either absorption or skip. Auroral sporadic E may also occur and cause blanketing or, in some cases, useful E modes.

The greater auroral disturbances (the worse months being the equinox months) spread down to temperate latitudes. As one goes further toward the equator the absorption becomes less but some depression of the MUF persists.

In a great storm the auroral type disturbance spreads into temperate regions and also covers the Polar Cap. Within the auroral zone itself there may be as many as 100 local "blackouts" in a single month.

2.3.5.4 Polar Cap Disturbance

A distinctly different type of disturbance occurs inside the auroral zone over the Polar Cap where oblique-incidence radio circuits are supposed to be much more reliable than those within the zone itself. This type of disturbance, frequently called a "proton event" is caused by positively charged particles streaming into the earth's atmosphere at night. The ionization is released by photo detachment in the daytime (according to one theory) repeating several days in succession. These disturbances start within 15 minutes to several hours after a solar flare. Polar Cap events may occur only 6 or 7 times a year and correlate with low geomagnetic-K figure. They were formerly called Type III disturbances.

2.3.5.5 Variation of Worldwide Radio-Disturbance Behavior with Sunspot Number

Experimental data gathered here are typical only of a sunspot maximum period. Such a period is characterized as follows:

a. A small number of large disturbances with high geomagnetic-K

b. Disturbances of short duration, say 48 hours, but with some after-effects

c. More disturbances in the equinox periods but scattered throughout the year

d. Disturbances "event-connected", i.e. following certain types of solar flares by say, 36 hours, as a rough average

e. Disturbances seldom following a recurrence pattern although this can happen as in the Spring of 1960

Beginning about 3 years before the sunspot minimum, disturbances appear somewhat as follows:

a. A large number of small disturbances, with slightly high geomagnetic-K, but causing more HF traffic interruption because of the necessary use of lower frequencies

b. Disturbances of long duration, frequently as long as 10 days

c. Disturbances mostly in the equinox periods

d. Disturbances not "event-connected" but concurrent with sunspots and certain associated activity

e. Disturbances follow a 27-day recurrence pattern

2.3.5.6 Problem of Predicting Transmission Loss

It is evident from the above that a variety of phenomena contribute to the loss of signal. It is also noteworthy that each phenomenon varies statistically, so that if one were to predict the transmission loss variation precisely one would have to be provided with data for each phenomenon and a theory as to the variation and correlation of all. If carefully taken, data over controlled representative paths can provide an accurate engineering representation of transmission loss behavior over these paths during the period of the study. However, it is questionable as to whether predictions may be made on the basis of these data for different paths and different months without some knowledge of how the contributing phenomena behave and how each came into play in the data which were obtained. In this connection several types of simultaneous observations ought to be made as follows:

Sweep-frequency pulses observed simultaneously with fixed-frequency signals should permit a determination as to which signal failures are due to high absorption and which to skip. It should also distinguish whether propagation is via the F2 layer, regular E, auroral sporadic E associated with disturbances, or the so-called "extra" layer. These distinctions would enable sorting of the data so that a total statistical result could be obtained from the statistics of each component.

The following other types of measurements would also assist in sorting the data.

Horizontal direction of arrival measurements would often explain cases of propagation observed when a signal along a great circle path should skip. It is believed that much of the propagation through auroral regions is non-great circle.

Vertical angle-of-arrival measurements should enhance antenna design and also sometimes indicate the presence of irregularities.

Fixed frequency pulses would be valuable for obtaining data on the attenuation of each mode, in identifying the modes with different angular behaviors and in distinguishing scatter from specular reflection.

Without these ancillary measurements one must, in making predictions, fit the CW transmission-loss data to a theory and rationalize its departures from that theory on the basis of inferred behavior of the various phenomena contributing to the final result. This approach was used in the interpretation of the data in this report.

It should be emphasized that current predictions are statistical; and it is not possible to say on what part of a distribution curve the transmission loss will fall at any given hour on any given day, except insofar as it is possible to predict a disturbance, which would place the prediction somewhere on the high-loss end of the curve.

3. EXPERIMENTAL APPROACH

CW transmitters with an output of approximately 2 kw, operating on frequencies near 5, 10, and 19 Mc/s were installed at Barrow, Alaska for recording at Kenai, Alaska and Boulder, Colorado. Two CW transmitters of a similar output owned by AACS and located at Thule were operated on frequencies near 9 and 12 Mc/s and recorded at Barrow. All transmitters normally were off the air 3 minutes at the end of each half hour except for brief code identification. These "off periods" produced "noise breaks" in the recordings during which noise and interference could be recorded.

Figure 1 is a map illustrating the paths in relation to an approximate concept of the auroral zone and Table I gives data pertinent to the experiment.

Receivers were Hammarlund Type 600-JX-17 modified to give an AGC output-voltage with a 12-second time constant on both charge and discharge of the AGC diode. Fade rate recorders used on some of the receivers (working on a signal taken from the IF output) recorded the average number of times the signal crossed a 6-second median level. The two RF tubes - type 6BA6 - were replaced by type 6AH6 with substantial noise-figure improvement, so that it was possible to detect signals even below KTB.

Bandwidths of the receivers at Barrow and Kenai were narrowed by the use of plug-in mechanical filters at the first IF stages.

Frequency adjustment to within a few cycles, so important in the use of narrow-band filters, was accomplished by the use of frequency-deviation meters which compared the IF signal with that from a 455-kc/s crystal.

At Boulder the 35 c/s noise bandwidth was obtained in a third IF stage at 1000 c/s. Frequency adjustment was accomplished by comparing the output with a standard source of 1000 c/s on an oscilloscope. The extra-narrow bandwidth at Boulder called for a precision standard for both low- and high-frequency receiver oscillators.

The AGC outputs of the receivers were fed into DC bridges and the outputs used to drive galvanometric continuous strip-chart recorders.

Calibrations were performed at Barrow and Kenai by the use of Measurements Corp. Model 80 signal generators which were modified by the insertion of low-series-resistance AT-cut crystals in series with the LC circuits to enable smooth frequency adjustment to within a few cycles. The outputs of the signal generators were fed into two 6-db pads followed by 120 db of pads in 10-db steps feeding a 50-ohm cable. In the calibration procedure the signal generator was substituted for the antenna cable. If the antenna is matched to its cable it can be shown that an available power calibration by the signal generator is equivalent to available power at the antenna less the antenna cable losses.

The calibrations were in terms of decibels below 1 watt available power on the basis of $\frac{E^2}{4R}$ equal to $\frac{E^2}{200}$ at the signal-generator cable output. Values used were -80 to -180 dbw in 10-db steps. Calibrations were made on the strip chart daily. In this system 1 microvolt at the cable output is equal to -143 dbw.

Scalings were made of the hourly medians of the field-intensity records. These were transferred to tabulations and eventually to punch cards.

Conversion of the values of dbw to system loss were accomplished by regarding the latter as a decibel ratio of power transmitted to available power received after correction for cable losses. Where received signal power is used in this report it is expressed in db below 1 watt rather than dbw (db above 1 watt) so as to avoid use of the minus sign.

4. AVERAGE BEHAVIOR OF THE SIGNALS

Figures 2 to 4 are plots of hourly-median and the upper and lower decile values of system loss for the circuits and frequencies. Tables 2 to 4 give the values appearing on each curve. Hours when the transmitter break was not visible on the recorded trace are designated in the tables with the symbol "R". In the graphs, open symbols are blacked in under these conditions. In both the figures and the tables the percentage of the time that the signal is below noise is shown in separate "outage" graphs.

The R-values represent the measured (noise) values increased by 10 db, on the assumption that stronger signals would have been detectable during transmitter breaks. In many cases a larger correction may have been appropriate. Thus "R" values represent a lower limit to the true system loss and should be interpreted in this way.

In the figures, values of system loss were plotted with system loss in the ordinates decreasing as one goes above the zero axis, so that the shapes of the graphs correspond to those formerly used for field strength, high system loss corresponding to low field strength.

An idealized diurnal curve of system loss for a single mode can be pictured assuming that there is an appreciable period of night and that the same mode persists during the day into darkness on each end of the day. Such a curve shows low system loss in the hours of darkness on each side of the sunlit portion of the day. During the day, system loss due to absorption in the D region increases in a roughly cosine shape until noon over the path since the absorption is related to the cosine of the sun's zenith angle. Then it decreases on the afternoon side of the graph. This picture is most likely to obtain on reasonably short paths and on the lower frequencies, although in the periods of high solar elevation, the signal may be below noise during much of the day.

Distortions of the ideal curve may be due to changes of modes, blanketing and skip at different portions of the day. Also since the largest number of points in an hourly distribution for a month is equal only to the number of days in that month there is often a considerable spread of values determining the median, resulting in hour-to-hour jogs.

At the higher frequencies the absorption is low but ionospheric reflection may be present only during part of the daylight hours, producing almost inverted curves.

Figures 5 to 7 show the monthly cumulative distributions of the hourly median system loss. In Tables 5 to 7 selected values are tabulated. These distributions have been normalized in such a way that each hour receives the same weight in spite of the disparity in the number of data available at different hours.

These graphs show the percent of the time the system loss is less than the ordinate values. Since values of signal-below-noise (R) distributed through the data could cause an error in the percent value assigned to any system-loss level, a method was sought to designate where such an error might occur. If all R values actually represented a system loss much greater than the stated level it is evident that the assigned percentage for a given level would be too high when the R's appear in the count as they do in the raw data. To indicate the likelihood of this being wholly or partially the case, values normally indicated by open circles were blacked in at such system-loss levels that all the R values in the original data at that level and below represented a percentage of all data equal to half or more of the difference between the percent level at that point and the next lower percent level.

The graphs of cumulative distributions are of value in assessing power requirements for operation at high percentages of reliability. The problem is complicated, however, by the fact that data are least reliable, or non-existent at the higher percentile value because of noise, interference, and disturbances. In estimating such requirements it is also, in principle, necessary to take account of the magnitude and statistical distribution of the noise and interference which may be encountered, as well as the signal fading properties, all in relation to the type of modulation.

It is noteworthy that the Thule-Barrow cumulative distributions of transmission-loss data generally show smaller spreads than the data for other paths in the same month. This is discussed under Section 5 below.

Distributions of values of transmission loss noted here should be compared with those given for auroral and non-auroral path in CCIR Report No. 159 [7].

It was recognized in this study that noise observed during the noise breaks could not be distinguished from interference and that the amount of interference observed on any frequency was largely fortuitous, depending upon frequency assignments and propagation from the interfering transmitters. Nevertheless, graphs of signal outage were drawn which are therefore no more than typical, showing the percent of the hours of outage at each hour of the day on each month, for each circuit and frequency.

The outage graphs of Figures 2 to 4 illustrate qualitatively what is generally known about frequency usage. The lower frequencies have more outages in the middle of the day than at night and more in summer than in winter. The higher frequencies are most reliable in the middle of the winter days. All frequencies suffer from more outages during disturbances.

5. SIGNAL BEHAVIOR UNDER DISTURBED CONDITIONS: NOISE LEVELS

5.1 General

In this part of the report hourly median signal behavior during radio disturbances at several frequencies and stations are represented concurrent with observations of other geophysical phenomena.

In attempting to represent disturbance effects it became evident that although several ways of presenting the data were possible none was altogether satisfactory. An obvious approach is to plot hourly median field strength in time sequence. However, the strong daily cycle occupies much space and masks the disturbance effects. It was therefore decided to use a "quiet day" reference from which to subtract each individual value of the system-loss data leaving only the disturbance effect.

Subtraction of the data from the monthly median was unsatisfactory since the change in the median from month to month was so great that the change in the remainder going from one month into the next could be greater than any disturbance. A 27-day running median in each hour might be a satisfactory quiet day reference median, since it would also eliminate any solar-angle effects. This variable proved to be difficult to obtain due to changes in the number of useful data and the problem of qualifying symbols (for instance for doubtful values). Even the 27-day running median does represent quiet conditions when most of the values were taken from part of a disturbed month, e.g. April 1960. The "undisturbed" reference used was an hourly median interpolated for each day between two monthly medians, at the hour, or sometimes a single convenient hourly median or interpolated hourly median was used at the quiet-day median for several days.

This assumed "undisturbed" reference from which the data were subtracted left reminder graphs showing disturbances in a general way, but it did not completely eliminate diurnal effects.

Outages due to transmitter and receiver failure or excessive interference are shown as small circles. When the signal was below the noise the period is shown by means of dashed lines. The dashed lines were placed at an arbitrary position such as -40 db for convenience. This position is no indication of the noise level. On some sets of graphs there are some points below these dashed lines. On some of the lower frequencies at certain times of day in some seasons the median itself was below noise. In this case the graph is broken and nothing appears during this interval. Since one does not know the relation between the noise level and the quiet median it is sometimes not easy to estimate the severity of a disturbance. However, one can often judge from the excursion below the quiet day value (which the system loss makes before the graph breaks) that the disturbance effect is at least no less than this amount.

5.2 Some Typical Disturbances

Firuge 8 covers the period 16 March, 00 UT to 16 April, 00 UT inclusive. Decibel differences obtained by subtracting the hourly median values of the 5 Mc/s signal strength of Barrow received at Kenai from a daily interpolated median for the hour appear in the second row. Above are the 3-hour geomagnetic-K indexes for College, Alaska, plotted with the low values at the top. Below are the values in db of the 5-minute medians on the hour of the Barrow-plus-Kenai 50 Mc/s oblique-incidence absorption relative to the quiet-day curve. (See Part II for other details of the riometer experiments). On the bottom row are plots of values of F min for the College vertical-incidence ionosonde.

At a rough glance one detects a general trend for all variables to go down during a disturbance. Frequent breaks in the riometer data are due to solar-noise storms which temporarily contaminate the data. One advantage of the riometer data not possessed by the other data is the fact that fine gradations of output are available for the most severely disturbed periods although for very slight disturbances the equipment errors vitiate the data. The F min data have the disadvantage of going off scale for no disturbance (arrows at the top) and again for strong disturbance (arrows at the bottom.) Besides, the value of F min is dependent upon the overall signal-to-noise sensitivity of the ionosphere recorder itself, which is a variable quantity.

The chief event shown here is the great storm of the end of March and the beginning of April 1960. This storm was preceded by several solar flares beginning on 25 March. Because of the complex beginning, the geomagnetic records did not show a "sudden commencement". Proton events occurred 31 March 0300 UT, 1 April 0930 and 5 April 0800. The 5 Mc/s signal began to deteriorate in the latter part of 28 March. The worst day was 1 April although the recordable signal had fallen from 15 db above the median at about 1130 UT on 30 March to 65 db below at about 0730 UT on 31 March.

Figure 9 shows the effect of the disturbance on several circuits and frequencies.

Reception of 5 Mc/s on the Barrow-Kenai path is compared with that of 9 Mc/s on the Thule-Barrow path and also with that of 5, 10, and 15 Mc/s on the Barrow-Boulder path. In each case the plot represents the difference between an interpolated median and the hourly median system loss. Note that the Barrow-Boulder 5 Mc/s signal because of normal absorption was only usable at night on any day.

In the great storm all signals faded at about 2100 UT on the 28th. On the 29th, the 5 Mc/s Barrow-Kenai path was disturbed more than was the 9 Mc/s Thule-Barrow path. During the 30th all signals deteriorated gradually. During 1 and 2 April signals were mostly below receiver noise with occasional hours of signal recovery, no doubt as a result of sporadic-E propagation. The least-disturbed path appeared to be the Barrow-Kenai 5 Mc/s path. The Barrow-Boulder path had longest periods of complete outage but this included periods when the signal would not have been seen under normal conditions. The relative absence of signal during the period for the Thule-Barrow path may in part be due to inferior performance of the receiver during this period, as will be seen in examining the noise plots later in this section. The Thule 9 Mc/s receiver adjustment was so poor that it could not be calibrated below 150 db below 1 watt during the worst of the disturbance, whereas the Kenai 5 Mc/s receiver responded to 170 db below 1 watt and better and the Boulder receivers with their narrower bandwidth were calibrated to 185 db below 1 watt.

Signals recovering around 3 April were blacked out in the middle of the day each day through 7 April on Barrow-Kenai 5 Mc/s. Barrow-Boulder 5 Mc/s was blacked out normally in the middle of each day so there was not much change as a result of the disturbance. Barrow-Boulder 10 Mc/s was blacked out in the middle of each day through 8 April and 15 Mc/s only through 6 April.

On the Thule-Barrow 9 Mc/s path the daily blackouts went only through 6 April. There appears to be a strong relationship between the susceptability of paths of these frequencies and lengths to regular ionospheric absorption and the number of days during which extra absorption persisted in the middle of the day.

Of interest is the fact that in undisturbed periods the fluctuations in the Thule-Barrow signals are very small in comparison with the behavior of the other signals. This is somewhat evident in comparing the cumulative distributions (Section 4) of Thule-Barrow with those for the other paths in the same months. Although relative moding and skip conditions were different on each path it is possible that this path reflects the relative quiet in the Polar Cap as compared to the auroral zone with regard to the many short-duration local blackouts in the latter.

Figure 10 is a plot covering the disturbed period 23 April - 11 May 1960. The average of the April and May system-loss medians was used as a quiet-day reference. The 9 Mc/s Thule-Barrow frequency and the 10 Mc/s Barrow-Kenai frequencies are shown along with the 3-hour planetary geomagnetic indices, Kp. Triangles mark the sudden commencements (SC). There appears to be no simple relationship between sudden commencements and signal deteriorations as may be seen from examining this and other SC's in this study.

It is noteworthy that there was almost no disturbance on the Thule-Barrow path during the 24 April period when the Barrow-Kenai path was down by about 20 db. However, in the disturbed periods following the proton events of 28 April at 0200 UT, 29 April at 0600, 4 May at 1030 and 7 May at 1030 the Thule-Barrow path was more severely disturbed than the Barrow-Kenai path. During the quiet periods the Thule-Barrow frequency again seemed to experience smaller system-loss fluctuations than did the others.

Figures 11a and b illustrate the behavior of several frequencies and of the world geomagnetic-K figure during the disturbed period 14-19 August 1960. In this and the following figures the August median system loss was used as a "quiet-day" reference. Figure 11a shows relative system loss for Thule-Barrow 9 and 12 Mc/s and Barrow-Kenai 5 and 10 Mc/s while figure 11b shows the same for Barrow-Boulder 10, 15, and 19 Mc/s as well as Kp for the period.

About 2 hours after the first SC with a geomagnetic K of only 4+ at about 1630 UT on 14 August there were signal dropouts on all paths and frequencies (19 Mc/s to Boulder was probably skipping at this time anyhow). The most serious immediate effect seems to have been on the Thule-Barrow 9 Mc/s path. However, on the 16th and 17th with large geomagnetic K's the effects were least on that particular channel.

The signal failures beginning in the middle of the 16th UT, around midnight on the paths, coincided with rising Kp (falling on the graph) and must have been due to auroral absorption because there was no effect on the Thule-Barrow paths and in general on the other paths the effect was worst on the lower frequencies.

The sequence beginning around 00 UT on the 17th with the geomagnetic K first rising fast and then falling slowly must have been connected with insufficient ionization in perhaps the F2 layer (skip conditions) because 9 Mc/s on Thule-Barrow and 10 Mc/s on Barrow-Kenai were not affected (10 Mc/s on Barrow-Boulder seems to have been but there were equipment outages).

On the other hand there were large drops in the 12 Mc/s Thule-Barrow and 15 Mc/s Barrow-Boulder signals. Later in the day, with a geomagnetic K which rose again and fell slowly beginning 0600 to 0800 local time on the various paths, auroral absorption seemed to govern. The paths not in the Polar Cap appeared again to be affected more in accordance with their susceptibility to absorption.

Beginning around 0800 UT on the 19th, under local night conditions, a skip phenomenon seemed to appear on Barrow-Kenai at 10 Mc/s and Barrow-Boulder at 15 Mc/s. Later in the day (toward local afternoon) both Kenai frequencies fell off again and there was some drop on Barrow-Boulder at 15 Mc/s, indicating absorption effects.

Once again it appears from the records that the transmission loss of undisturbed times is less variable in the Polar Cap than in paths crossing the auroral zone, although the paths are not directly comparable.

Equipment outages in August 1959 made it difficult to study the disturbances in that period. The reader is referred to Reference 8 for studies of HF arctic propagation at that time.

5.3 Noise Levels

Studies of noise and signal-to-noise ratio were made for only part of the experimental period. The high-frequency spectrum is so completely filled with various services throughout the world which intentionally or unintentionally share approximately the same frequency that it was believed that even with receiver bandwidths as narrow as 35 cps it would be impossible to distinguish between noise and interference. However, it was believed to be advantageous to reproduce graphs of noise level during the disturbed periods studied, in part to illustrate the varying noise level conditions in the various receivers which had made it difficult to assess the relative effects of the more severe storms, and also to demonstrate some characteristics of these noise levels.

The figures show the median noise (and interference) levels scaled in the three-minute half hourly carrier "noise breaks" for all stations and frequencies in decibels below one watt. Also shown, as a dashed line, is the equivalent noise level of the receiver noise output. It is to be noted that both sets of values are equivalent noise powers for the noise bandwidth and noise or interference spectra involved in each case, having been obtained from the CW signal generator calibrations.

Figure 12 is for 25 March - 10 April 1960.

Figure 13 is for 27 April - 10 May 1960, and Figure 14 is for 14 - 19 August, 1960.

It is noted in general that on 5 and 10 Mc/s the noise levels have a strong but more or less regular diurnal variation, indicating ionospheric propagation of noise or interference. Sharp multiple peaks in the diurnal curve as in Figure 13 suggest interference from several stations on regular schedules. The fact that these diurnal noise curves do not diminish in amplitude during most of the disturbances makes it appear that the noise or interference sources in those cases are to the south. Barrow-Kenai 5 Mc/s in Figure 13 is one exception. Considerable advantage would have been gained from the use of directive antennas with a good front-to-back ratio.

Usually the external noise and interference was above the receiver noise but there were times of day when the set noise was limiting. On Thule-Barrow 9 Mc/s in the March-April and April-May disturbances the diurnally-varying noise and other strong external noise were eliminated at the height of the disturbance, incidentally proving that they had been ionospherically propagated. At these times and at certain regular times of day in the March-April period the poor receiver noise figure was a limitation. The same effects were present but less marked on 12 Mc/s.

As the frequency increases diurnal trends become less apparent showing that the larger proportion of the observed noise is then cosmic and man-made.

5.4 Frequency Usage During Disturbances

A set of empirical frequency-usage graphs is presented for all frequencies and receiving locations during three disturbed periods in 1960. Figure 15 is for 25 March-10 April, Figure 16 is for 27 April-11 May, and Figure 17 is for 14-19 August. Solid horizontal lines represent a recordable signal on the hour and date of the abscissas. Equipment outage or known excessive interference is shown by small circles.

The behavior of the frequencies shown on these graphs was in no small way determined by the amount of interference on each channel and the condition of each receiver, but the graphs do illustrate principles of frequency usage in a general way.

In looking at the Barrow-Kenai frequencies in Figure 15 one notes that the first manifestations of the disturbance are on the lowest frequency, 5 Mc/s, as if absorption rather than skip were governing. The 19 Mc/s frequency is not regarded here since it had been skipping every day prior to the disturbance. For a brief period on 31 March 15 Mc/s was the lowest good frequency. Beginning at 1400 UT on 1 April all frequencies were out 13 to 16 hours. Again on 2 April for a brief period 15 Mc/s was the only good one. About 1000 on 4 April the lower frequencies were again the better ones.

It is noted that the disturbance forces operation on higher frequencies rather than on lower in the majority of cases in the three sets of graphs, e.g. in Figure 16 on the Barrow-Kenai path on 30 April at 1600 UT and 1900 to 2100 UT, 19 Mc/s was the only usable frequency. This was also true on 7 May at 0500, and on 28 April at 0700 on the Barrow-Boulder path.

The farther south a radio circuit is from the auroral zone the less is the effect of a disturbance in causing absorption, so that the proportion of the effect due to depressing the MUF increases. Experience in temperate latitudes seems to have developed a tradition that the operating frequency should be lowered in a disturbance. It appears from evidence obtained over the limited period of the experiment that the opposite is usually true in arctic regions but the graphs show also that operation on a high frequency may be good for only brief periods. The presence of auroral sporadic E helps to make the higher frequencies useful and also explains the brief periods of usefulness which sometimes exist.

5.5 Disturbance Indicators and Fade Rates

5.5.1 K, F min and Vertical-Incidence Riometer

Mass plots were made of hourly median field intensity in db below 1 watt during March and April 1960 on the Barrow-Kenai 10 Mc/s path against several parameters to see if propagation conditions could be judged by an examination of other data. In each case a graph was drawn on the mass plot through the medians of all the field intensities occurring at the chosen digital values of the other variable. The expediency of using the medians was desirable because in all cases the low field intensities (to the right on the graphs) included the cases where noise governed.

Figure 18 illustrates the 3-hour Fairbanks (College) geomagnetic-K figure versus available signal power, Figure 19 the hourly value of F min (the lowest recordable frequency) for the College ionosonde, versus available signal power, and Figure 20 the value of the db difference between hourly medians and the quiet day curve for the College 27.6 Mc/s vertical-incidence riometer versus available signal power. All illustrate considerable spread about the median values represented by the heavy line. The geomagnetic-K seems to be the best, there being, however, a possible question of availability. The F min has the disadvantages of being a function of ionosonde sensitivity, and having a low-frequency and high-frequency cutoff determined by the equipment frequency range and sensitivity. The riometer has the advantage of simplicity but the disadvantage of occasionally recording solar noise storms when cosmic noise data are needed.

5.5.2 Fade Rates

Time did not permit a detailed study of fade rates. Figure 21 is a mass plot of maximum hourly fade rates against values of system loss for the same hour from 5 March to 30 April 1960 on 10 Mc/s on the Barrow-Boulder path. There is no obvious correlation between the two. Fade rates up to 24 per second were noted and at fairly high transmission loss but lower values occurred almost anywhere in the system-loss range.

A relationship observed between fade rates and disturbances has been reported by Koch, Beery and Petrie [9] and elaborated by J. W. Koch privately. Higher fade rates tend to be associated with higher geomagnetic-K indices. Within a particular hour an increase of fade rate usually precedes a drop in signal amplitude of 10 to 20 decibels. However, during periods of extended absorption the fade rates are low again.

At the Anchorage, Alaska station of the North Pacific Radio Warning Service of CRPL, fade-rate meters on chosen CW monitoring circuits have been in use for indicating the onset of radio disturbances.

Figure 21 indicates that on auroral circuits the fade rates are high a large proportion of the time. It has been stated by Koch that fade rates as indicated on instruments such as those used in this study [10] when of a magnitude of 8 per second or more are detrimental to reception of intelligible radio telephone when conventional AM (amplitude modulation double-sideband) is used. With single-sideband the intelligibility is not seriously affected until the fade rate reaches 15 to 20 per second. The inferiority of the former method is attributed to a need for phase coherence between the sidebands.

6. TRANSMISSION LOSS PREDICTION

6.1 General

Data obtained in the project are of value in assessing the validity of presently-available techniques of predicting signal attenuation. The method of correcting for auroral zone absorption as described in NBS Circular 462 [11] does not hold for all hours of the day and all seasons.

In this analysis it was assumed that the transmission loss for any mode is composed of both geometric and ionospheric absorption factors. Effort was first concentrated upon the ionospheric-absorption component of transmission loss although it became evident that geometric factors in transmission loss were going to present difficulties, especially the effect of low angles.

The geometric portion of the prediction yields the transmission loss expected if the ionosphere were a perfect reflector at an assumed equivalent layer height for the mode and with the antennas and ground-reflection coefficients assumed. The ionospheric-absorption portion of the prediction is the part added to the geometric portion to predict transmission loss.

Prediction was made using simple inverse-distance attenuation plus antenna-pattern data obtained from the Signal Corps Technical Report No. 2 [12]. Ground-reflection losses and ionospheric-absorption data were originally contained in Signal Corps Technical Report No. 9 (RPU203) [13], with modifications currently being made for adaptation to the transmission loss concept [14].

Monthly observations of reception over any experimental path provides for each hour of the day in that month a distribution of values of transmission loss (field strength in db below 1 watt is actually tabulated). If only one mode of propagation were active in that particular hour of the day, it would be reasonable to regard the lowest value of transmission loss (or the highest value of field intensity) as typical for undisturbed conditions [15], with the higher values of transmission loss representing varying degrees of ionospheric disturbance. This concept is somewhat supported by the fact that quiet periods over arctic paths are similar to quiet periods elsewhere.

In the studies of field-strength data made in the preparation of Signal Corps Technical Report No. 9 it was noted that the average spread between the highest observed value of field strength and the median observed value for any hour of the day in any month was 8.9 db. The highest observed night value of field strength (corresponding to the lowest transmission loss) was assumed to be the equivalent of a wave propagated via the ionosphere without absorption. This was predicted on the basis of a perfectly-reflecting ionosphere and the mode which would exist on the basis of median MUF predictions. On the average the median was observed to be 9 db below this value. During the hours of subsolar absorption the highest observed value of field strength for the month also averaged about 9 db above the median.

The analysis reported herein is on the assumption that the lowest observed transmission loss (corresponding to the highest field intensity) should correspond to that predicted for undisturbed conditions and that the difference between this value and the observed median at any hour should be the value to be added to the first prediction so as to account for disturbed conditions, thus including all arctic effects.

It will be seen later that since numerous modes are possible on any path the lowest observed transmission loss may be due to a mode which is seldom present so that this value will not, in general, agree with the predicted transmission loss of the strongest signal when the assumed mode is based on median values of MUF for the various layers. However, since the median signal will tend to be propagated by the predicted mode it is more reasonable, although still not completely valid, to regard the difference between the observed median transmission loss and the predicted value as an important experimentally-determined operational quantity which will vary with auroral absorption conditions and, as shall be seen, other factors. These other factors are equivalent height of the reflecting layer and a seasonal absorption factor.

Following the principles outlined above the lowest hourly median value of system loss in decibels observed was regarded as transmission loss and designated as L. The "unabsorbed" transmission loss computed for the perfectly-reflecting ionosphere and theoretical antenna patterns and ground reflection coefficients was designated as U. Then the apparently-observed absorption was

$$A_a = L - U \quad (1)$$

The theoretically-computed absorption was A_t. The amount which would have to be added to A_t to give A_a was designated D

$$D = A_a - A_t \quad (2)$$

D was determined and plotted against month for periods near noon and midnight for the three paths in Figures 22 to 24.

By analogy to the observed transmission loss for undisturbed conditions L, the predicted transmission loss for the case of no disturbance would be

$$L_p = U + A_t \quad (3)$$

At night under these circumstances $A_t = 0$. With the amounts of disturbance existing in any one case the observed hourly median T is greater than L_p by an amount δ

$$\delta = T - L_p \quad (4)$$

Of course δ includes any errors in computing L_p, such as erroneous assumption of modes.

The average value of δ in Signal Corps Technical Report No. 9, mentioned previously, was 9 db; plots of δ for the cases considered in the experiment are also shown in Figures 25 to 27.

Other sets of plots, Figures 28 to 30, are shown for the spread S_1 between the median system loss and lowest observed.

In terms of transmission loss

$$S_1 = T - L \quad (5)$$

It is obvious that if $L = L_p$, $S_1 = \delta$

On the same plots are shown the spread S_2 between the median system loss and the lower decile. Again in terms of transmission loss

$$S_2 = T - L_d \qquad (6)$$

Here L_d is the observed lower decile of transmission loss.

Above all the plots is marked for each month the assumed strongest mode of propagation. These modes were deduced from CRPL predictions, except for the Barrow-Kenai path where the College, Alaska ionosonde data were used. On the Thule-Barrow path sporadic-E data were supplemented by observations made the previous year at Fletcher's Ice Island.

In the antenna pattern and ground reflection predictions, poor ground was assumed except where otherwise stated.

6.2 Calculations of D

Figure 22a is a plot of an average D for the 3-hour period centered around 1230 MST for the Barrow-Boulder path for the period of operation of the equipment on 10 and 15 Mc/s. The 5-Mc/s signals were too weak for use at this time of day.

The curve for 10 Mc/s with the circles at the plotted points was computed for an assumed 300-km height of the F_2 layer. Modes assumed were 2-hop F_2 from September to February and 3-hop F_2 from March to August. It shows that, on the basis of the assumptions of Section 6.1, as much as 22 db should be added to the computed absorption in December and as much as 9 db should be subtracted in May. The use of minimum-virtual-height predictions for each month was next adopted as recommended in Signal Corps Technical Report No. 9 as a crude correction for seasonal absorption variations. The increase of the obliquity factor in winter increases the computed absorption. The plain graph incorporates this correction. It is seen that the seasonal variation is only partially accounted for.

Next it was assumed that perhaps in July and August the frozen tundra would be sufficiently thawed that the ground might be called "good". This reduced the computed value of U in equation (1), increasing the value of A_a and consequently the value of D by an amount of 5 db. This increase of A_a is illustrated by the solid triangle.

It has been known from vertical-incidence measurements of ionospheric absorption that a large seasonal effect exists in addition to that due to changes in the obliquity factor at oblique incidence. This was brought out in Chapter 7 of NBS Circular 462. Since the Signal

Corps Technical Report No. 9 averaged those seasonal effects which were not due to an obliquity factor it was assumed possible to correct for these by adding 13% to the absorption during November, December, January and February and subtracting 13% during May, June, July, and August. These corrections upon the previously height-corrected wave were introduced merely to observe their effect and are indicated by open triangles. Where the ground-constant corrections already exist (solid triangles in July and August) these corrections are added to the values used with the open triangles. The resultant most probable curve based on all these assumptions is a composite of the height-corrected curve and a dashed curve joining the open triangles. It still has a fairly strong seasonal component but oscillates about a mean correction close to 5 db.

Ordinarily only the solid height-corrected curve with a modification indicated by the chain curve going through the "good ground" points in July and August should be used since the seasonal correction will not appear in Reference 14. The extremes of the curve are + 15 db in December and -7 db in May.

The 15 Mc/s curves were constructed in a similar manner. However, since a 2-hop F2 mode was predictable for less than half the time in the summer months, 1-hop F2 had to be assumed although the path was over 4000 km long. Its existence along with other modes was confirmed by the use of sweep-frequency pulses, as will be seen in Section 7. The angle of elevation of the waves for the assumed layer heights varied from about +1 degree to -1 degree after correction for tropospheric bending. No complete well-established procedure existed for direct computation of the value of U in equation (1) at grazing incidence. Focusing was computed in accordance with a wave-theory equation, equation (18), p. 42 of Reference 3. The antenna cutback factors were obtained from antenna-pattern curves under preparation for Reference 14 using the theory of Wait and Conda [16]. Changes in the angle of arrival because of tropospheric bending were taken from Thayer and Bean [17].

The theory of propagation of sky waves which would arrive at the earth's surface at negative angles as shown in Reference 3 is that sky waves actually traverse only a segment of the path, leaving and returning to earth at zero elevation angle and that the rest of the path is traversed as a ground wave with heavy attenuation per unit distance. These attenuations are incorporated with the antenna patterns and give a very rapid rate of change of the equivalent gain of the antenna and its associated ground as the elevation angle goes from low positive values to zero and into negative values.

The overall corrected curve of D vs month with assumed seasonal corrections of absorption is again a dashed line connecting with the height-corrected curve. The July-August "good ground" correction was negligible and is not shown. Again, ordinarily only the solid height-corrected curve would be used. This shows the usual seasonal trend but with a small rise around June and July. The large negative values of D in the summer, as much as -30 db in August, make it appear from equations (1) and (2) that U should be predicted smaller in summer or A_t should be predicted smaller.

The predictions for winter for 19 Mc/s on one hop F2 in the daytime are not shown since the system losses were of the order of 100 db too great. Angles as low as -5° had been computed, suggesting that virtual-height estimates were too low.

The curves of Figure 22b for the Barrow-Boulder path at night are all for a predicted 3-hop Es mode. No height correction is used. A 5-Mc/s curve is shown indicating that from March to August the absorption should be predicted 7 or 8 db higher. The 10-Mc/s curve again runs to fairly large negative values in summer. The 15-Mc/s curve is very irregular. D may be larger during months when there was not enough sporadic-E to carry the signal.

Figure 23a is for the Barrow-Kenai path around 1230. For the 5-Mc/s plots for March to August 1960 with all known correction factors (the dashed line) the average value of D is about -4 db. This includes a ±13% seasonal factor (open triangles). With the correction just for height and good ground in July and August the plain line plus the chain line oscillates around -10 db. The plots for 10 Mc/s show an extreme negative correction in the summer months, following the general trend. The positive peak in May could be due to too small a sample of data with L in equation (1) too large.

The 15 Mc/s curve for 1-hop F2 propagation in December, January, and February shows a small D of the order of -5 db.

Figure 23b is for 1-hop Es at night on the Barrow-Kenai path. The plot for 5 Mc/s shows D of the order of -10 db for March to August 1960. The plot for 10 Mc/s shows winter corrections close to 0 db and again large negative corrections in summer. The anomaly of a

-1 db correction in May may be due to a small data sample, or lack of sporadic E. Higher frequencies were not shown because of skip.

Figure 24a is for the Thule-Barrow path around 1030 AST (Alaska Standard Time) which is approximately noon over the path. Data for August to November 1959 are not as reliable as the March to August 1960 data because the former transmissions were "borrowed" teleprinter emissions. The later points on 9 Mc/s on the plain curve plus the July and August chain-line curve show corrections ranging from 13 db in March to -5 db in July, preserving the usual trend. The 12-Mc/s group shows a large height correction bringing the March-August 1960 data all into the positive region.

Figure 24b for Thule-Barrow around 2230 AST shows similarly shaped curves with the dip again in summer.

6.3 Calculations of δ

It is assumed that the calculated values of δ, the amount to be added to the predicted transmission loss to give the median observed are more reliable than D because they are not influenced as much by strong modes occurring a small proportion of the time. The corrections and symbols used in this group of plots are similar to those used in Section 6.2 except that the assumed seasonal-correction factor points using ± 13% factors deduced from NBS Circular 462 are not illustrated here.

Figure 25a shows values of δ for Barrow-Boulder around 1230 MST. The plots for 10 Mc/s run only from September 1959 to March 1960; other months were characterized by medians below noise (symbol R). The plain-line height-corrected curve can be used for obtaining medians of transmission loss from predictions made for instance by use of Signal Corps Technical Report No. 9. The value of δ is a correction to the prediction assuming the correctness of the observations herein reported. The largest correction is 30 db for December and the smallest 15 db for March.

The plots for 15 Mc/s again have the grazing-angle months April - September with a second hump around June. Values of δ on the height-corrected curve are as high as 25 db in December. It is possible that the anomalous negative values in August and September were caused by assuming elevation angles too far in the negative region.

Figure 25b shows night values for Barrow-Boulder. The 5-Mc/s curve for March to August shows a fairly constant δ, around 25 db, when one changes to the chain-line good-ground curve in July and August. The 10-Mc/s curve shows 20-db values around November and December. The June and July values of 2 or 3 db are very low and indicate too high a value of U or of A_t (equations 3 and 4). Pulse studies indicate that a variety of lower-order modes play a role here in addition to the 3-hop Es mode here regarded as the strongest.

Figure 26a is for Barrow to Kenai around 1230 AST. For 5 Mc/s from March to August 1960 the plain height-corrected curve plus the chain-line curve incorporating a good-ground correction in July and August indicate a peak δ of 29 db in April and a low of 5 db in July. April was a month of peak world disturbance.

The 10 Mc/s curve for December 1959 to August 1960 again shows an April peak, this time + 40 db and a trough in July of -15 db. Another trough of + 1 db exists in February which has no counterpart on the other paths.

The small portion of a period for which a regular-layer MUF was available for propagation in December, January, and February on 15 Mc/s reveals values of δ ranging from 6 to 9 db.

Figure 26b shows results for the Barrow-Kenai path for the period around 0030 AST. Again for 5 Mc/s the values of δ vary from a high of + 17 db in April to a low of +1 db in June. Behavior on 10 Mc/s at this time is different at least in degree from what it is in daytime, values of δ ranging from a high of +17 db in April to a low of +5 db in August.

Figure 27a is for Thule-Barrow daytime and Figure 27b is for Thule-Barrow night, results from March to August 1960 being the more reliable. Values of δ in all cases here tend to be smaller in summer.

6.4 Data Spread

Figures 28 to 30 are plots of the spread S_1 between the lowest observed system loss and the median as well as the spread S_2 between the lower decile system loss and the median. The symbol R marks months where the median was below noise. The spreads in general are not as good indicators of general storminess as might be hoped. Only April 1960 at the higher frequencies on the Barrow-Kenai path,

Figure 29 a and b, seems to be a month in which large values of S_1 and S_2 are associated with disturbances (high world Kp).

6.5 Discussion of Transmission-Loss Prediction Results

Throughout this section the reader should refer to equations (1) to (6). System loss data are regarded as transmission loss. The trend curves studied do not include the Circular 462 seasonal correction unless so stated. The curves discussed for daytime are the plain height corrected curves. These merge into chain-line good-ground curves for July and August where the good-ground correction was appreciable. There were no height corrections at night but the good-ground correction was valid in some cases.

Values of apparent absorption A_a under conditions of no disturbance were obtained for periods near noon and midnight for each month on the three paths. The predicted strongest mode for a particular hour in the month was assumed to be the same for the values of median transmission loss at that hour on each of the days and the lowest transmission loss recorded was assumed to be that for an undisturbed day. From this (L) was subtracted a calculated value of transmission loss for the path (U) for the assumed mode and the appropriate antennas and ground, regarding the ionosphere as a perfect reflector with no absorption. The remainder was A_a.

Figures 22 to 24 are values of correction D to be added to the prediction absorption A_t to give A_a. These curves nearly all show a pronounced decrease of D in summer. Sometimes D goes far into the negative region, indicating an apparent observed <u>negative</u> absorption. Extreme values of D most probably mean that the wrong mode was chosen making U incorrect, the negative values meaning that the observed mode was actually a more efficient one and that if it had been correctly predicted A_t should have been smaller.

One of the most nearly-regular looking curves was Figure 22b for D in the case of 5 Mc/s at night for Barrow-Boulder 3-hop Es, where it appeared that a correction of the assumed U of about +5 db would bring the predictions into line. On the Barrow-Kenai path for the same frequency in the daytime, Figure 23a if one did not include the Circular 462 seasonal correction (open triangles and dashed line) there was a seasonal effect; the plain height-corrected line plus the chain line for July-August good ground indicate a summer dip. The

1 Es mode at night (Figure 23b) also exhibits some of the summer dip.

It is believed possible that the regular behavior of 5 Mc/s at night on the Barrow-Boulder path (Figure 22b) is due to the fact that E-layer ionization always exists at the equivalent vertical-incidence critical frequency and that the higher layers are always shielded. On the Barrow-Kenai $2F_2$ daytime path at 5 Mc/s (Figure 23a) the lower-order modes must have been well shielded, so that the seasonal effects may have been due to other causes. It is to be noted that the dashed-line Circular 462 seasonal correction smooths the 5-Mc/s curve. On summer nights some of the regular-layer modes must have dominated over Es on most of the other frequencies and paths.

The fact of the possibility that the lowest transmission-loss values were not for the predicted modes made it appear that δ, the correction to be added to the predicted undisturbed transmission loss L_p (which includes A_a) to give the median transmission loss would be a more reliable variable than D. However, Figures 25 to 27 for δ illustrate similar trends to those of the previous curves. Now the curves are higher since the median transmission loss T is higher than L. However, a summer dip appears on nearly all the curves and a winter rise on some.

The height-corrected Barrow-Boulder 10 Mc/s daytime curve, Figure 25a, could unfortunately not be continued into summer because of the high absorption which placed the median observed transmission loss below the noise. It is possible that some of the peaking in winter is due to a seasonal factor and some to the fact that some days higher order modes than the predicted $2F_2$ governed if lower-order modes were shielded. The same can be said for the 15 Mc/s daytime curve in winter.

Values of D and δ for the grazing-angle 1-hop F modes on Barrow-Boulder 15 Mc/s beginning in April were probably not predicted with great precision because of the poor knowledge of heights and thus of elevation angles. The large predicted transmission losses on 19 Mc/s compared with those observed indicate that that frequency was propagated from much higher heights than those assumed. The use of minimum virtual heights, in accordance with Signal Corps Technical Report No. 9, could be improved by data acquired or estimated for the heights at which a transmission curve intercepts the h-f curve. See Circular 462, Chapter 6. This is particularly true for operating frequencies near the MUF.

In the nighttime Barrow-Boulder modes (Figure 25a) the 5 Mc/s curve shows a δ of about +25 db for March to August, suggesting a constant auroral absorption correction. The 10 Mc/s curve has a summer dip. Perhaps a regular layer mode was operative here some of the days. On the 15 Mc/s curve the high December night values might have been associated with skip (in view of the R value in November).

The April disturbances show prominently on the Barrow-Kenai 5 and 10 Mc/s curves, Figure 26, as increases of δ especially in the daytime, which were not manifest in the D curves. However, the disturbed-month effects in most of the other cases were possibly masked by mode changes. It seems reasonable that the Barrow-Kenai 5 Mc/s 1230 AST dip to +5 db is normal with perhaps a small seasonal correction, since July was very quiet.

The Barrow-Kenai 1-hop E 10 Mc/s 1230 AST curve dipping to -15 db on the chain-line good-ground curve in July makes it appear that perhaps lower-order modes were present. The calculated value of U for 1 hop E was 128 db below 1 watt. Had 1-hop F2 been assumed it would have been 116 db, this change alone raising the curve to -3 db. Then decreased absorption would have reduced A_t by the ratio of the secants of the apex angles, bringing a predicted A_t of 23 db down to 8 db; making A_t smaller would lift the curve higher by 15 db bringing it to +12 db.

On the nighttime curves for Barrow-Kenai, Figure 26b, if 1F2 had governed, the 5-Mc/s curve in July would have been lifted 12 db for U and 5 db for A_t or 17 db, removing the summer dip. On 10 Mc/s it would have been lifted 12 +2 or 14 db also removing the summer dip.

On the Thule-Barrow path at 9 Mc/s at 1030, Figure 27a, the lower-order mode 1F2 has a higher value of U, 122 db, than that for 2F, 119 db, so that if 1F2 governed, A_a by equation (1) would decrease 3 db. The predicted July absorption A_t = 21 db would go down to 15 db for 1F2 so the net rise of the curve by equation (2) would be +3db (equations 3 and 4) affecting the dip in the chain-line curve only slightly. The dips in the 12-Mc/s height-corrected curve and both night curves, Figure 27b, are hard to explain since a 1-hop F2 mode is already hypothesized, the worst being the 9 Mc/s night curve.

The spread of data of Figures 28 to 30 correlate poorly with periods of worldwide disturbance. Perhaps they reflect local storminess and changes of moding.

On the whole the data demonstrate a mixture of seasonal effects, changes of mode and auroral absorption which are difficult to sort.

7. SWEEP-FREQUENCY PULSE EXPERIMENTS

During April, May, and June 1960, hourly sweep-frequency records were made over the Barrow-Boulder path in connection with another project, using two standard model C3 ionosphere recorders with reception at Barrow. These were examined to acquire supplementary information pertinent to the studies of Section 6.

Because there was only one operator on duty and manual tracking was needed, best records were made on the path in the 16-hour period between 1100 and 0300 MST.

The range-versus-frequency records illustrated that during a large part of the day many modes existed and that these modes changed from day to day with changing ionospheric conditions.

The range-versus-frequency sweep of Figure 31 is an illustration of the modes existing under undisturbed conditions on the Barrow-Boulder path on 2 June 1960 at 2306 MST. It demonstrates that under undisturbed conditions the moding on an auroral path is not unlike that on a non-auroral path. The probable layer combinations in the modes are marked.

The MUF is seen to be about 23.6 Mc/s and is for a 1-F2 mode in the illustration. It may be seen that the following modes were probably active at the given CW operating frequencies:

19 Mc/s	1 F2 low and high rays
15 Mc/s	1 F1 low, 2F2 low and high
10 Mc/s	1 F2 low, 2F2 low, 2F2 + 2E, 3F2, 3F2 + 1E, 4F2

Thus it is seen that at least 6 modes were active at 10 Mc/s, but only 3 of them seen from the photograph to have been strong and comparable. Since the modes do not have a stable phase and are not phase-correlated a combination of modes produces a resultant whose total power is the sum of the power in each. Three equal modes would then produce a resultant only 4.7 db stronger than one of the modes. In the daytime the number of important modes should be even less than at night because the higher-order modes (once an elevation angle is reached which has a favorable antenna response), will be attenuated because of extra passages through the absorbing regions.

Figure 32 for the Barrow-Boulder path on 14 April 1960 at 1205 MST shows, in contrast to Figure 31, the effect of a mildly-disturbed period on the structure of a signal passing through the auroral zone. The MUF is in this case about 14.5 Mc/s. The F2 echoes are so highly diffuse that the various orders of modes are not distinguishable. This is the effect of the auroral spread-F phenomenon .

The straight trace terminating at about 23.8 Mc/s is a 3-hop sporadic-E mode, sporadic E being associated with auroral disturbances. This frequency could be identified with an operational MUF for a circuit with properties identical with those of the ionosphere sounding equipment. However, under unstable conditions such as these the sporadic-E mode can vary greatly or disappear in a matter of minutes or hours and, in fact, all modes can disappear for periods up to several hours even in a moderate disturbance.

In Figure 32 at the CW operating frequencies the following modes are noted:

20 Mc/s	Es
15 Mc/s	Es
10 Mc/s	Es, Spread F
5 Mc/s	Es, Spread F

An attempt was made to select modes from each available sweep record around noon and around midnight which appeared to have contributed to the total CW signal observed at the same time. Tables 8, 9, and 10 for each of the frequencies for April, May, and June illustrate the modes which probably made up the CW signal on each day that records were available to be scaled. Note that these were all simple modes. Modes in which the wave was propagated by combinations of hops via more than one layer, such as E and F2, usually appeared in the late afternoon.

All the days in each month for the two hours beginning 1200 MST and 0000 MST when 1-hop F2 either existed alone or contributed most of the signal power on each frequency were listed and the observed values of system loss for those days tabulated. Then an analysis similar to that in Section 6 was performed on the selected data. The lowest value of system loss observed in the part of the day under study, when regarded as transmission loss, corresponded to L in equation 1. Since the 1-hop F2 mode was observable at night it was likely that the lowest value would occur at a time when $A_a = 0$ so that L was then equal to U. Thus it was, in principle, possible to obtain values of L and U observed for the proper moding as well as a median T for this case. These could be used to obtain D and δ and compared with the results in taking the whole month's data as was done in Section 6.

The method usually suffered from lack of enough data in any one category to provide a good distribution. However, night values of U on 10 and 15 Mc/s appeared to be not greatly different from those computed and used in Section 6. In the daytime for 15 Mc/s in May 1960 the value of A_a and consequently of D in equation 2 and Figure 22 was not greatly different from that calculated, i.e., -7 instead of -8. It must be remembered, though, that U was obtained for a nighttime F2 layer height and that this might be quite different from that which applies to a daytime layer height.

Thus the whole question of the low and often large negative values of D and δ as summer approached, which were noted in Section 6, remains unsolved. It is also again even more obvious that precise knowledge of equivalent layer heights as well as moding are important to an accurate prediction of path transmission loss. It is unfortunate that the Barrow-Boulder path over which the pulse test was made is one on which the grazing-angle one-hop F2 mode is important, since the calculation of transmission loss for this range of angles depends critically upon their angles being known accurately.

It should be noted particularly that the pulse data have shown that the 1-hop F1 mode is often important [18].

8. CONCLUSIONS

8.1 Statistical Signal Behavior

The monthly signal behavior departs from the ideal of low transmission loss in the early morning and early evening to the extent that skip and moding changes affect the signal. Percent signal outages are the result of regular skip and moding changes plus the added effect of disturbances.

Monthly cumulative distributions of median hourly transmission loss generally show smaller spreads in the same month for the Polar Cap than for the auroral zone. This may be because of the absence of the many blackouts over small areas which are characteristic of the auroral zone. If small local blackouts cause a large part of the spread in the distribution of transmission loss values for signals on auroral paths it may be expected that signal distribution for longer auroral paths will show smaller spreads than those for the shorter ones because the larger Fresnel Zones and non-great circle modes should always, except during large disturbances, enable some energy to arrive with relatively low transmission loss.

8.2 Disturbances

The general impression which these experiments convey relative to arctic disturbances is that there is a wide variety of effects upon high frequencies. As noted above a Polar Cap path appears to have less variability of transmission loss under quiet world conditions than an auroral zone path and to be less susceptible to small disturbances.

The large disturbances are frequently associated with proton events (Polar Cap or PC events) which cause blackouts in the daytime at low geomagnetic K in the Cap, but more important in frequency of occurrence if not in severity, is the fact that the auroral types of disturbance spread into the Cap in the great storms. In fact the Polar Cap events were not readily amenable to isolation in the HF system-loss data over the Cap. This is partly because no Polar Cap events isolated from auroral disturbances like the 23 February 1956 event were noted. However, the absorption in these events, occurring fairly low in the D region, would probably not affect the high frequencies markedly.

On arctic paths a disturbance appears to make operation desirable on a higher frequency more often than on a lower frequency.

8.3 Transmission-Loss Predictions

An attempt was made to obtain corrected factors δ to add to transmission losses predicted by techniques used for non-auroral paths. Figures 25, 26, and 27 show a result which is a mixture of trends due not only to disturbance effects but to a seasonal effect and a lack of knowledge of moding. It has also become evident that knowledge of equivalent reflection heights is not sufficiently precise to produce the best results in grazing-angle predictions, the use of minimum virtual heights being erroneous particularly as the operating frequency approaches the MUF.

8.4 Sweep-Frequency Pulse Results

Pulse patterns demonstrated that a large number of modes may be present at any one time, and illustrated the difference between modes on disturbed and undisturbed days. However, these data shed very little more light upon the seasonal behavior of apparent absorption.

9. RECOMMENDATIONS

Future experiments should be done on two reasonably short paths, one auroral and one non-auroral. Barrow to Kenai is an ideal auroral path. The other path could possibly be Kenai to an island in the Aleutians, which would be non-auroral except during disturbances. Since mode identification has proven to be so important there would be sweep-frequency transmissions from Kenai to Barrow and the Aleutian point. The fixed-frequency CW transmissions would also originate at Kenai and would be broken periodically to permit reception of not only noise, but fixed frequency pulses for amplitude measurements on pulse modes identified by the sweep technique. Perhaps the fixed frequency transmitters could continuously emit a long (say 22-millisecond) pulse followed by a 50-microsecond pulse 10 times a second. At the receiving sites equipment would be used to measure elevation angle and bearing of the modes. Fading, phase-stability measurements and spectrum studies would also be made.

With an adequate supply of mode information analyses could be based upon the distribution of amplitudes in each mode during the month. Thus CW observations could be interpreted more readily. Translation of results into a prediction technique, however, would require a precise method of predicting ionospheric parameters at all times.

10. ACKNOWLEDGMENTS

The author wishes to acknowledge the liberal cooperation of the staff of the Arctic Research Laboratory (Office of Naval Research), Barrow, Alaska whose generous provision of facilities and assistance made conduct of the experiment in that location possible. Appreciation is expressed to the Federal Aviation Agency at Anchorage for permission to use a site at Kenai, Alaska and for much assistance rendered by the staff at both Anchorage and Kenai.

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Robert M. Davis, Jr., Boulder Laboratories
David L. Ross, Boulder Laboratories
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12. LIST OF FIGURES

32. Mode Structure Observed Over a Path Through the Auroral Zone During a Season and Time of Day of Moderate Disturbance, Barrow, Alaska to Boulder, Colorado, 14 April 1960

13. LIST OF TABLES

9. CW-Signal Modes Derived from Sweep-Pulse Records, May 1960

10. CW-Signal Modes Derived from Sweep-Pulse Records, June 1960

KEY TO TABLES 2, 3, 4

For each hour the following summary of each month's data is tabulated. The symbols in the column headed type have the following meanings:

CT	Number of hourly medians of system loss available
90%	Lower decile of system loss
50%	Median of system loss
10%	Upper decile of system loss
%R	Percent of time signal below noise

An R above a value indicates that the signal was below noise. Although the value is corrected the actual system loss may be greater than the tabulated value.

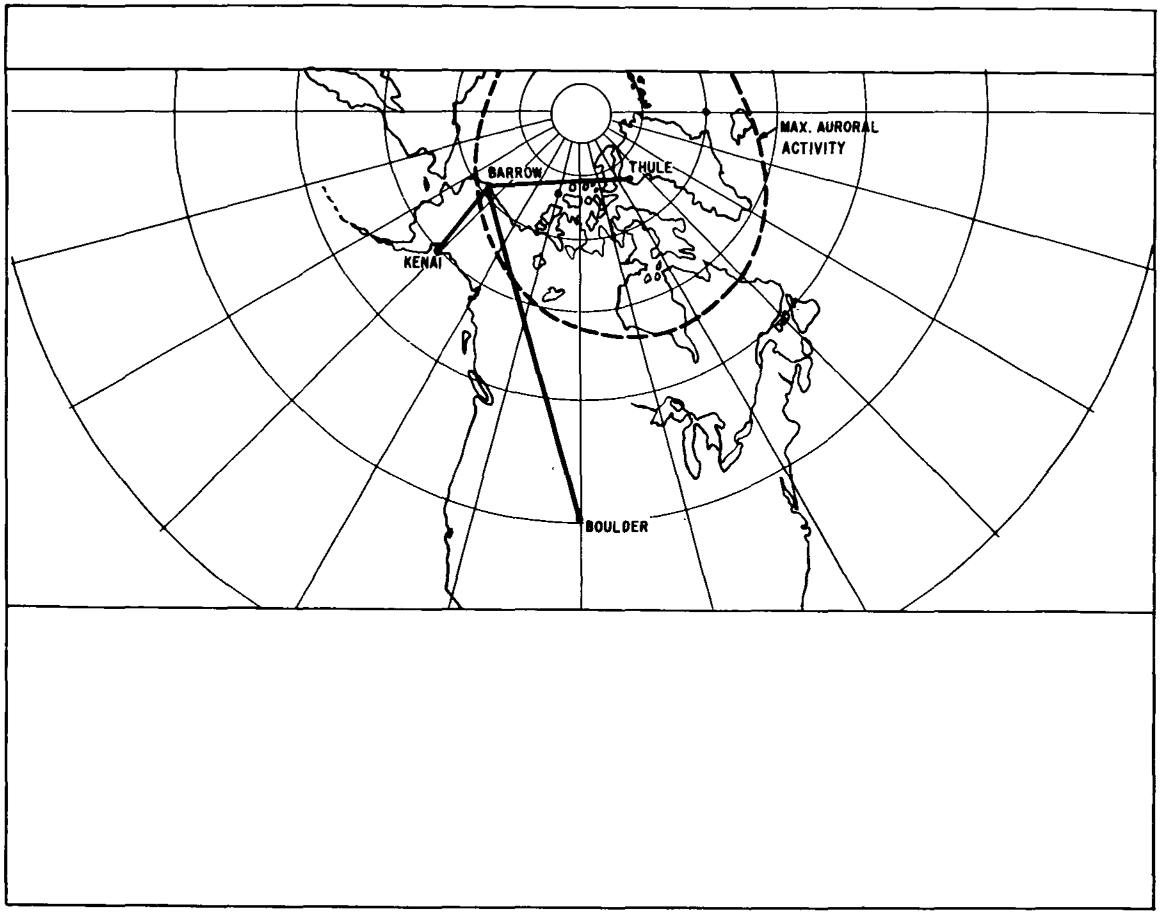
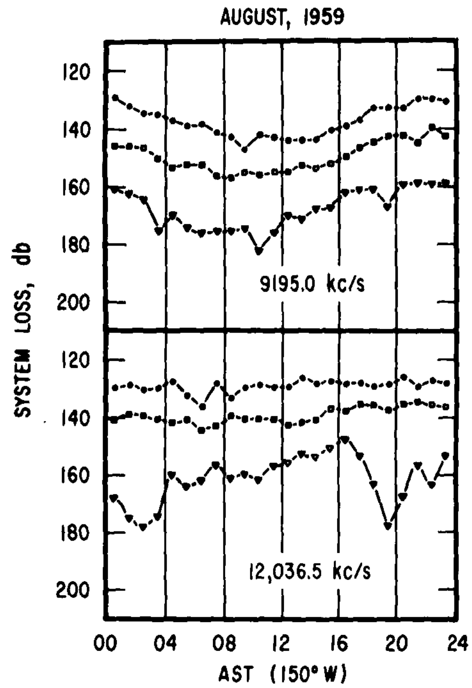


Figure 1. Experimental Paths



DIURNAL VARIATION OF SYSTEM LOSS PLOTS

- LOWER DECILE
- MEDIAN
- UPPER DECILE

SOLID SYMBOLS REPRESENT LOWER LIMIT OF SYSTEM LOSS BECAUSE SIGNAL WAS BELOW NOISE

PERCENT TIME SIGNAL BELOW NOISE PLOTS

THULE - BARROW PATH

- 9195.0 kc/s
- 12,036.5 kc/s

BARROW-KENAI AND BARROW-BOULDER PATHS

- 5128.0 kc/s
- 9947.5 kc/s
- 14,688.0 kc/s
- 19,247.0 kc/s

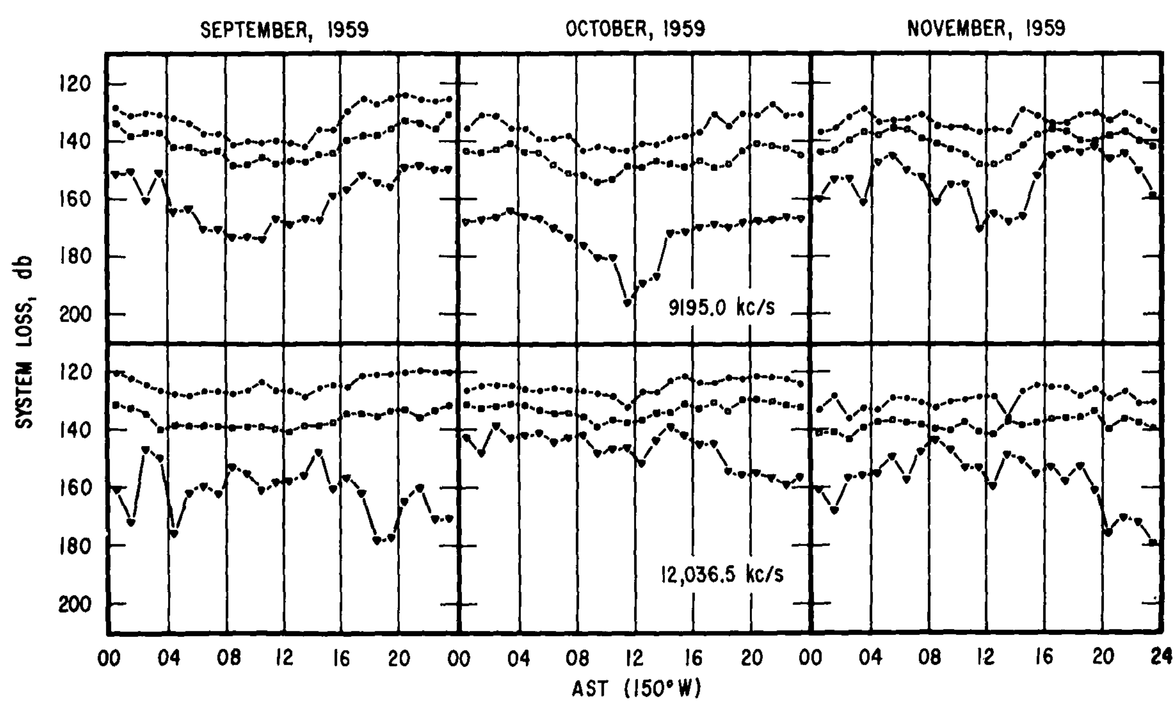


Figure 2a. Monthly Diurnal Variation of System Loss and Percent Time Signal Below Noise for Thule-Barrow Path

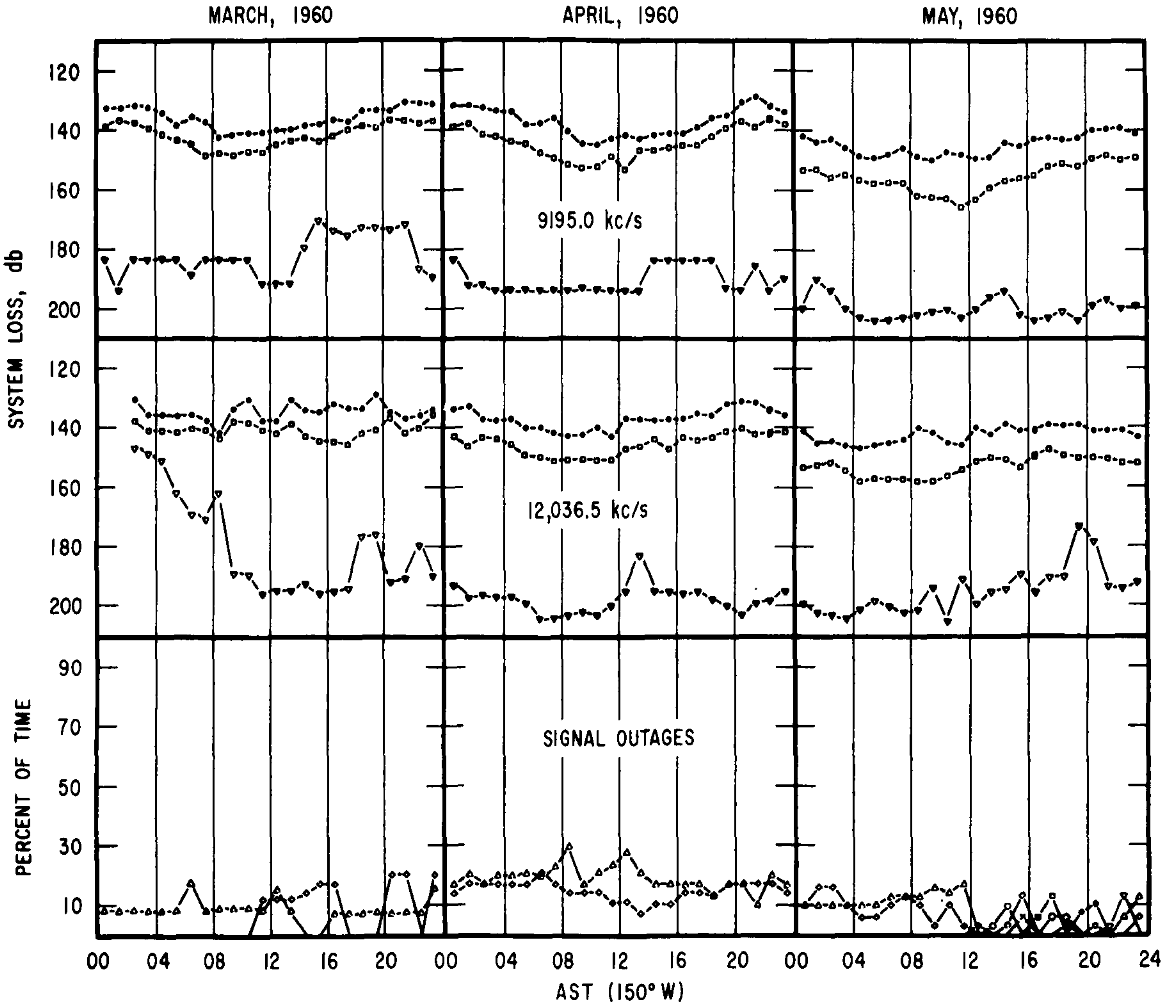


Figure 2b. Monthly Diurnal Variation of System Loss and Percent Time Signal Below Noise for Thule-Barrow Path

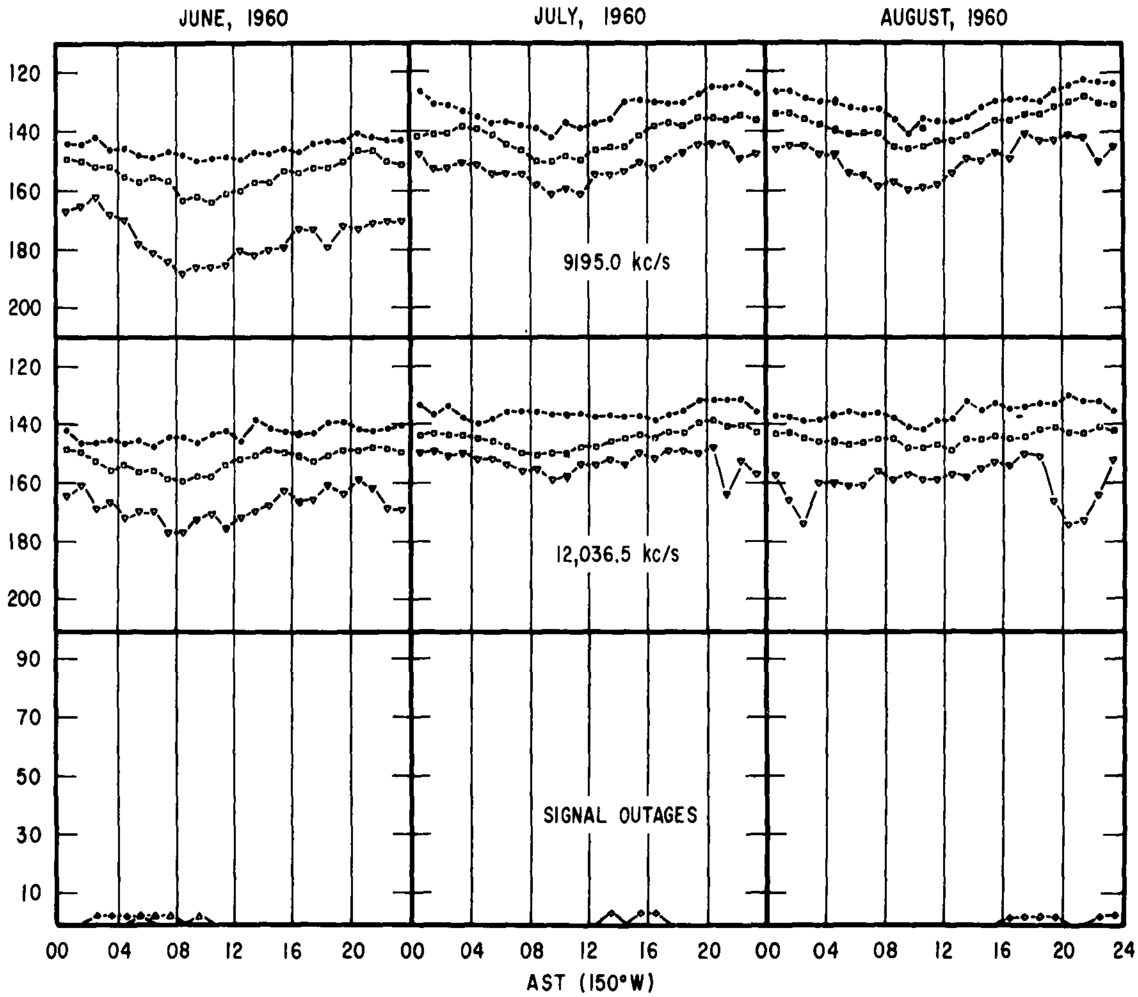


Figure 2c. Monthly Diurnal Variation of System Loss and Percent Time Signal Below Noise for Thule-Barrow Path

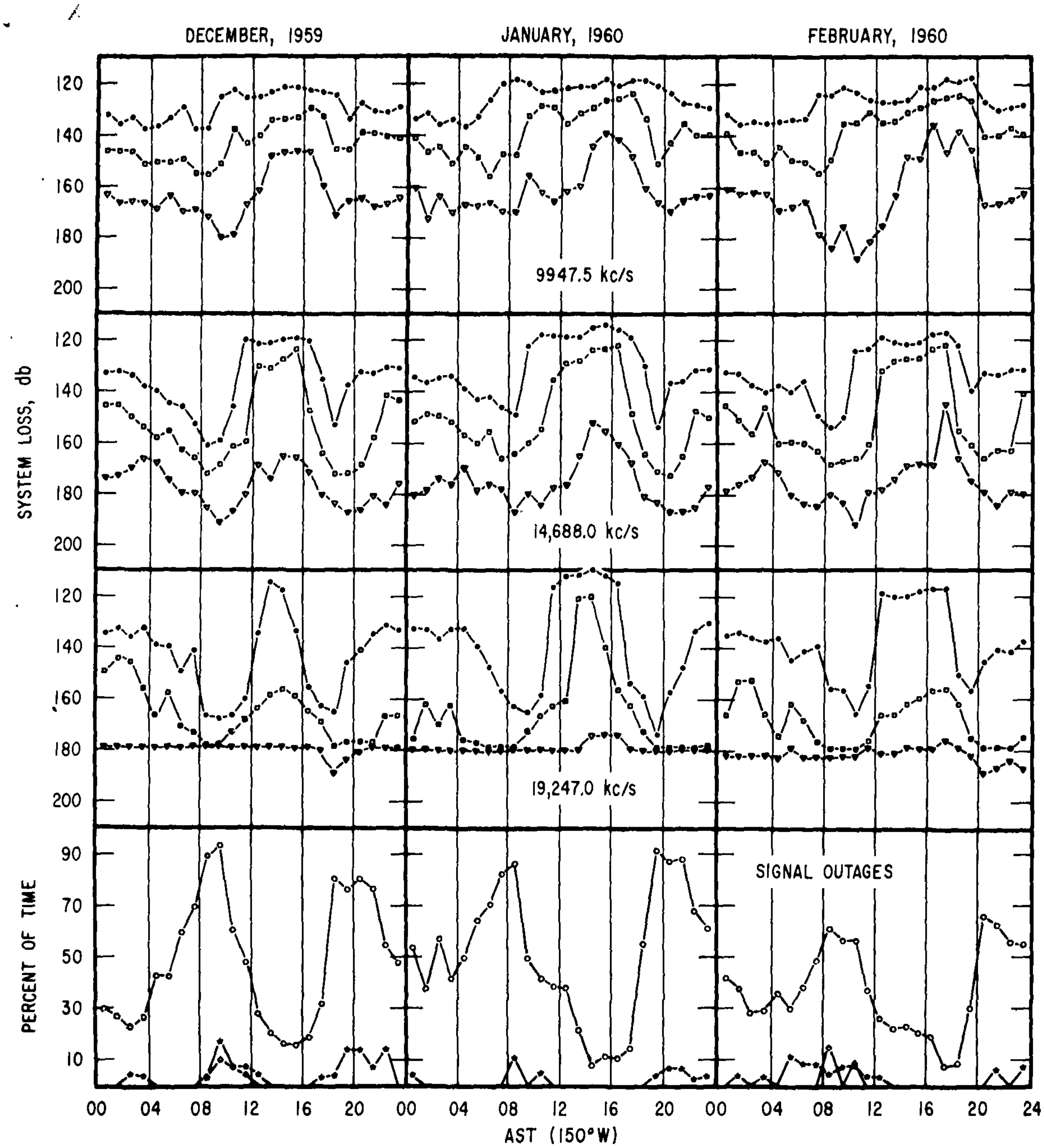


Figure 3a. Monthly Diurnal Variation of System Loss and Percent Time Signal Below Noise for Barrow-Kenai Path

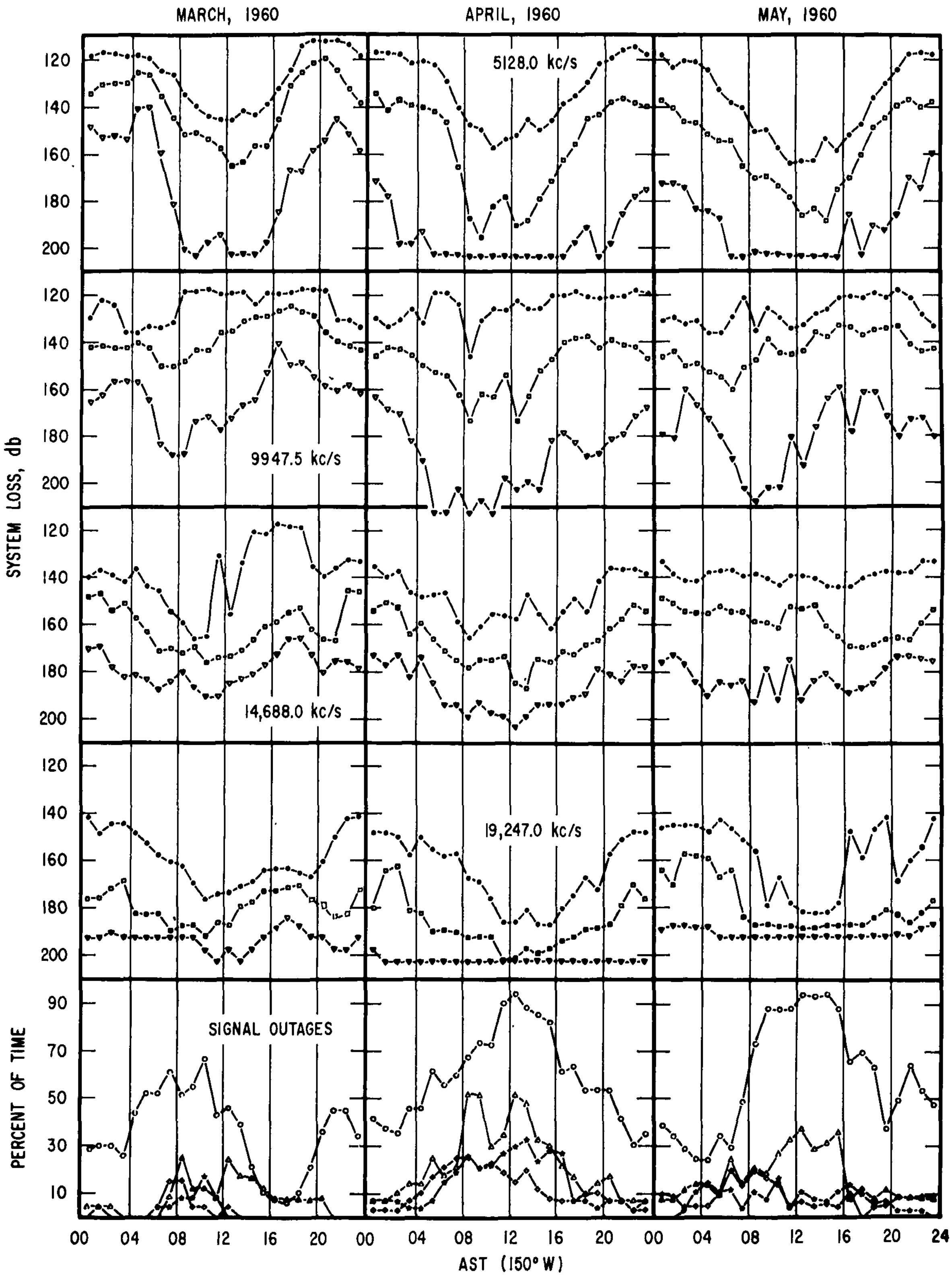


Figure 3b. Monthly Diurnal Variation of System Loss and Percent Time Signal Below Noise for Barrow-Kenai Path

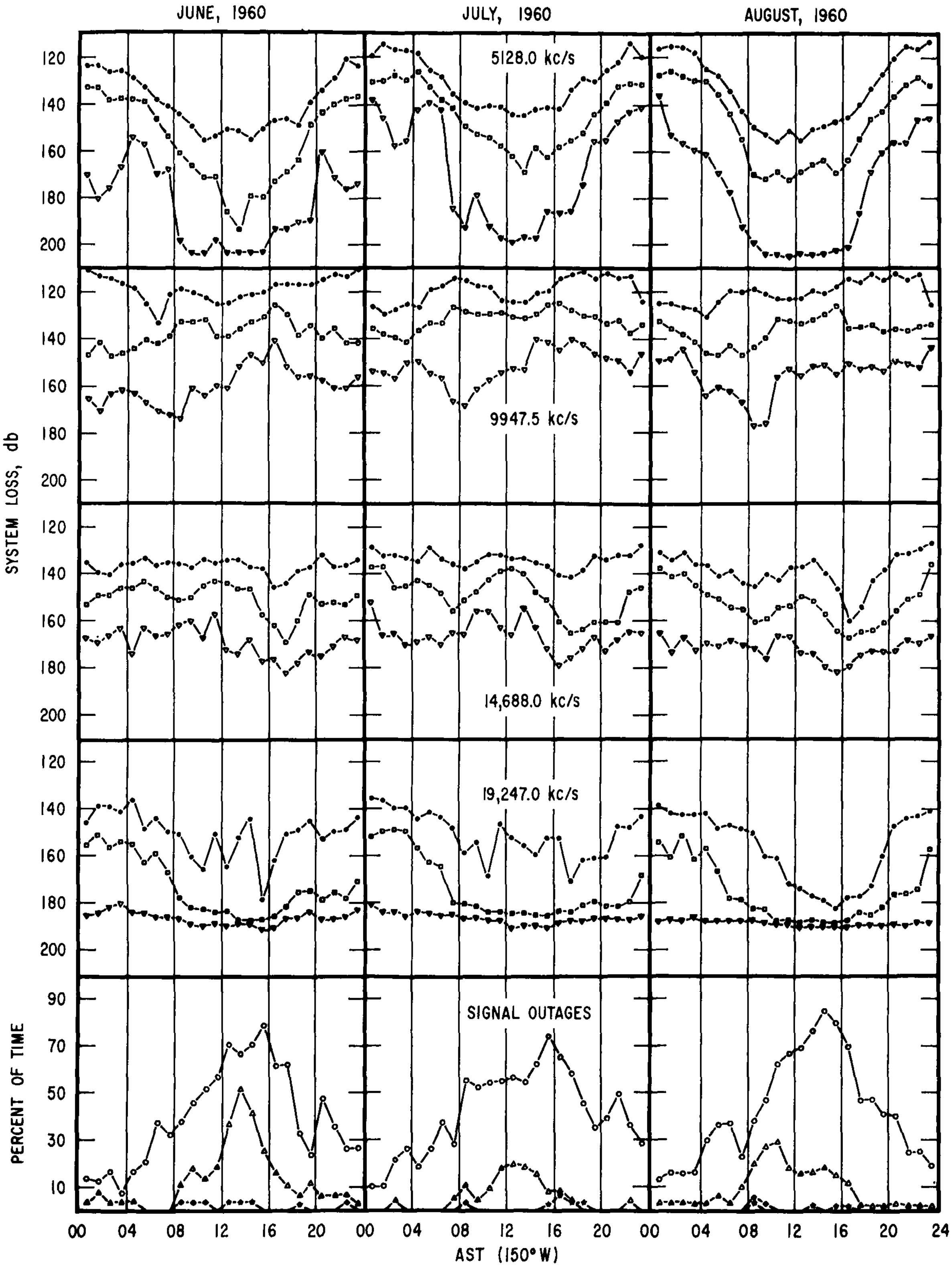


Figure 3c. Monthly Diurnal Variation of System Loss and Percent Time Signal Below Noise for Barrow-Kenai Path

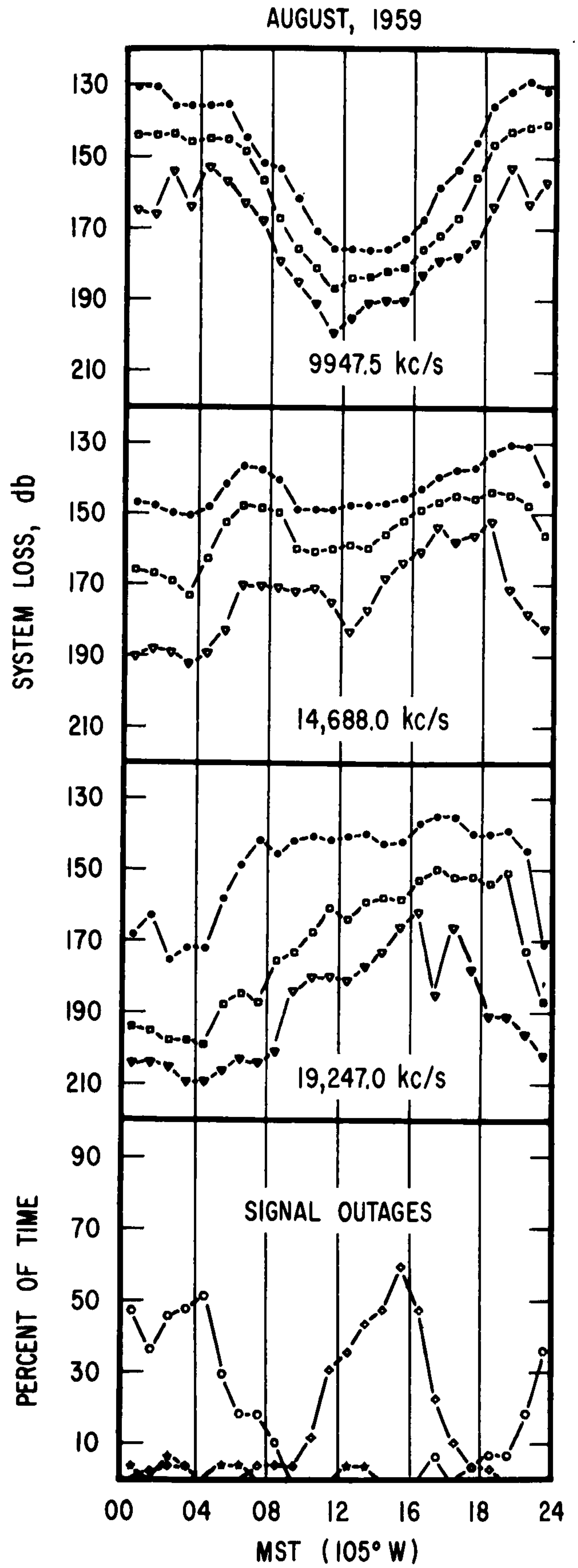


Figure 4a. Monthly Diurnal Variation of System Loss and Percent Time Signal Below Noise for Barrow-Boulder Path

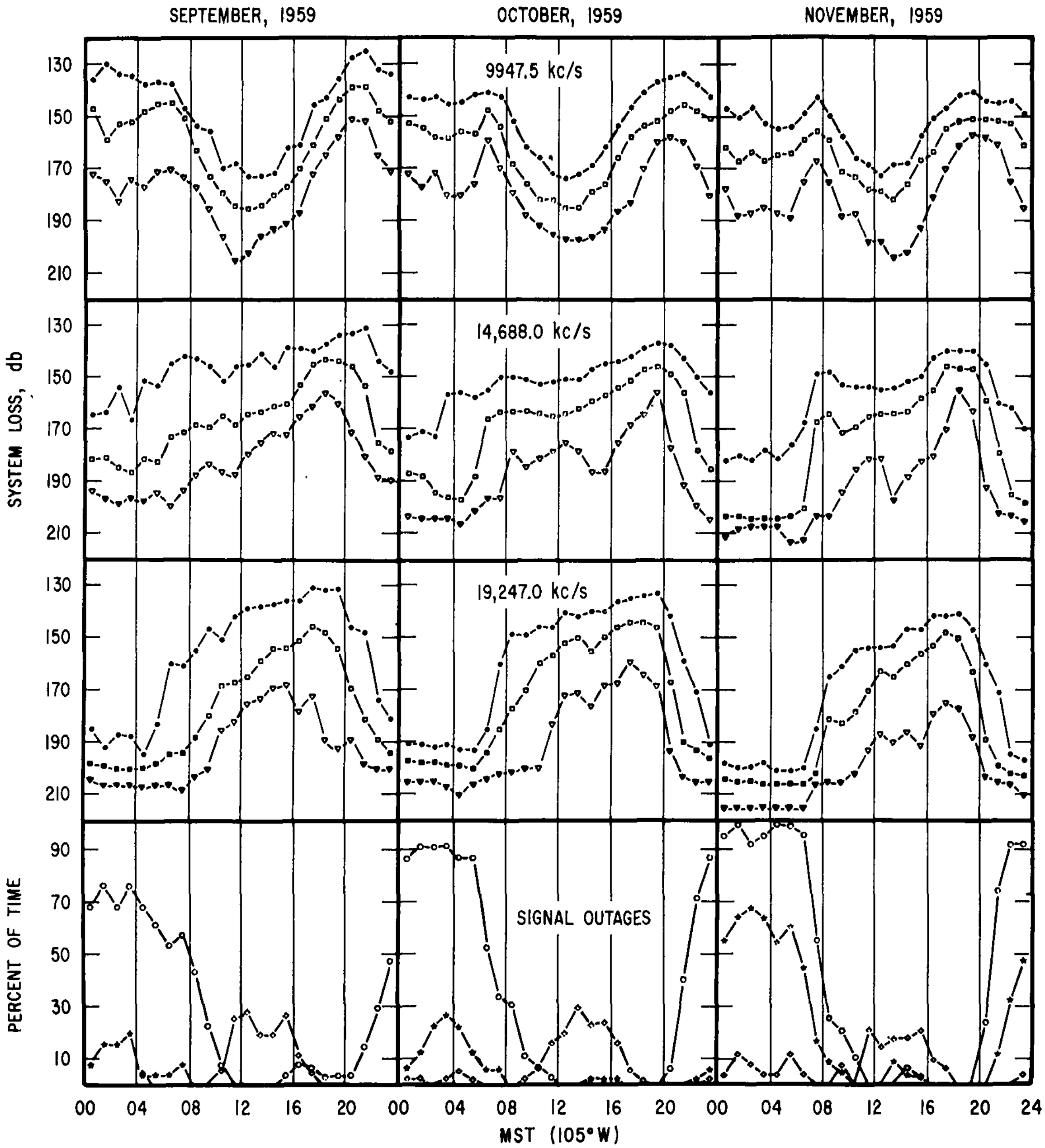


Figure 4b. Monthly Diurnal Variation of System Loss and Percent Time Signal Below Noise for Barrow-Boulder Path

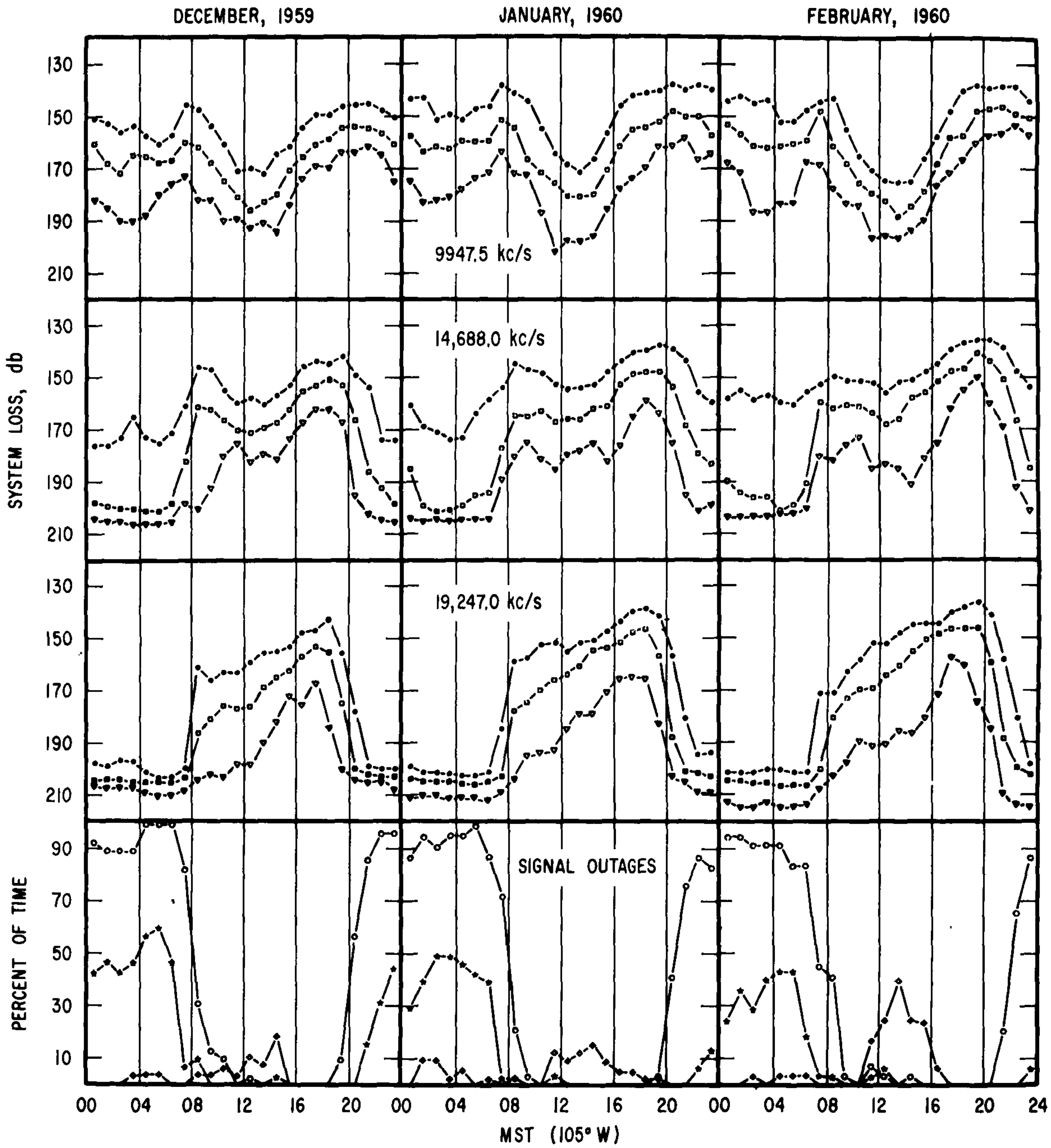


Figure 4c. Monthly Diurnal Variation of System Loss and Percent Time Signal Below Noise for Barrow-Boulder Path

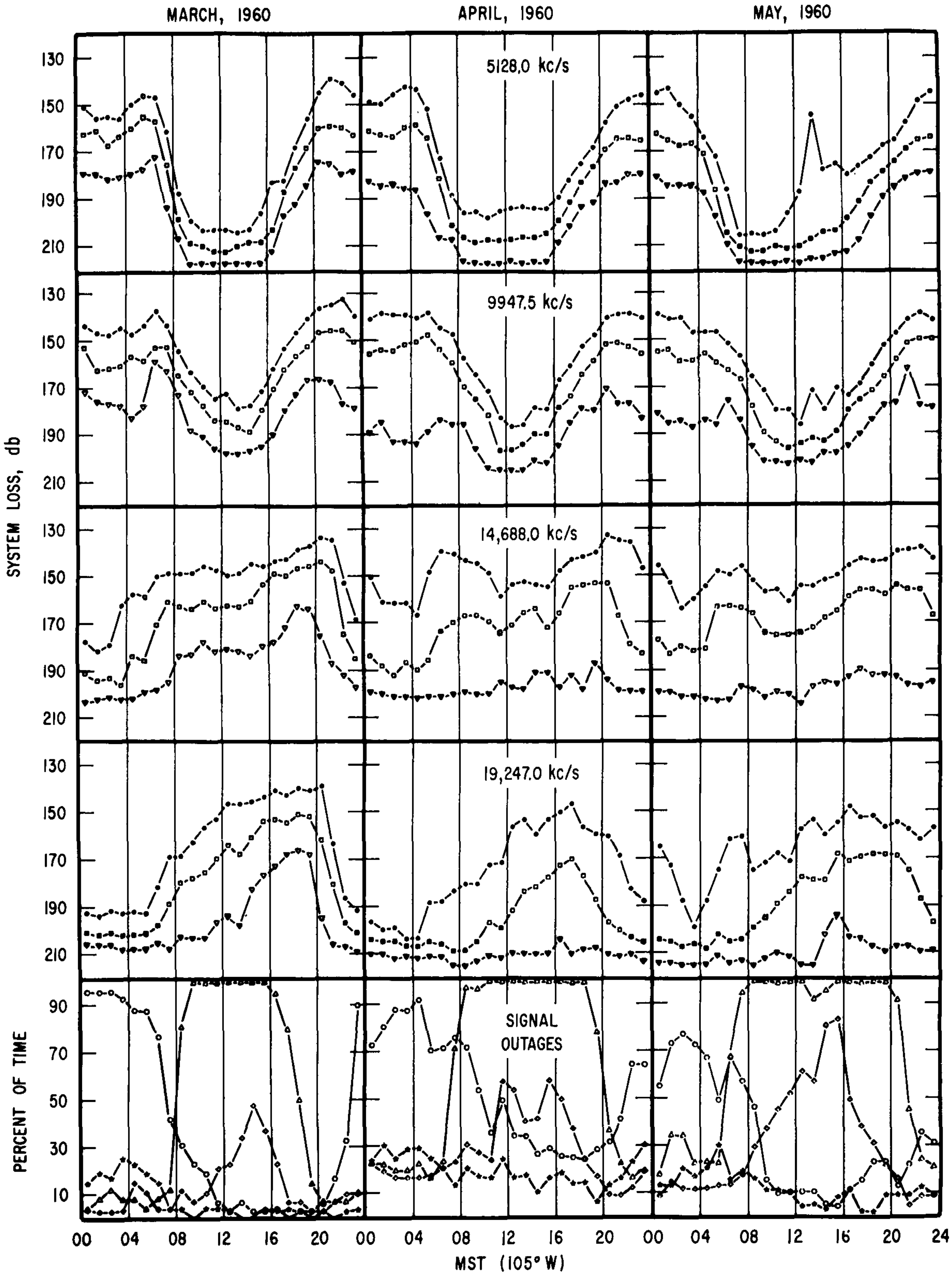


Figure 4d. Monthly Diurnal Variation of System Loss and Percent Time Signal Below Noise for Barrow-Boulder Path

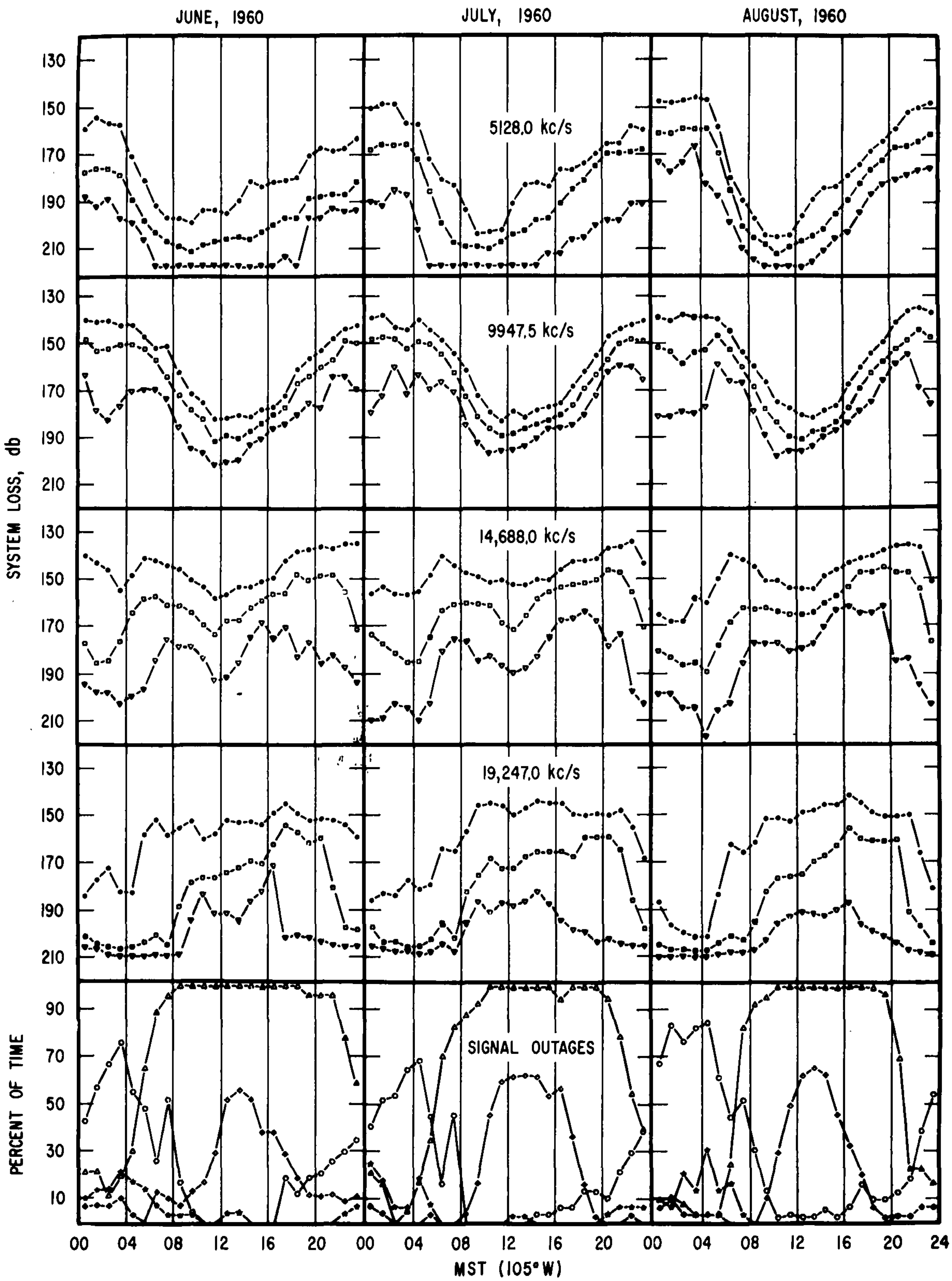


Figure 4e. Monthly Diurnal Variation of System Loss and Percent Time Signal Below Noise for Barrow-Boulder Path

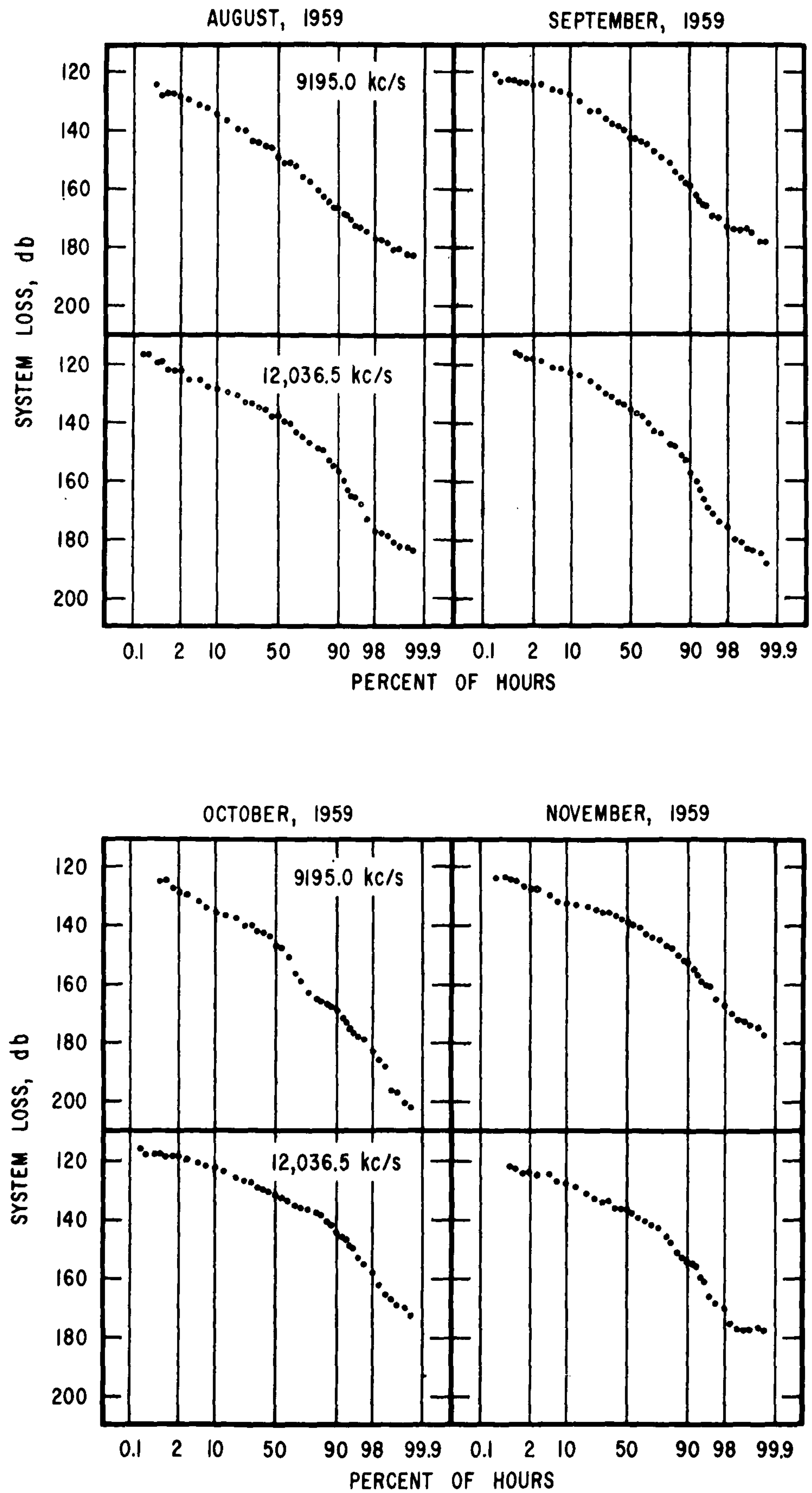


Figure 5a. Monthly Cumulative Distribution of System Loss for all Hours for Thule-Barrow Path

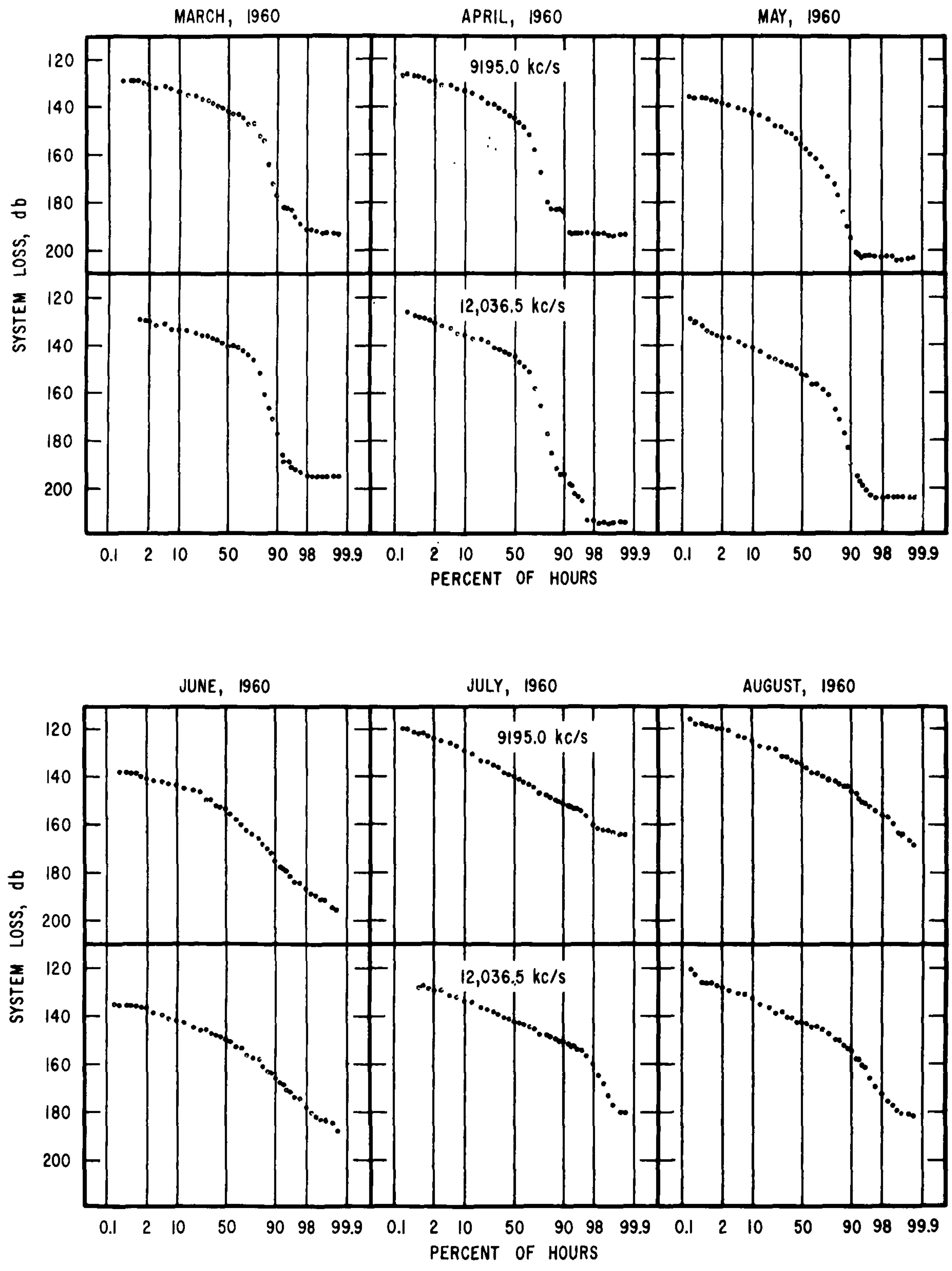


Figure 5b. Monthly Cumulative Distribution of System Loss for all Hours for Thule-Barrow Path

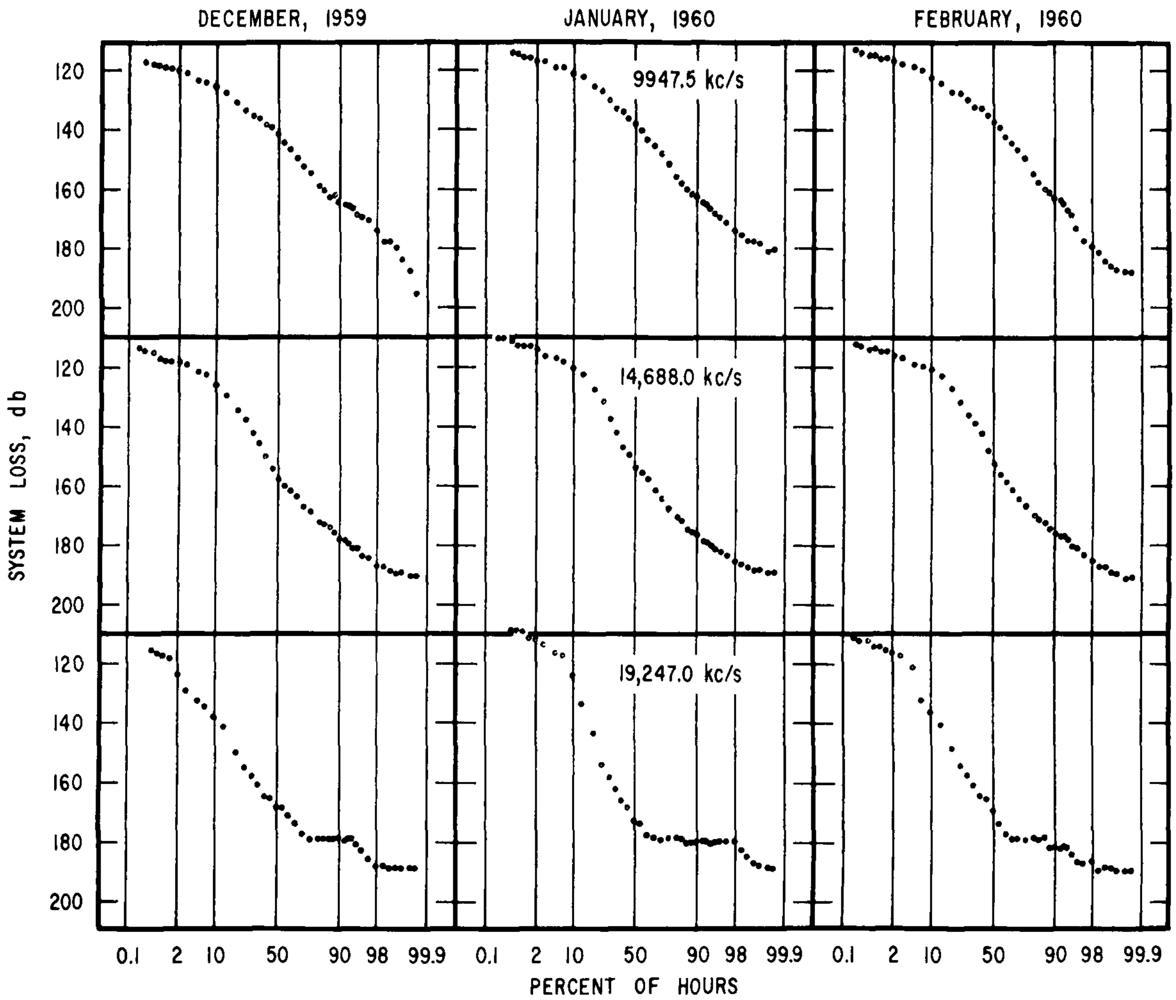


Figure 6a. Monthly Cumulative Distribution of System Loss for all Hours for Barrow-Kenai Path

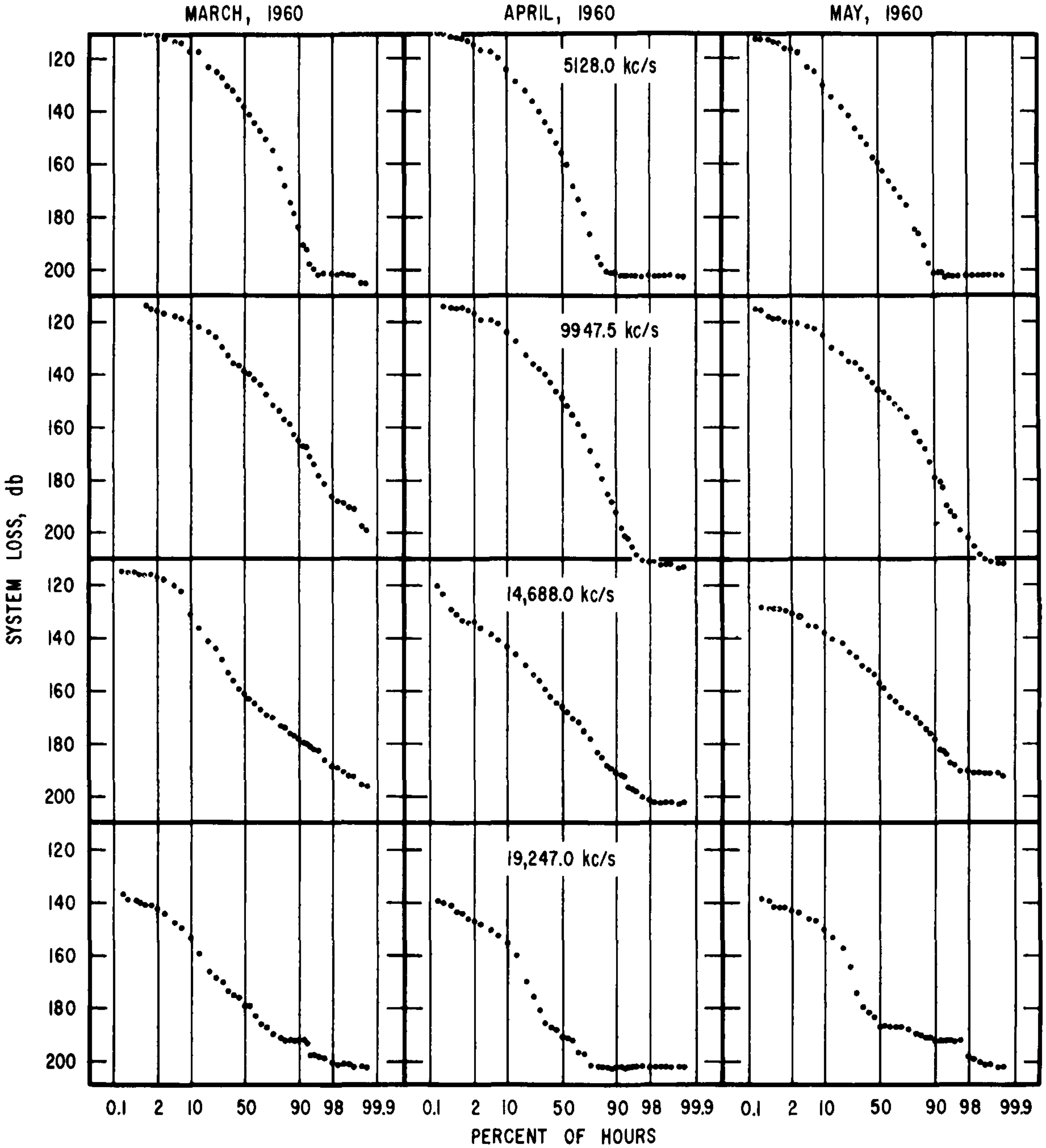


Figure 6b. Monthly Cumulative Distribution of System Loss for all Hours for Barrow-Kenai Path

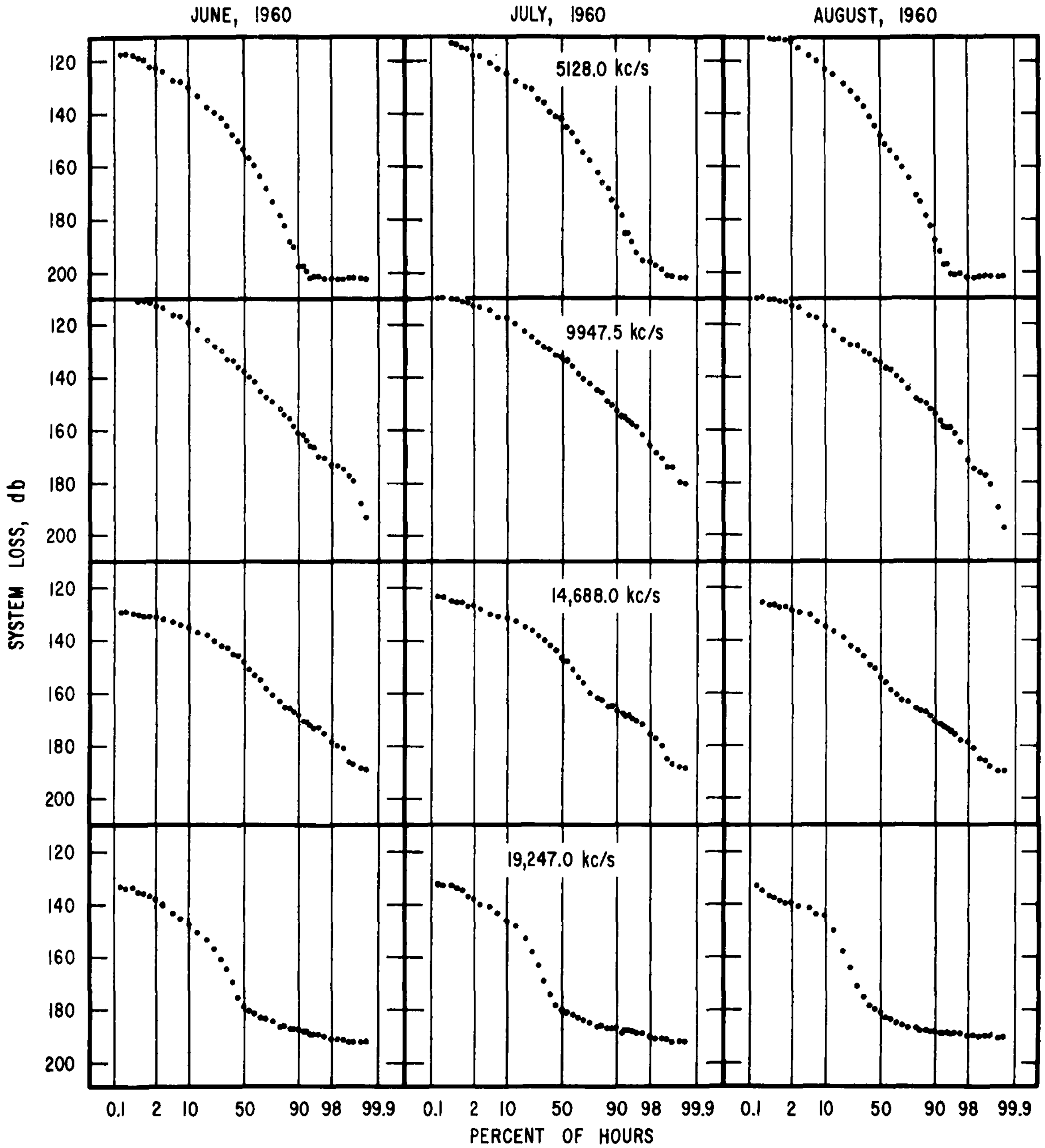


Figure 6c. Monthly Cumulative Distribution of System Loss for all Hours for Barrow-Kenai Path

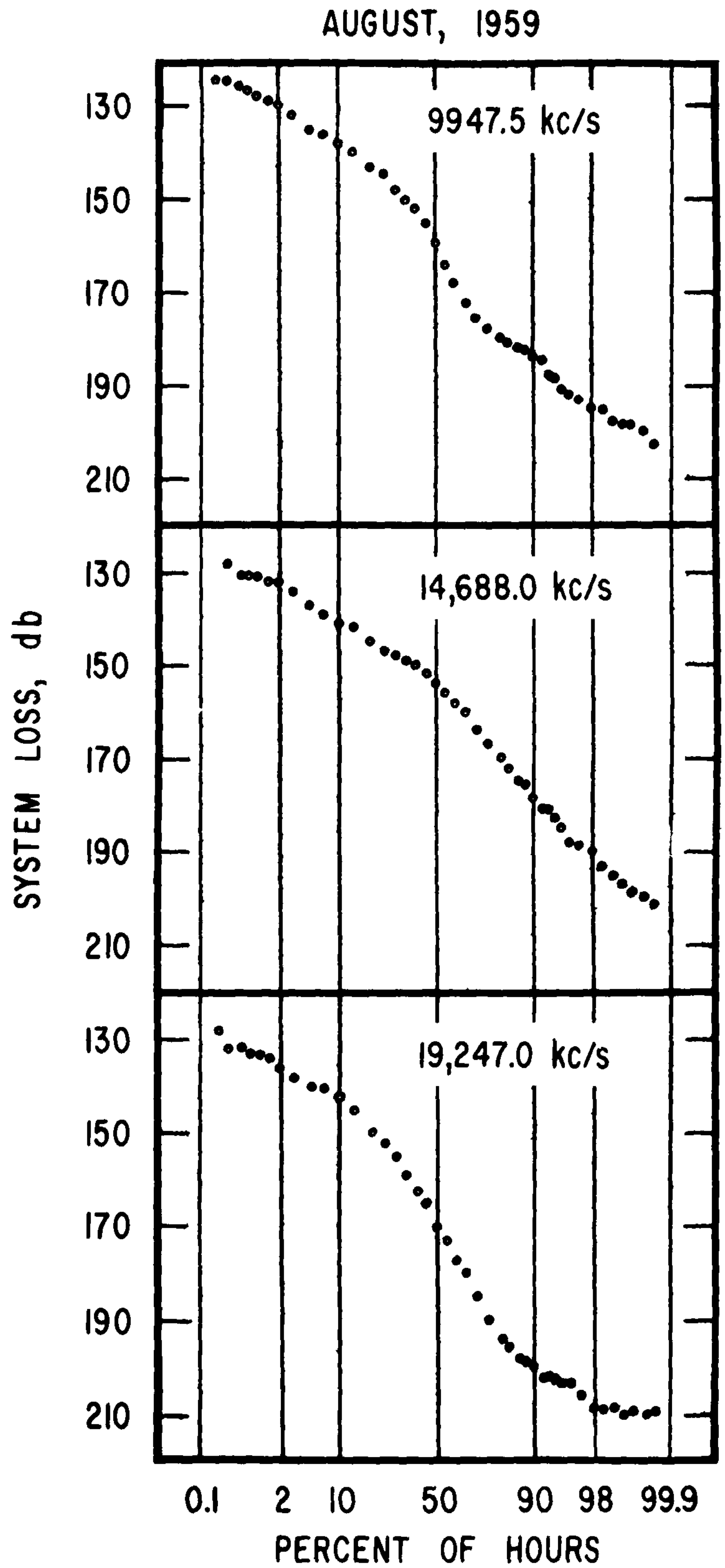


Figure 7a. Monthly Cumulative Distribution of System Loss for all Hours for Barrow-Boulder Path

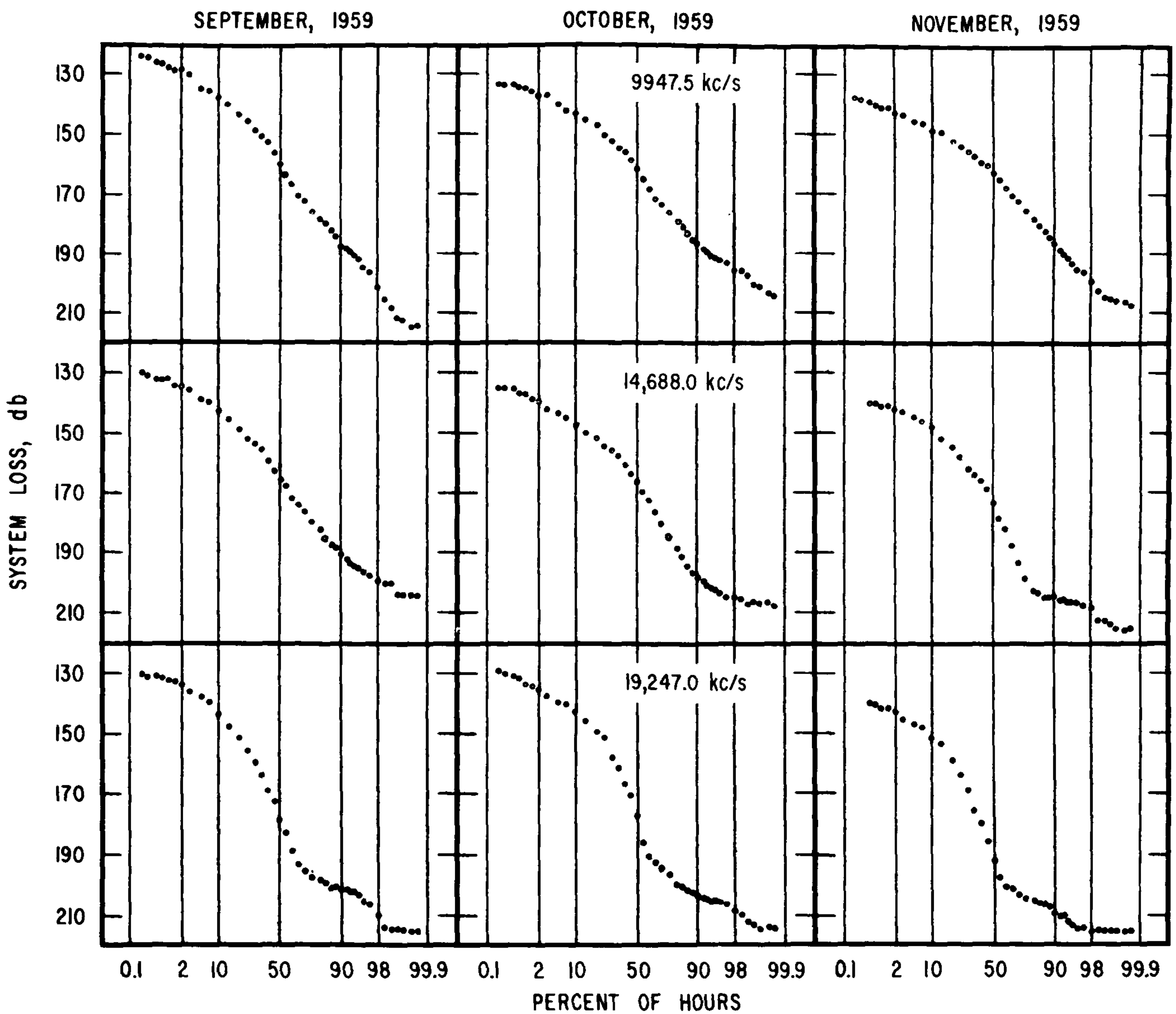


Figure 7b. Monthly Cumulative Distribution of System Loss for all Hours for Barrow-Boulder Path

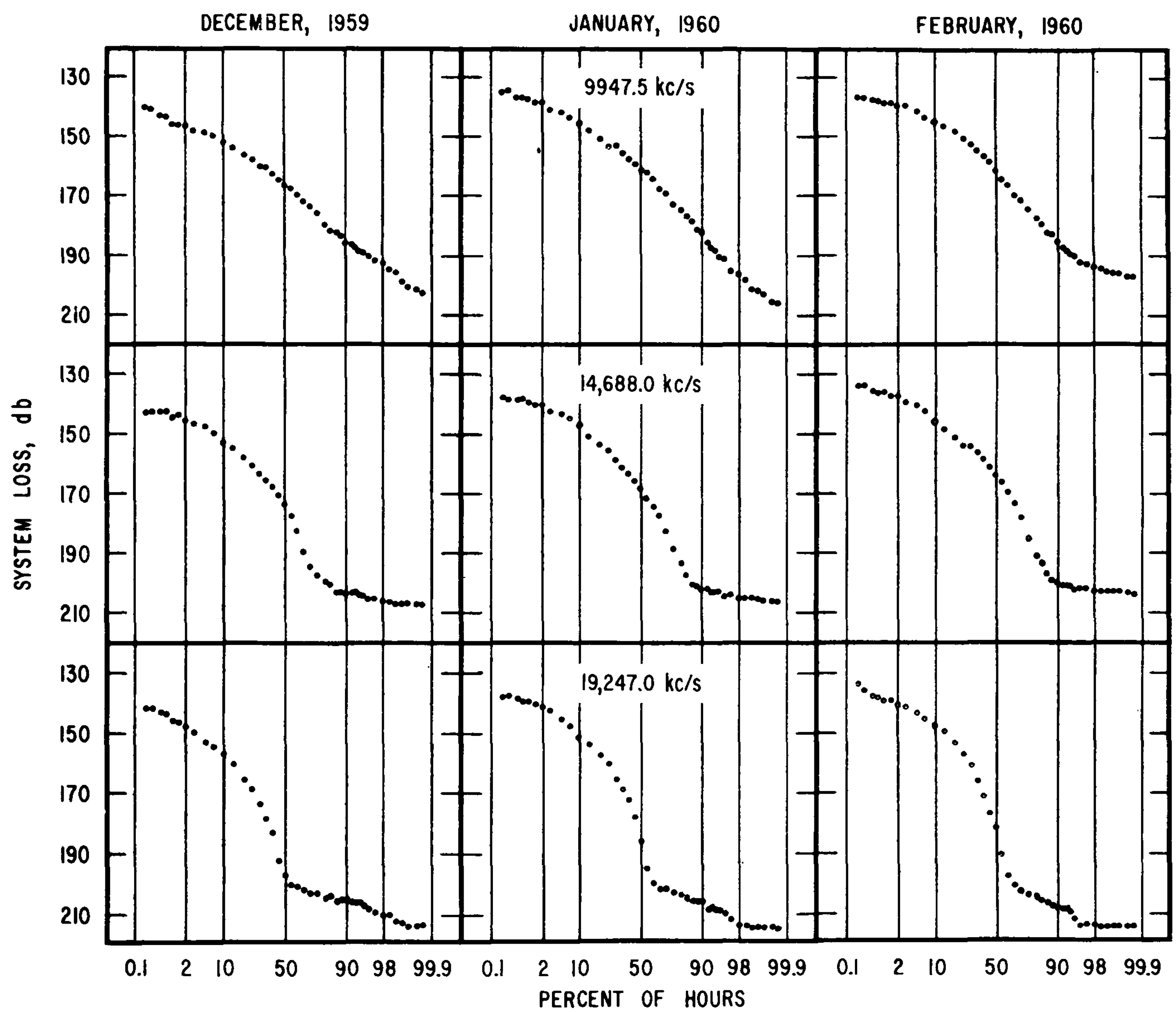


Figure 7c. Monthly Cumulative Distribution of System Loss for all Hours for Barrow-Boulder Path

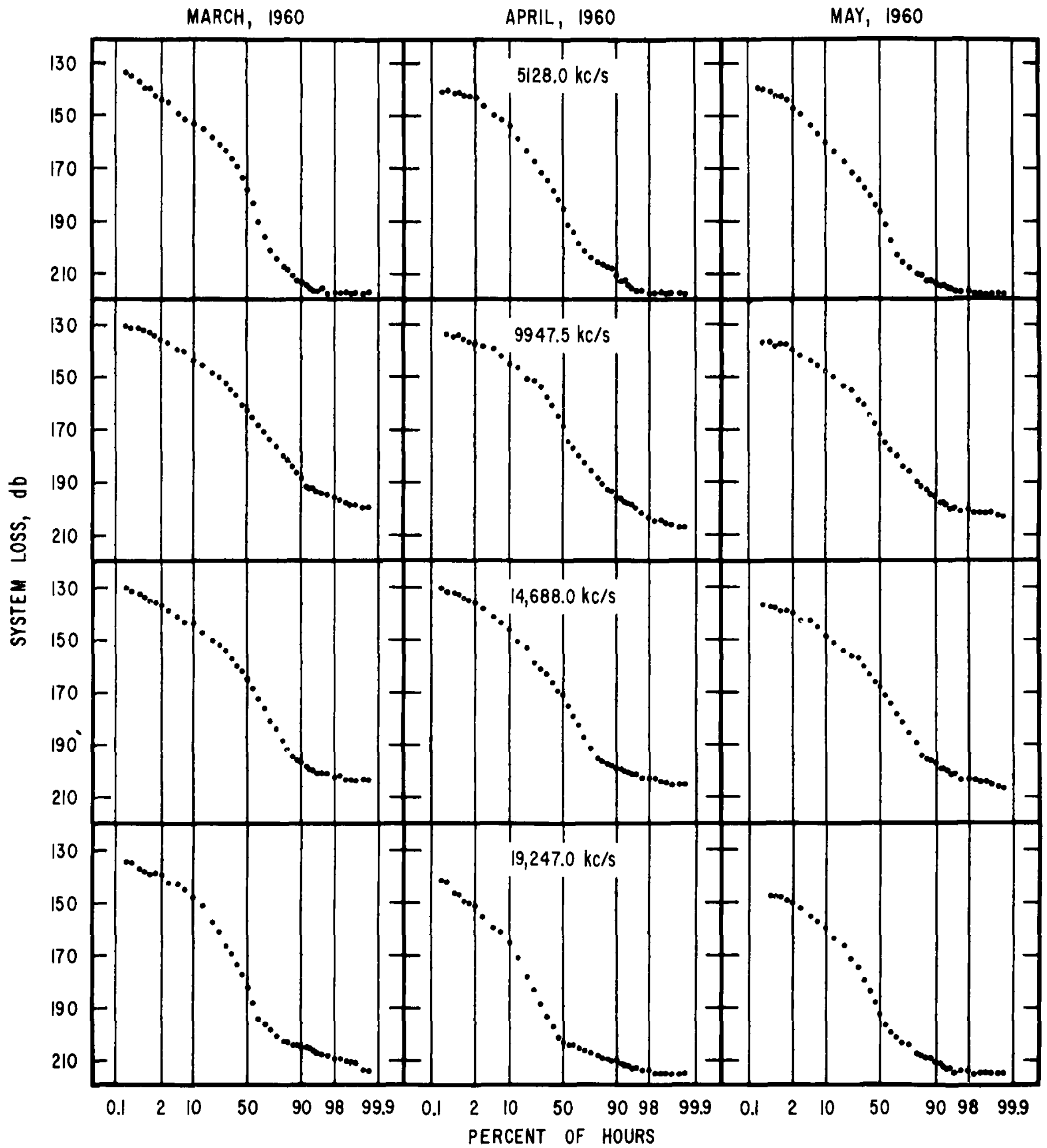


Figure 7d. Monthly Cumulative Distribution of System Loss for all Hours for Barrow-Boulder Path

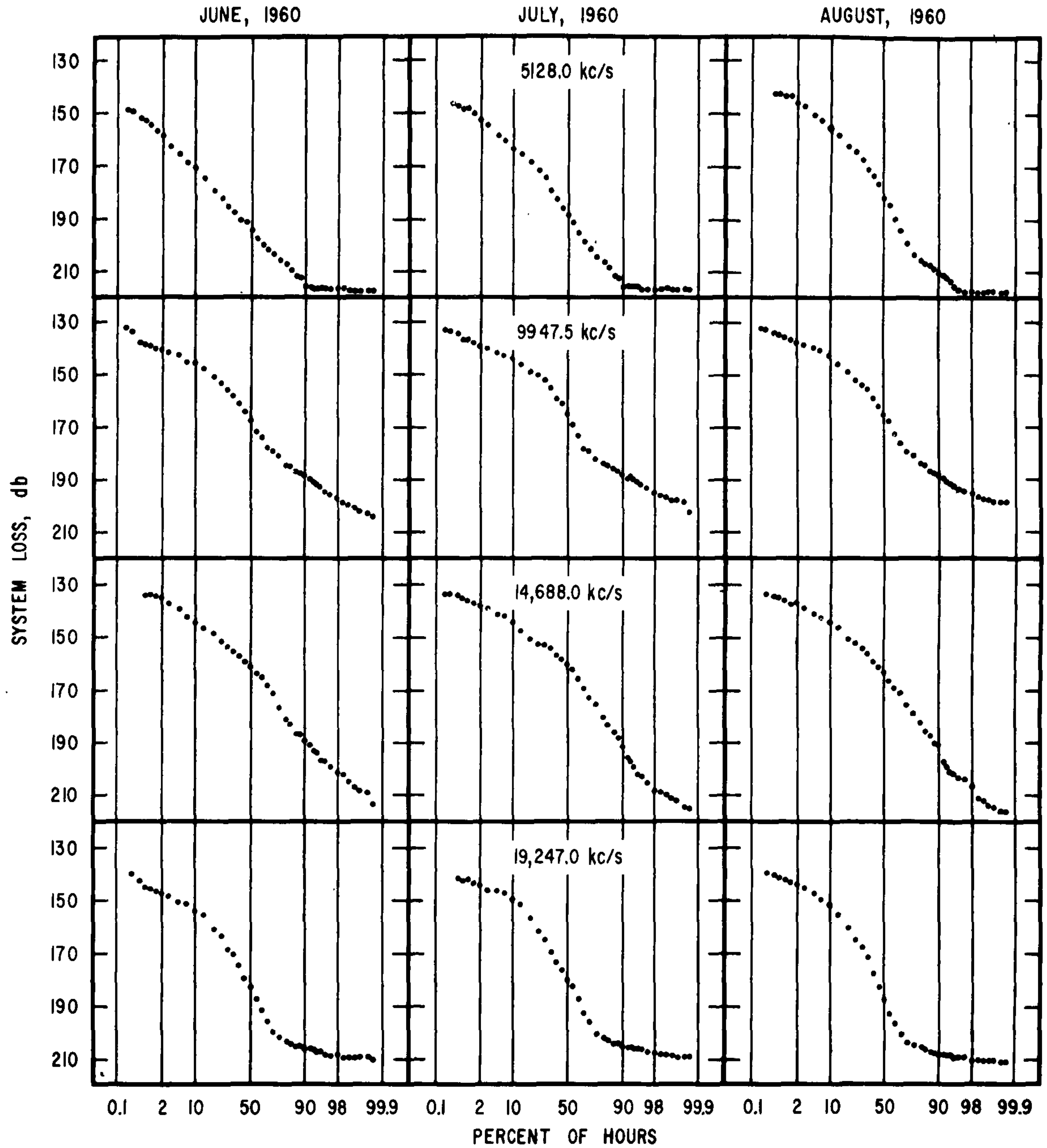


Figure 7e. Monthly Cumulative Distribution of System Loss for all Hours for Barrow-Boulder Path

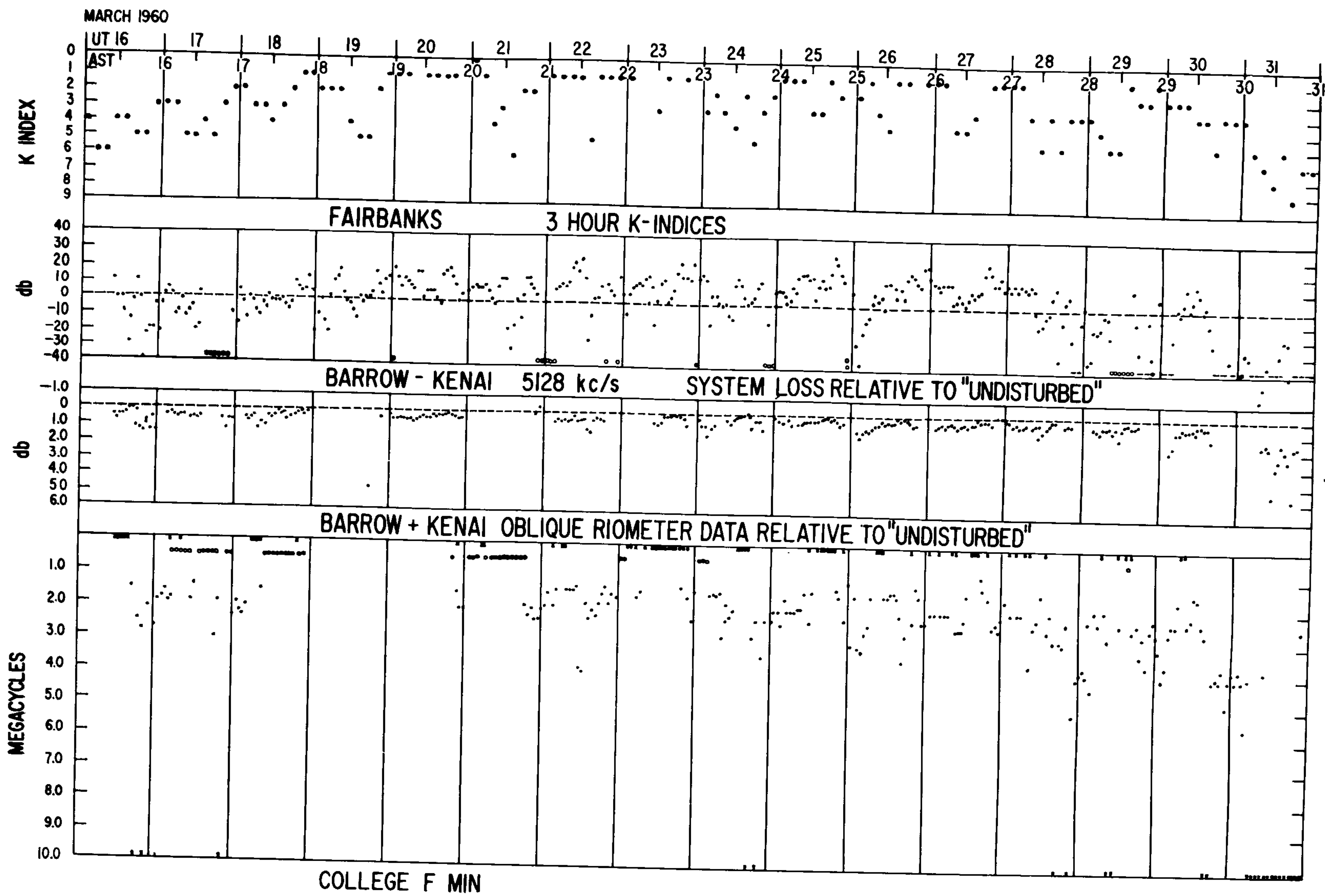


Figure 8a. Comparison of Barrow-Kenai 5 Mc/s Relative System Loss with other Geophysical Data 16 March - 15 April 1960

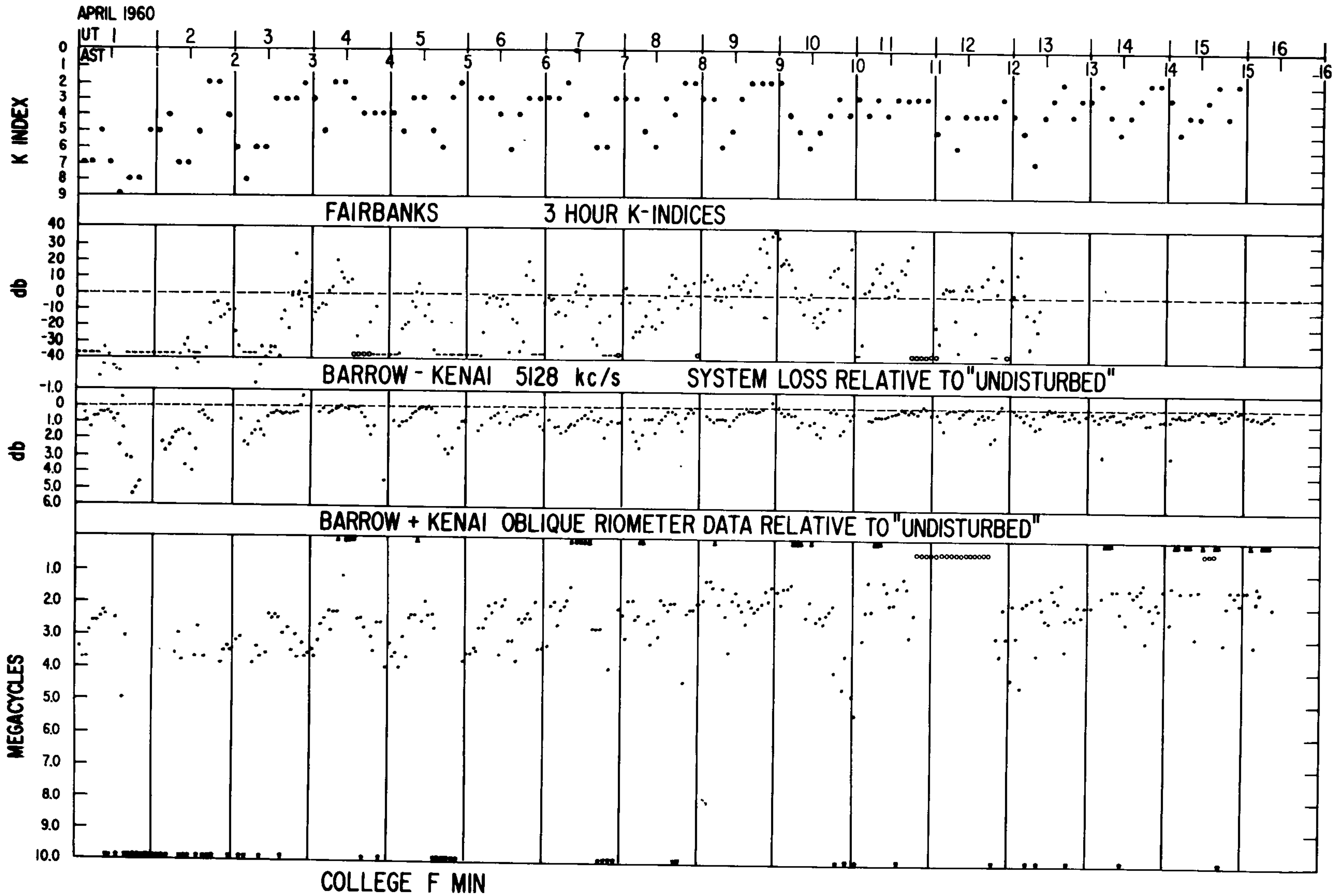


Figure 8b. Comparison of Barrow-Kenai 5 Mc/s Relative System Loss with other Geophysical Data 16 March - 15 April 1960

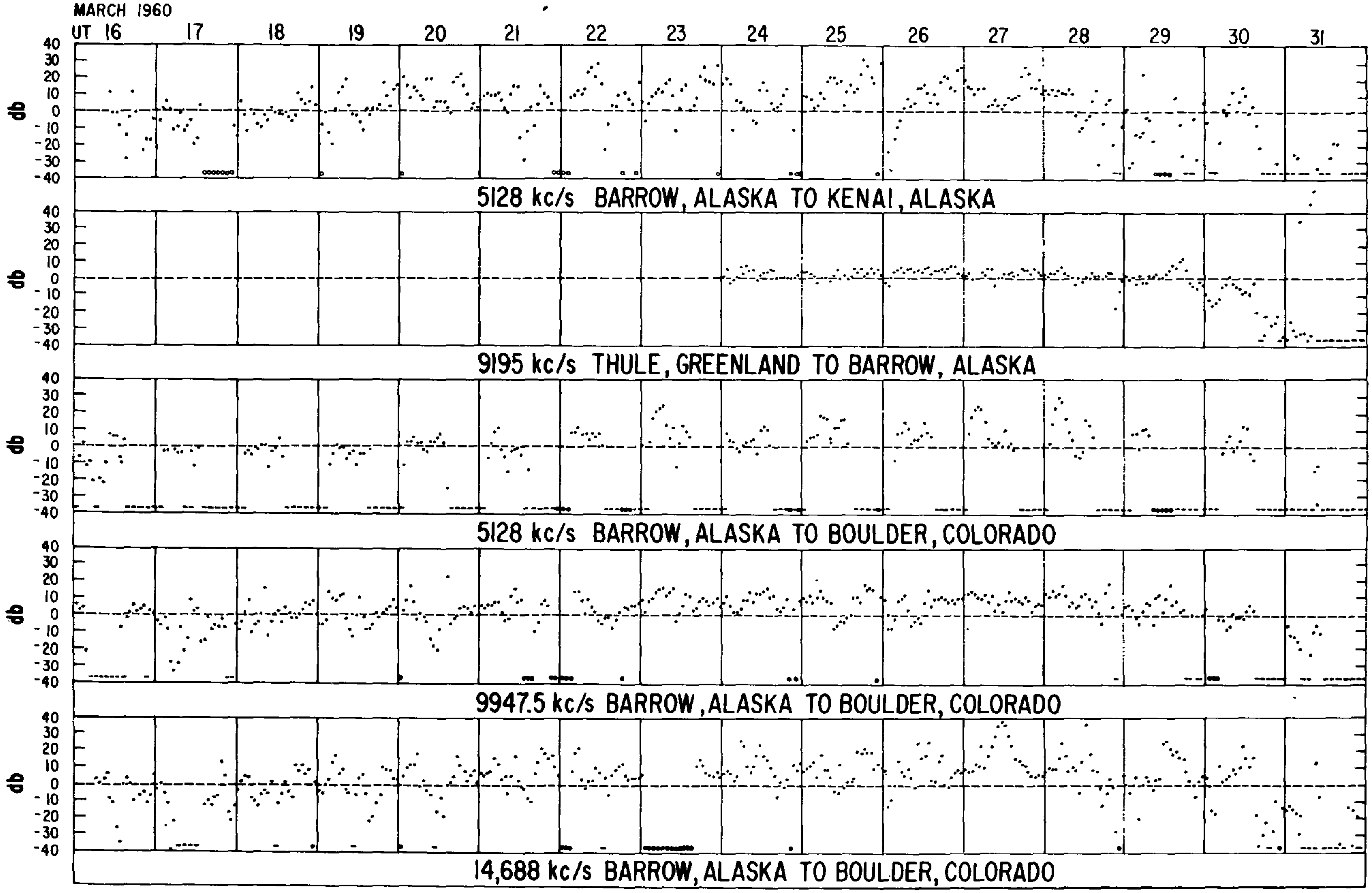


Figure 9a. Relative Behavior of Several Signals
16 March - 31 March 1960

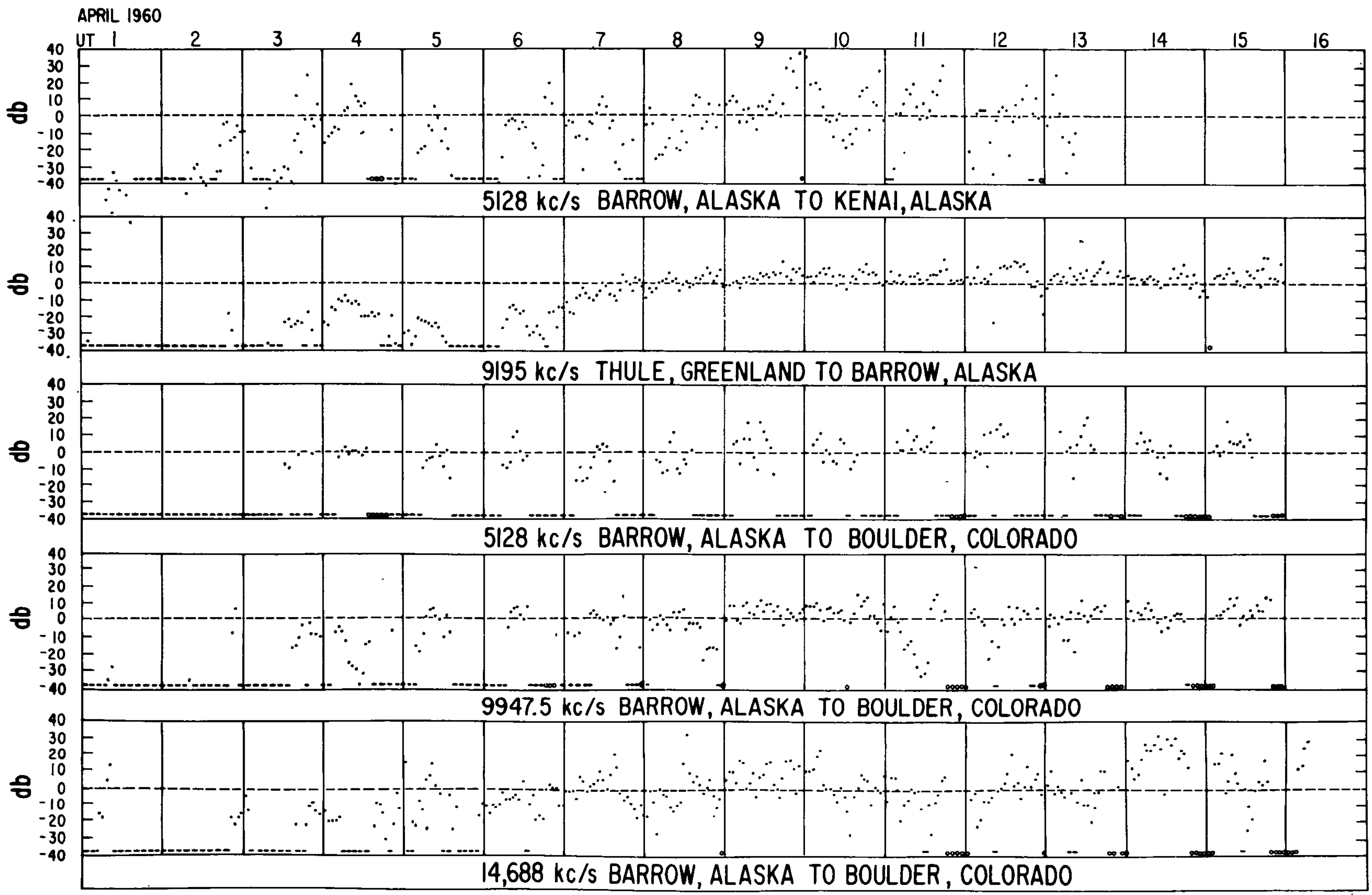


Figure 9b. Relative Behavior of Several Signals
1 April - 15 April 1960

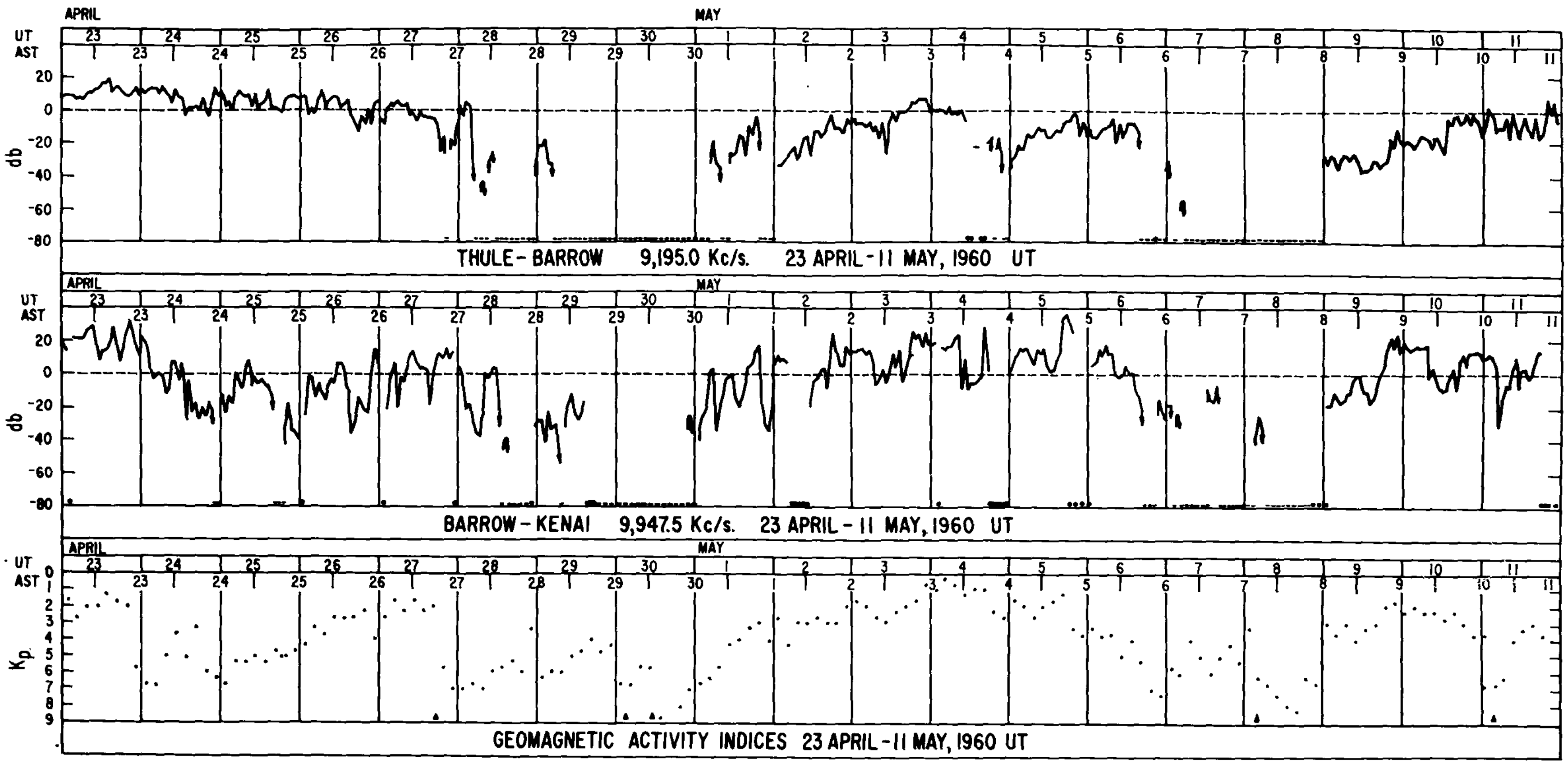


Figure 10. Effect of 23 April - 11 May 1960 Disturbances

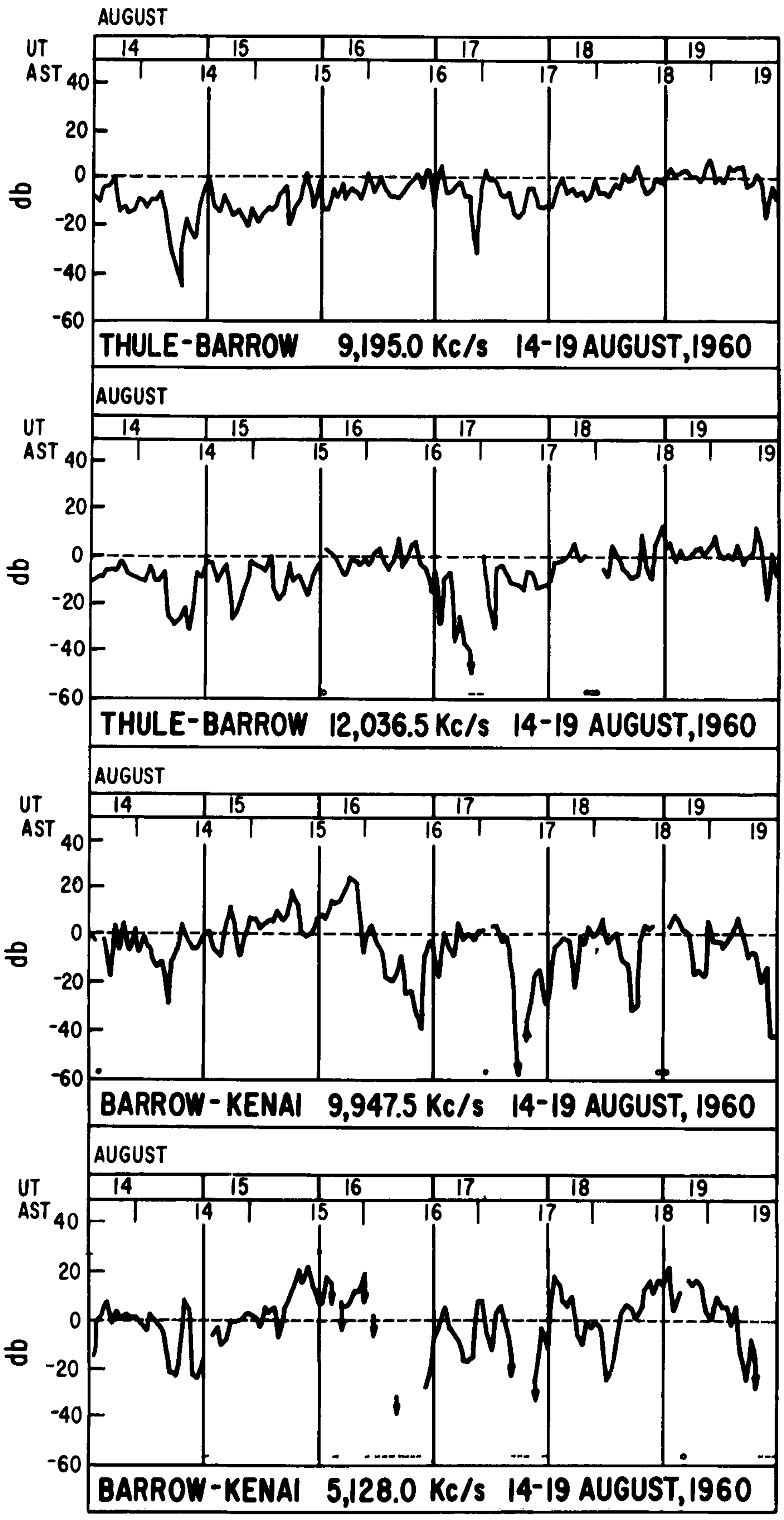


Figure 11a. Effect of 14-19 August 1960 Disturbances

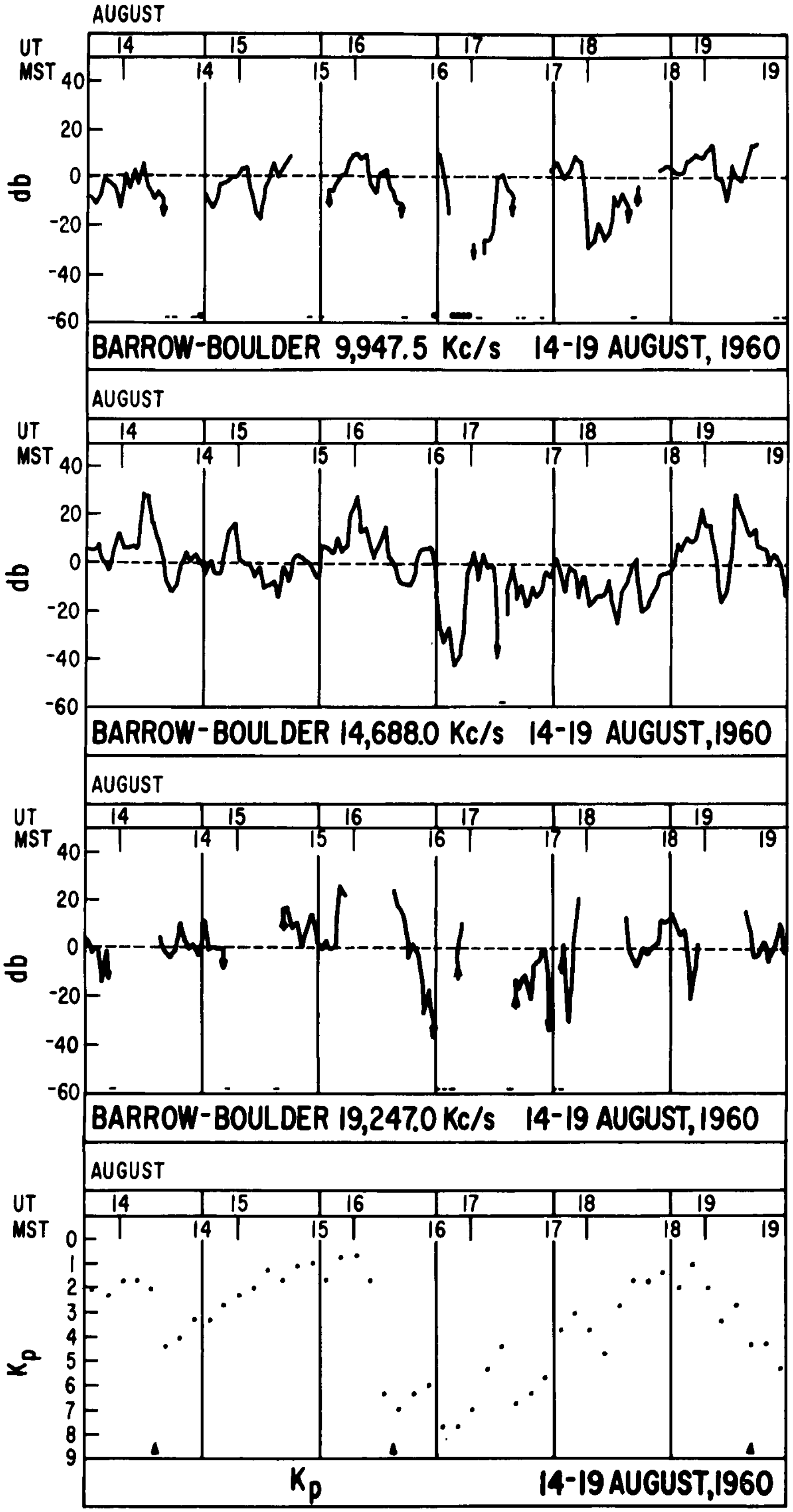


Figure 11b. Effect of 14-19 August 1960 Disturbances

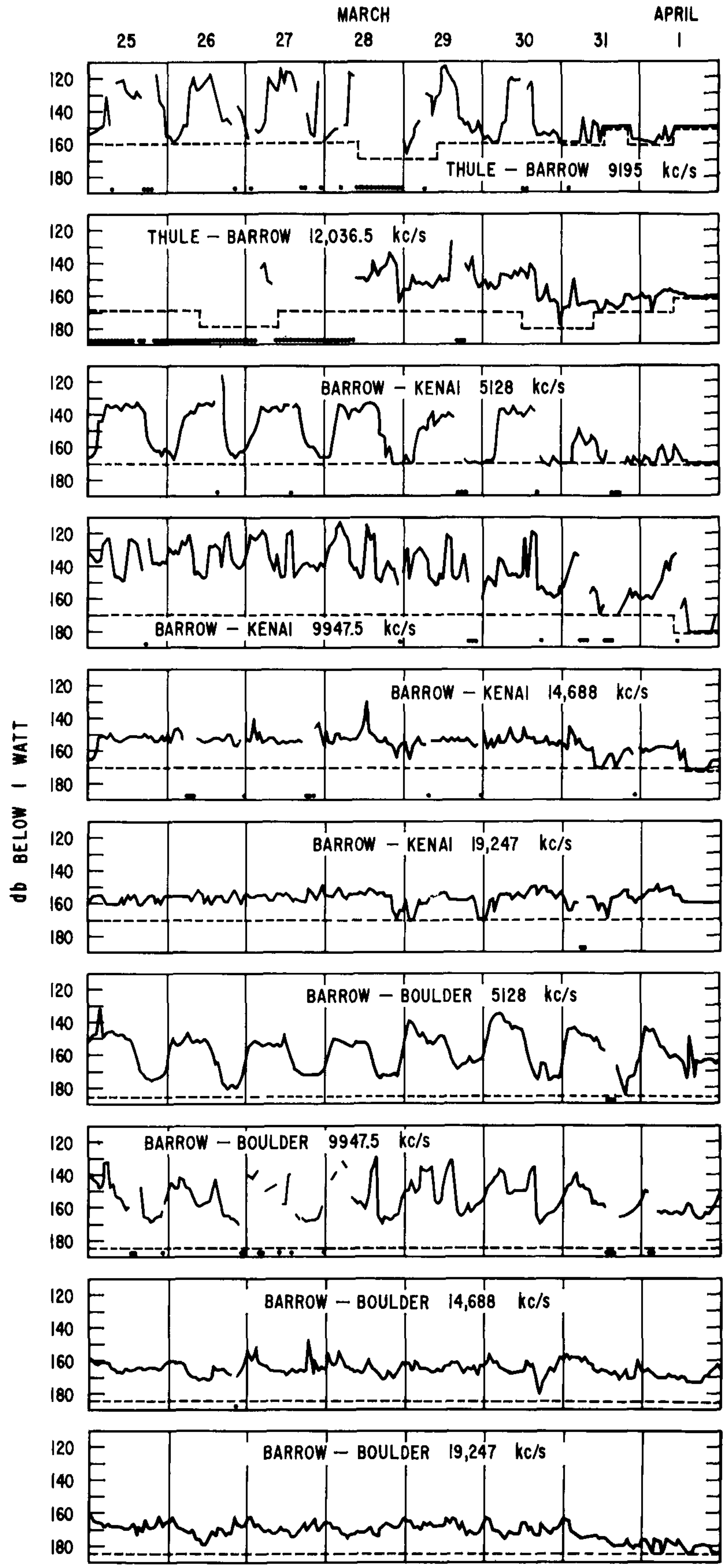


Figure 12a. Noise Levels 25 March - 10 April 1960

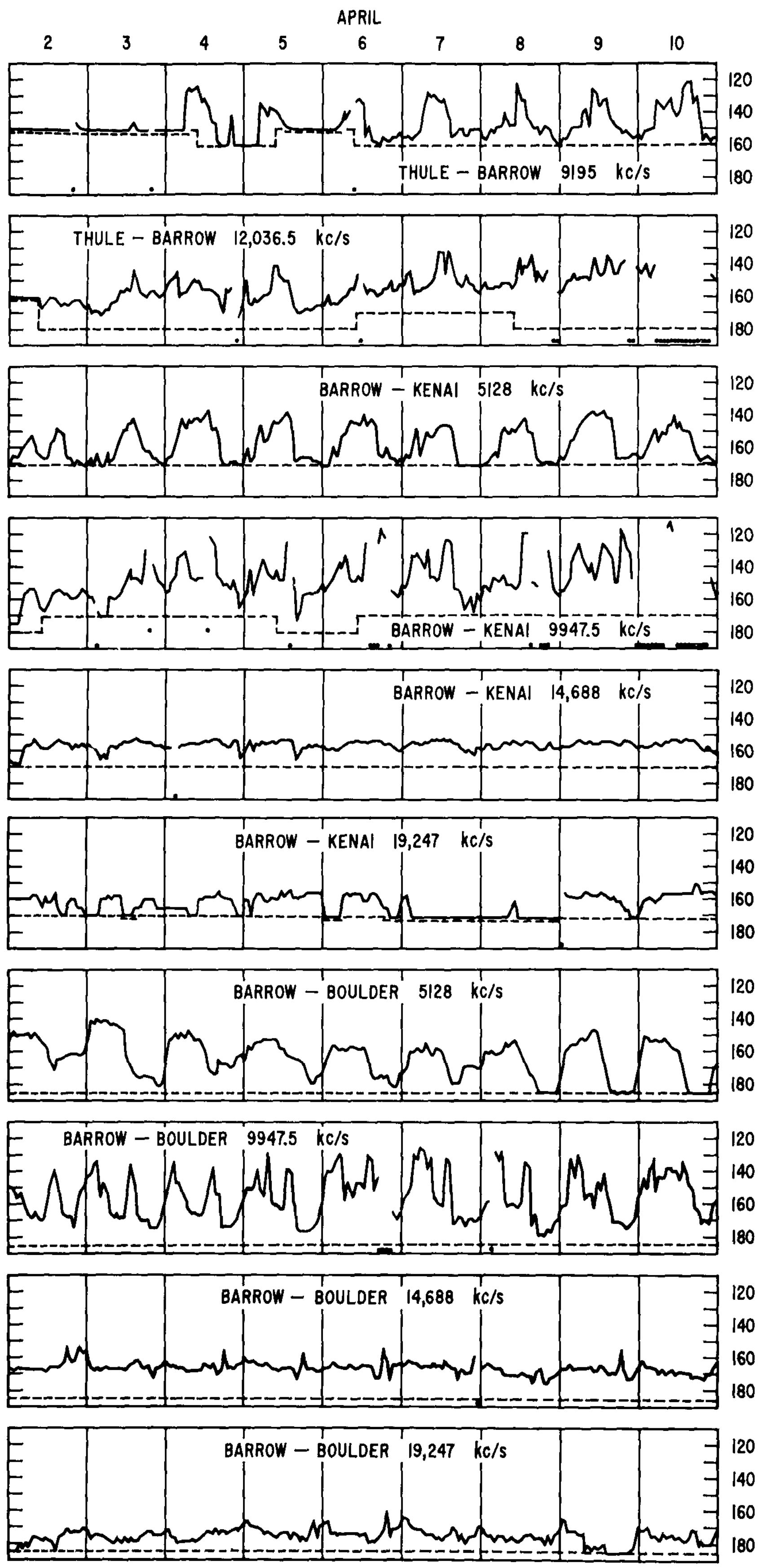


Figure 12b. Noise Levels 25 March - 10 April 1960

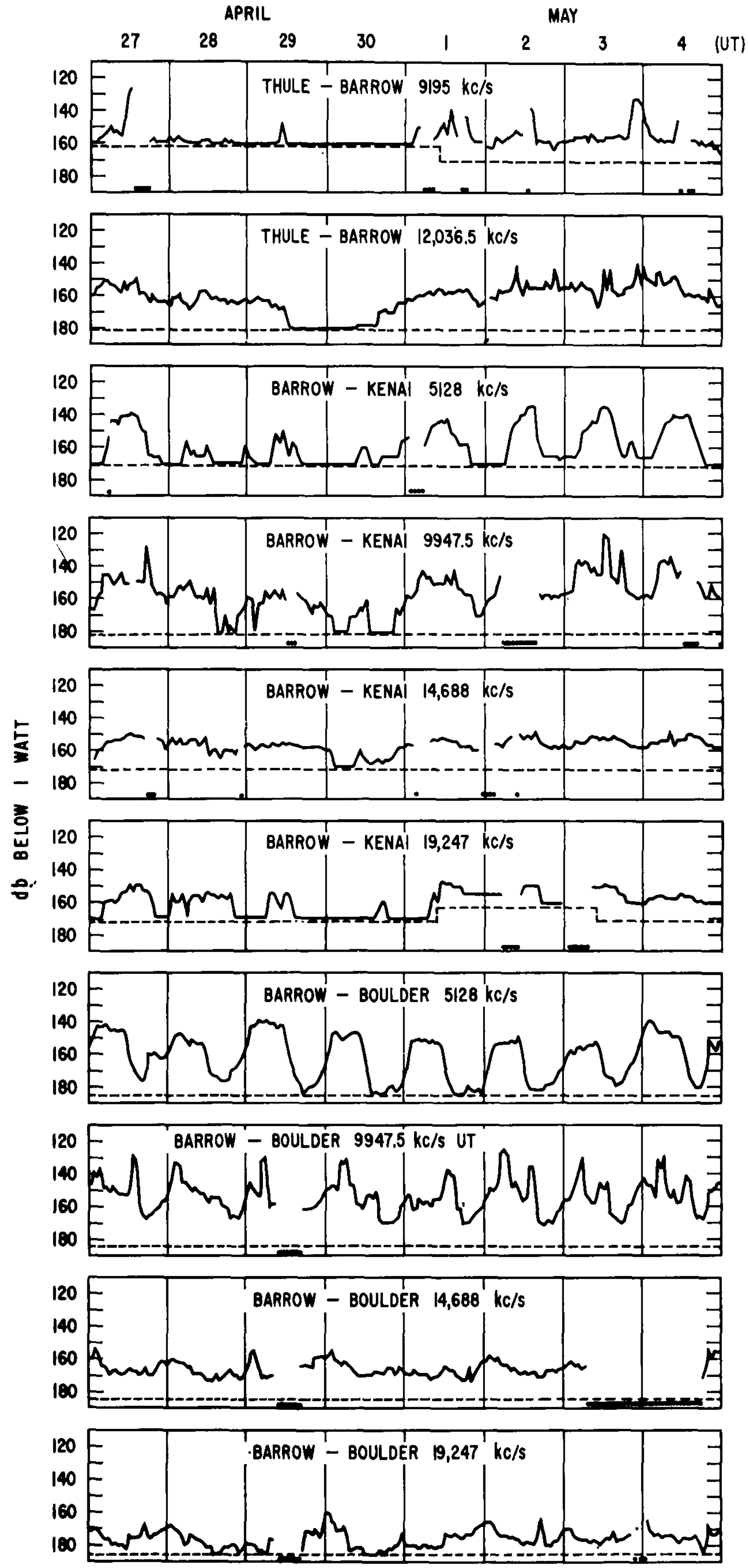


Figure 13a. Noise Levels 27 April - 11 May 1960

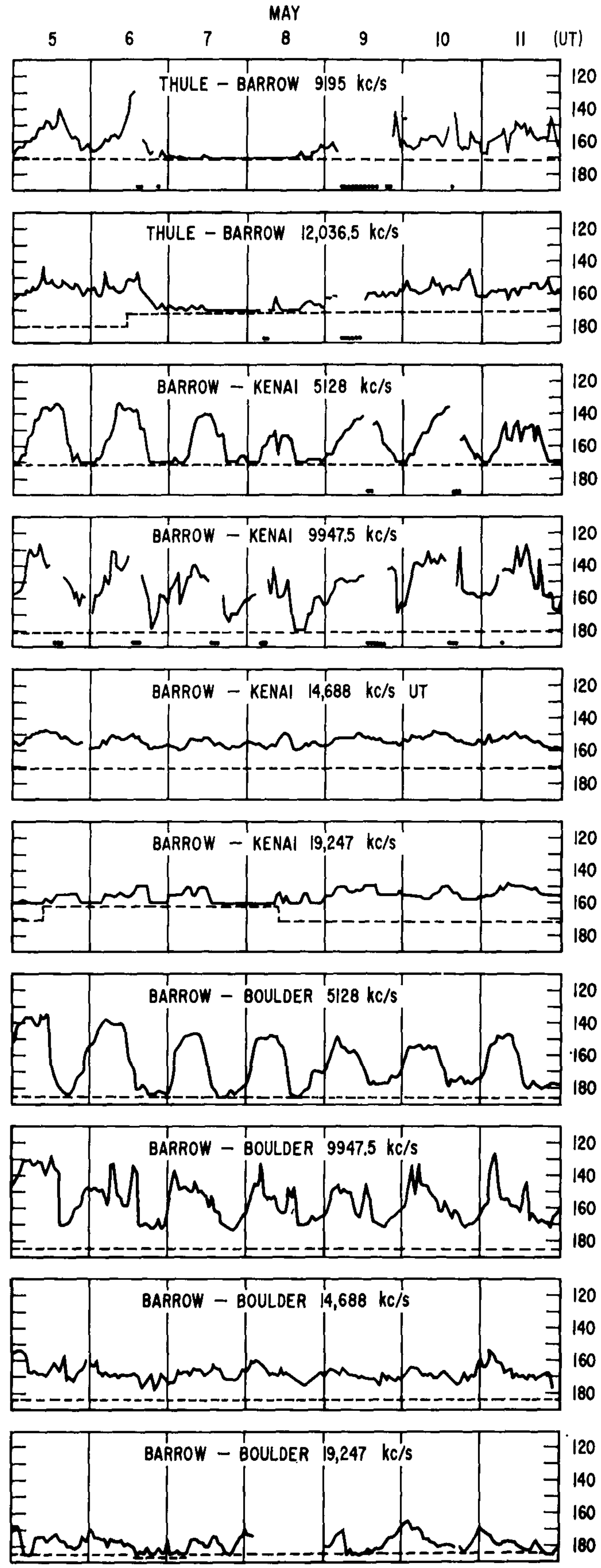


Figure 13b. Noise Levels 27 April - 11 May 1960

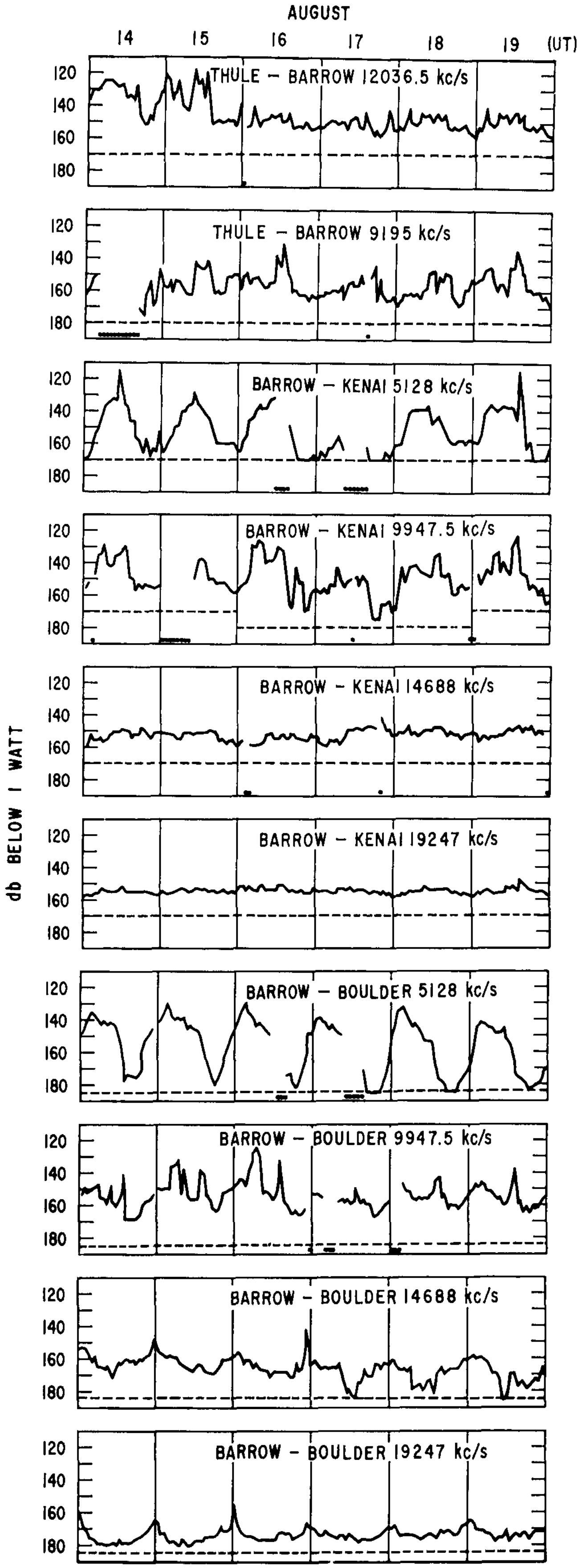


Figure 14. Noise Levels 14 - 19 August 1960

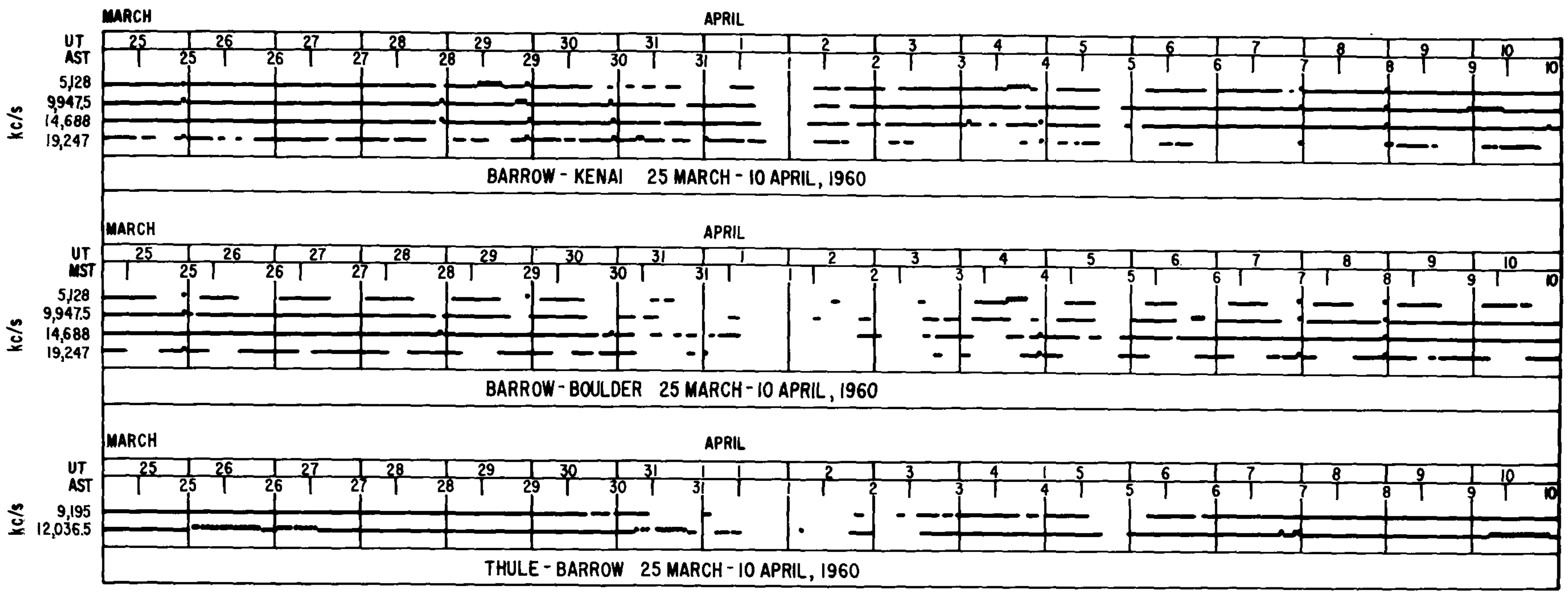


Figure 15. Frequency Usage, March-April Period

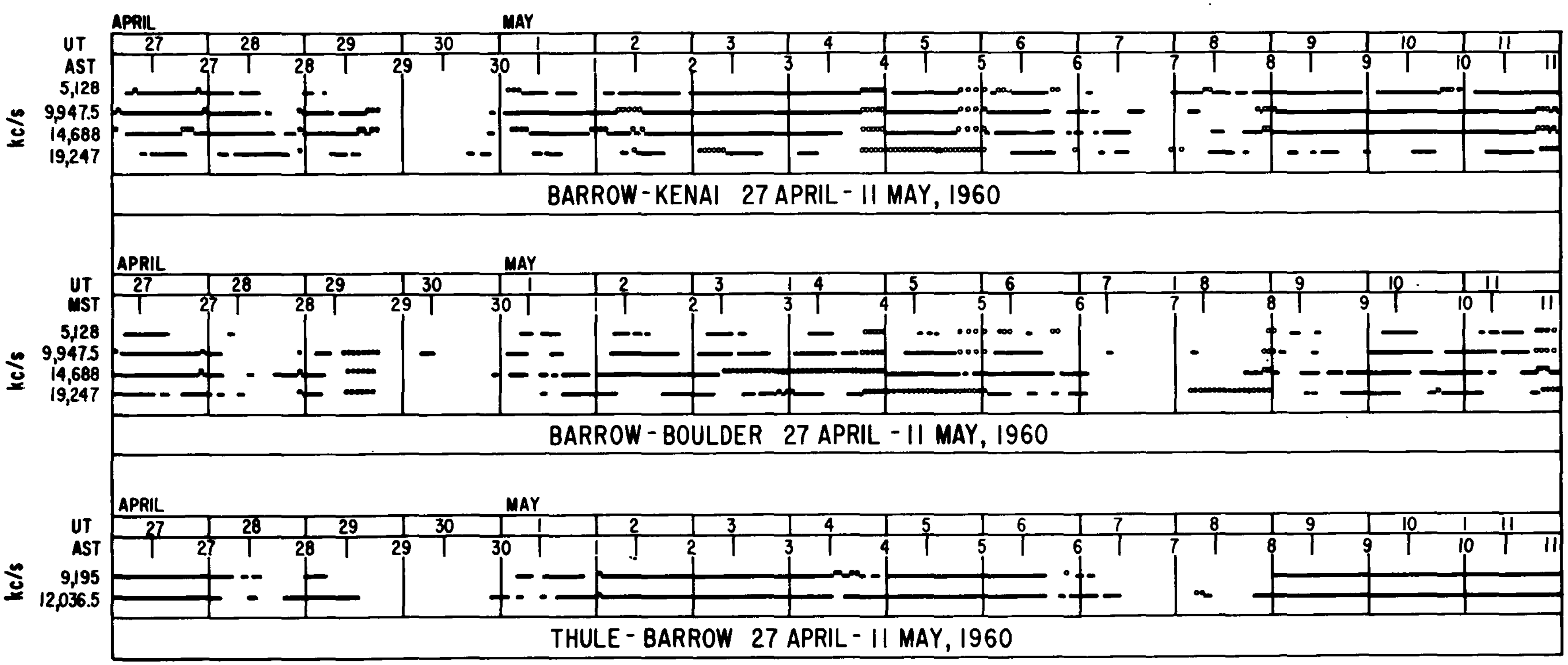


Figure 16. Frequency Usage April-May Period

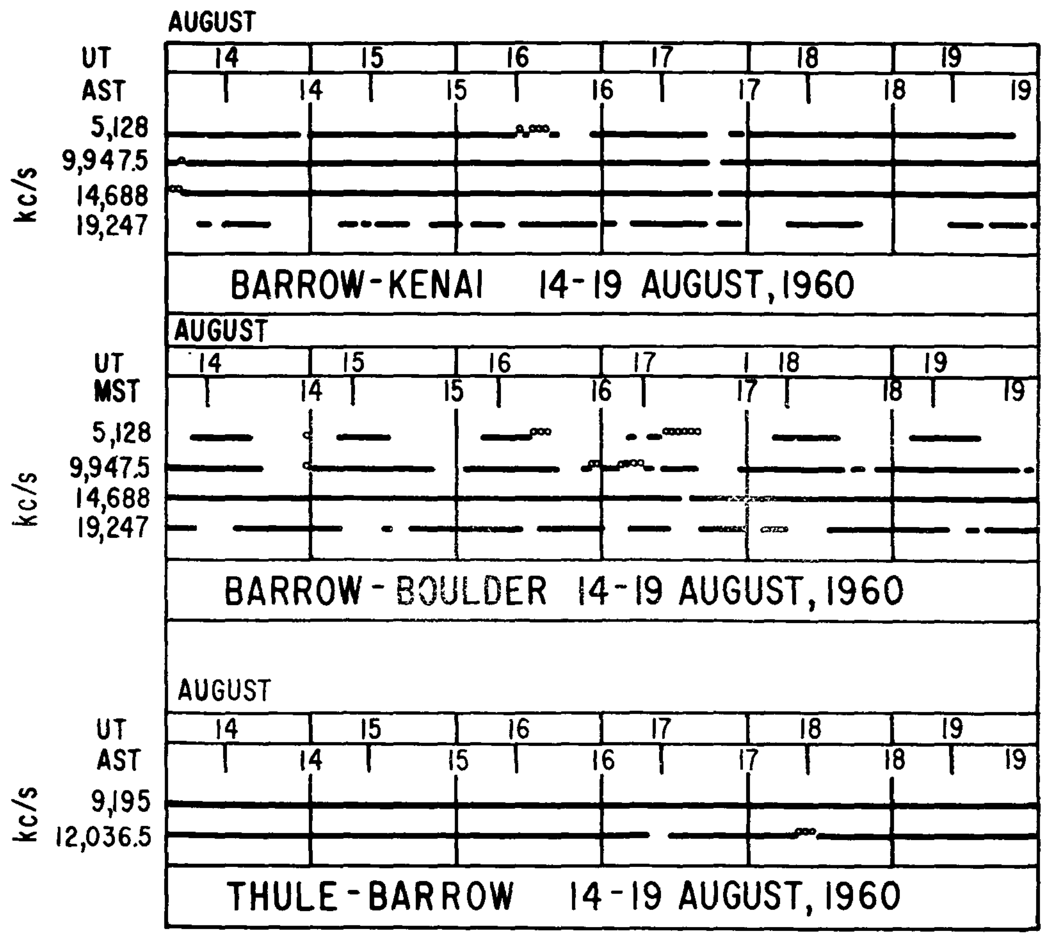


Figure 17. Frequency Usage, Mid-August Period

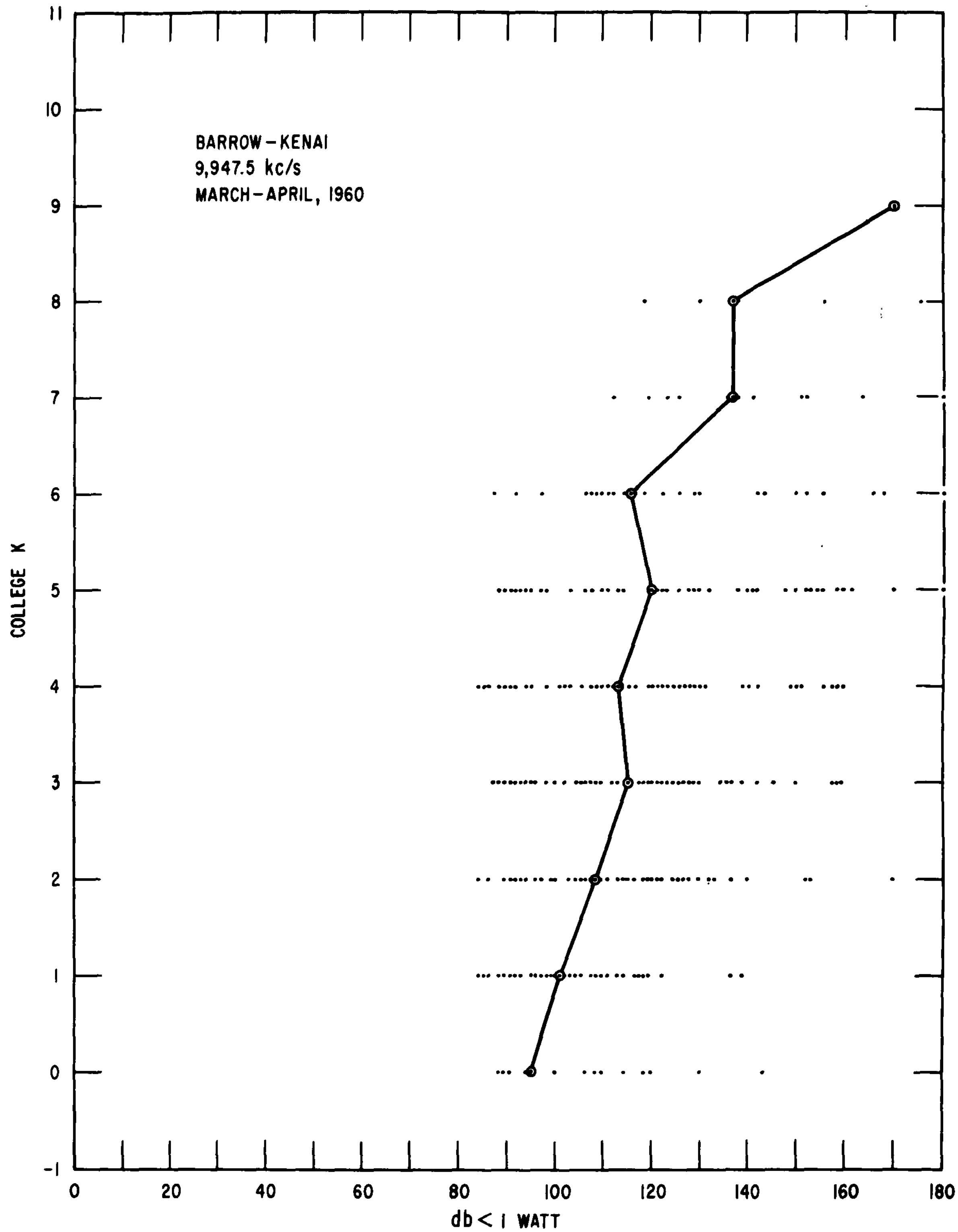


Figure 18. Local Geomagnetic K vs. Available Signal Power

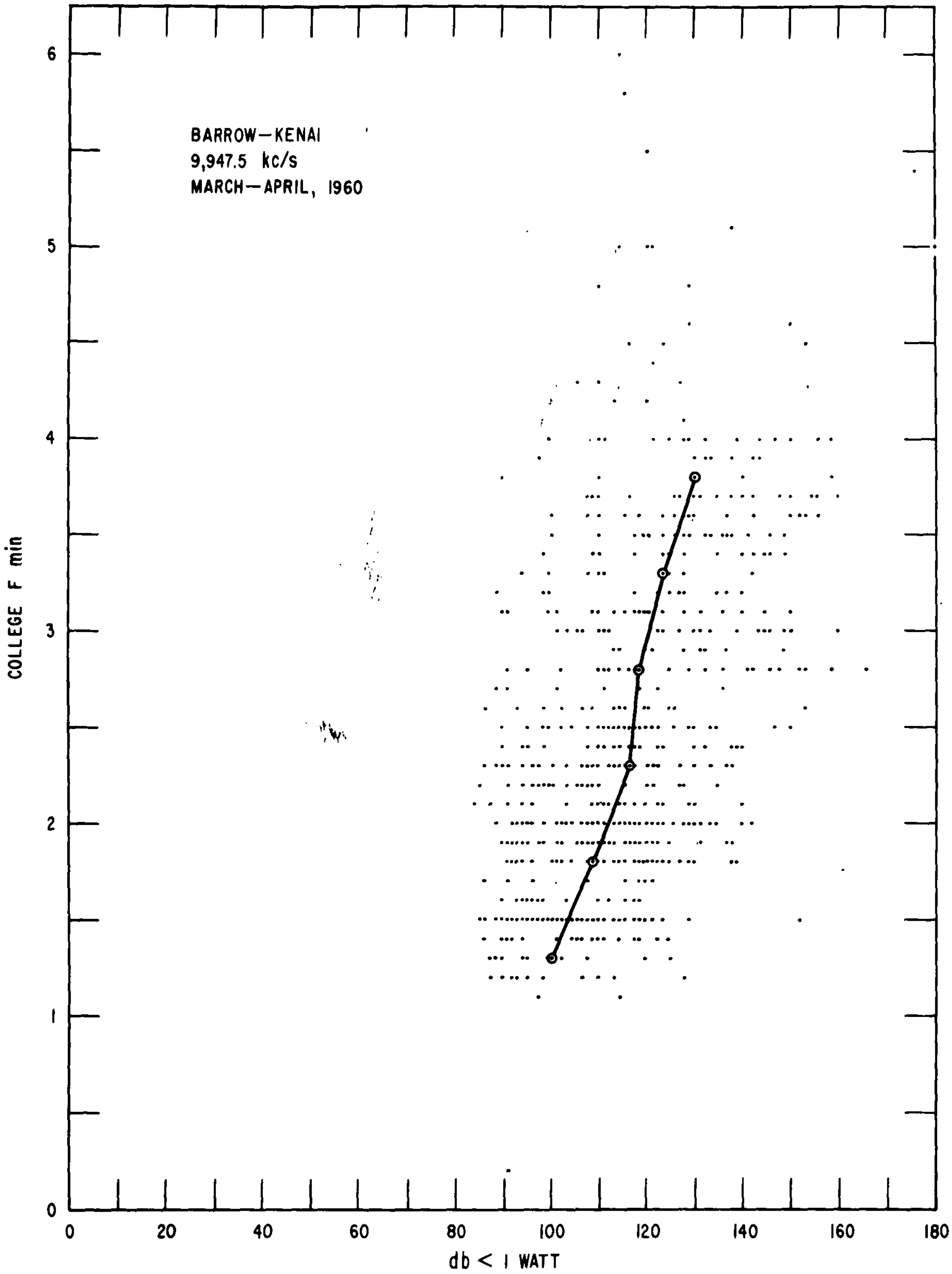


Figure 19. Local F min vs. Available Signal Power

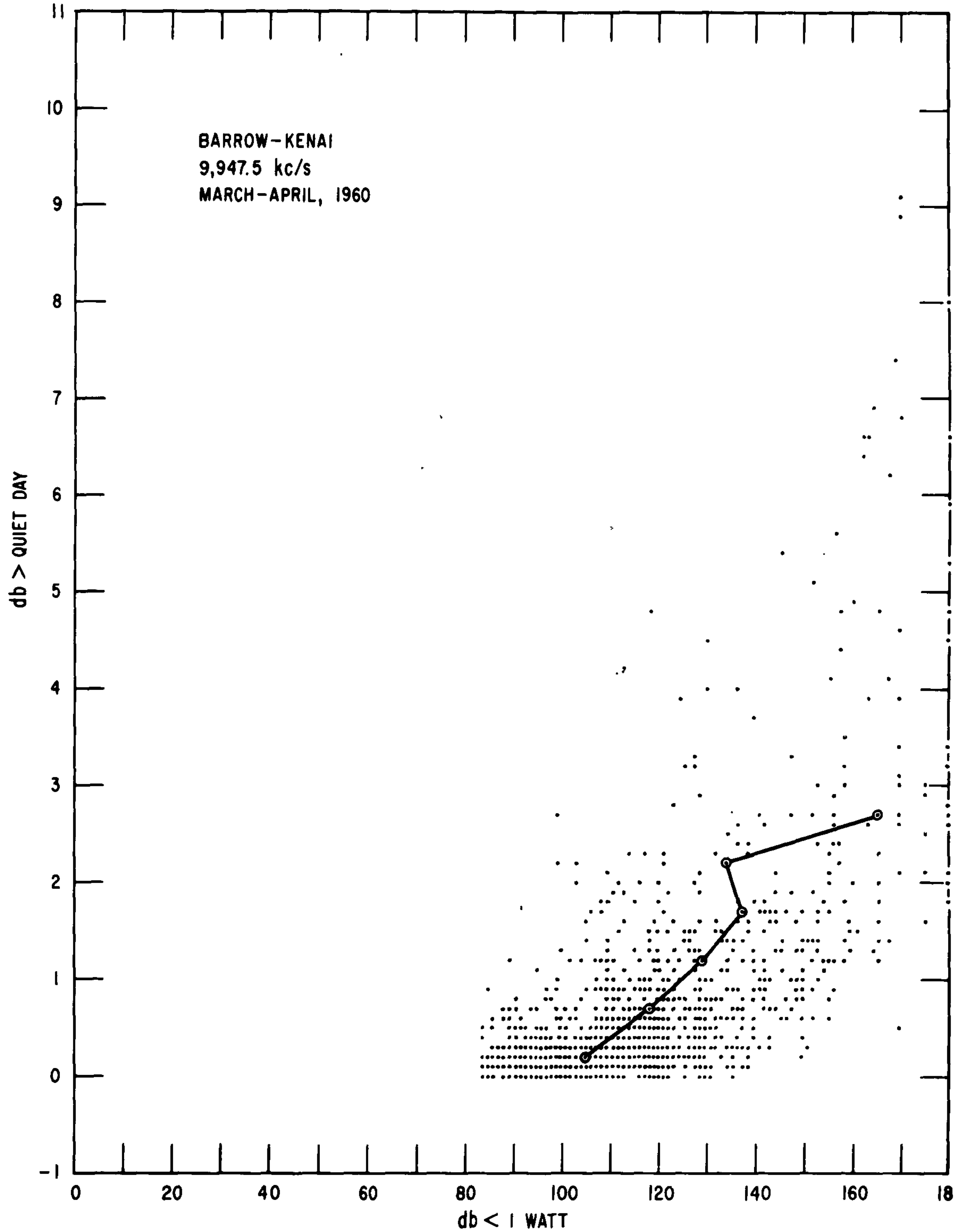


Figure 20. Vertical-Incidence Riometer Data vs. Available Signal Power

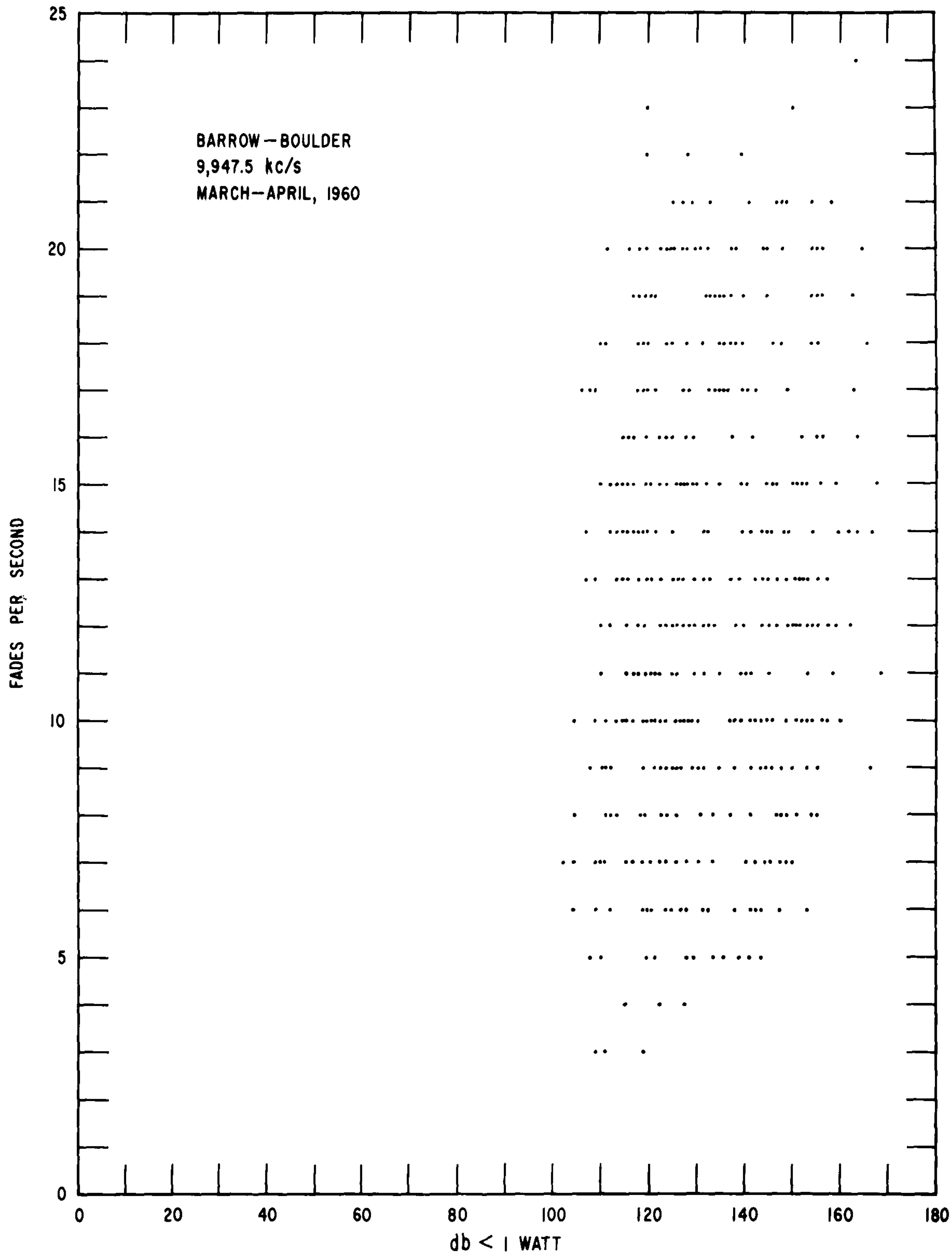


Figure 21. Fade Rates vs. Available Signal Power

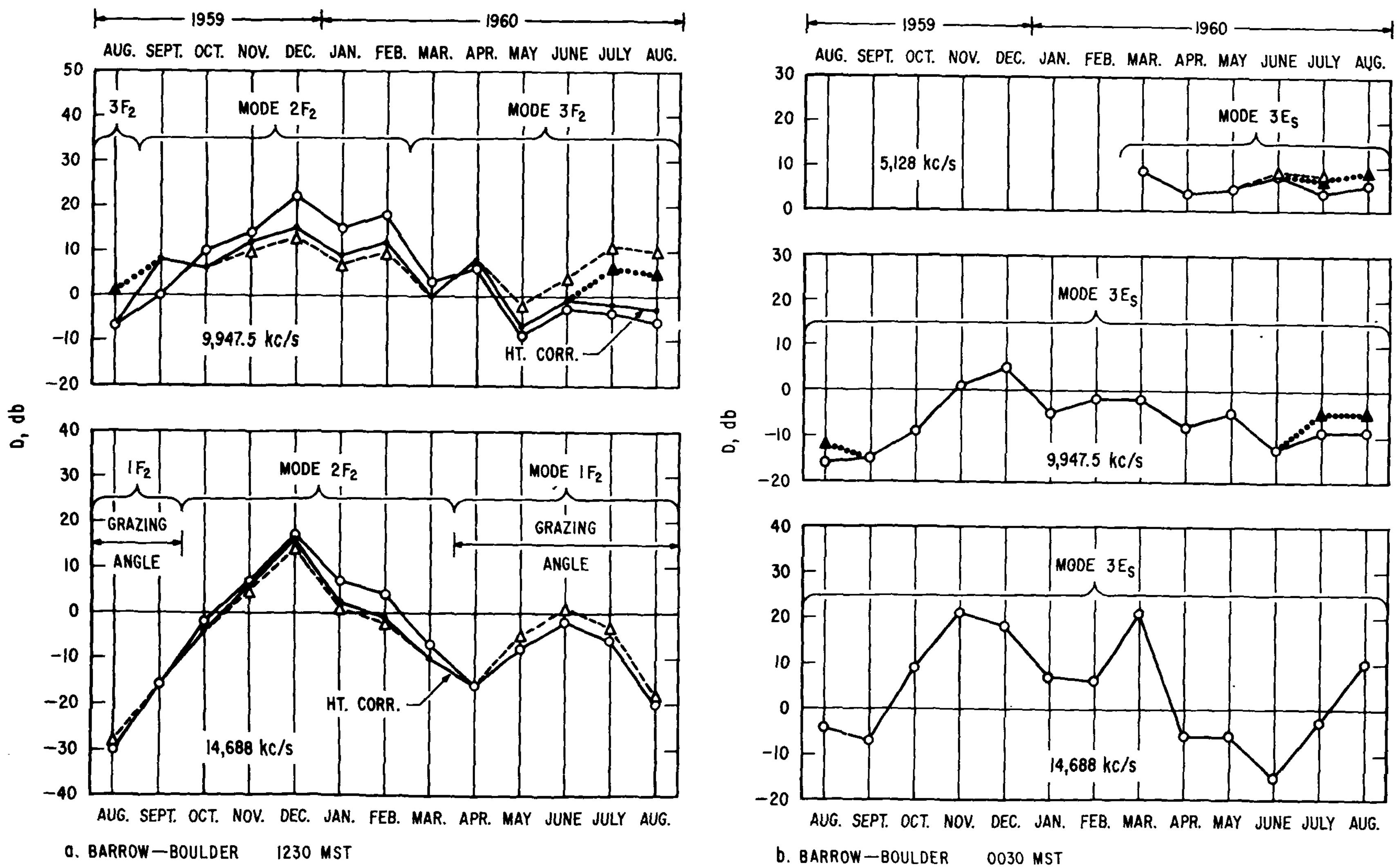


Figure 22. Increment D to be added to Absorption Prediction for Observed "Undisturbed" Value

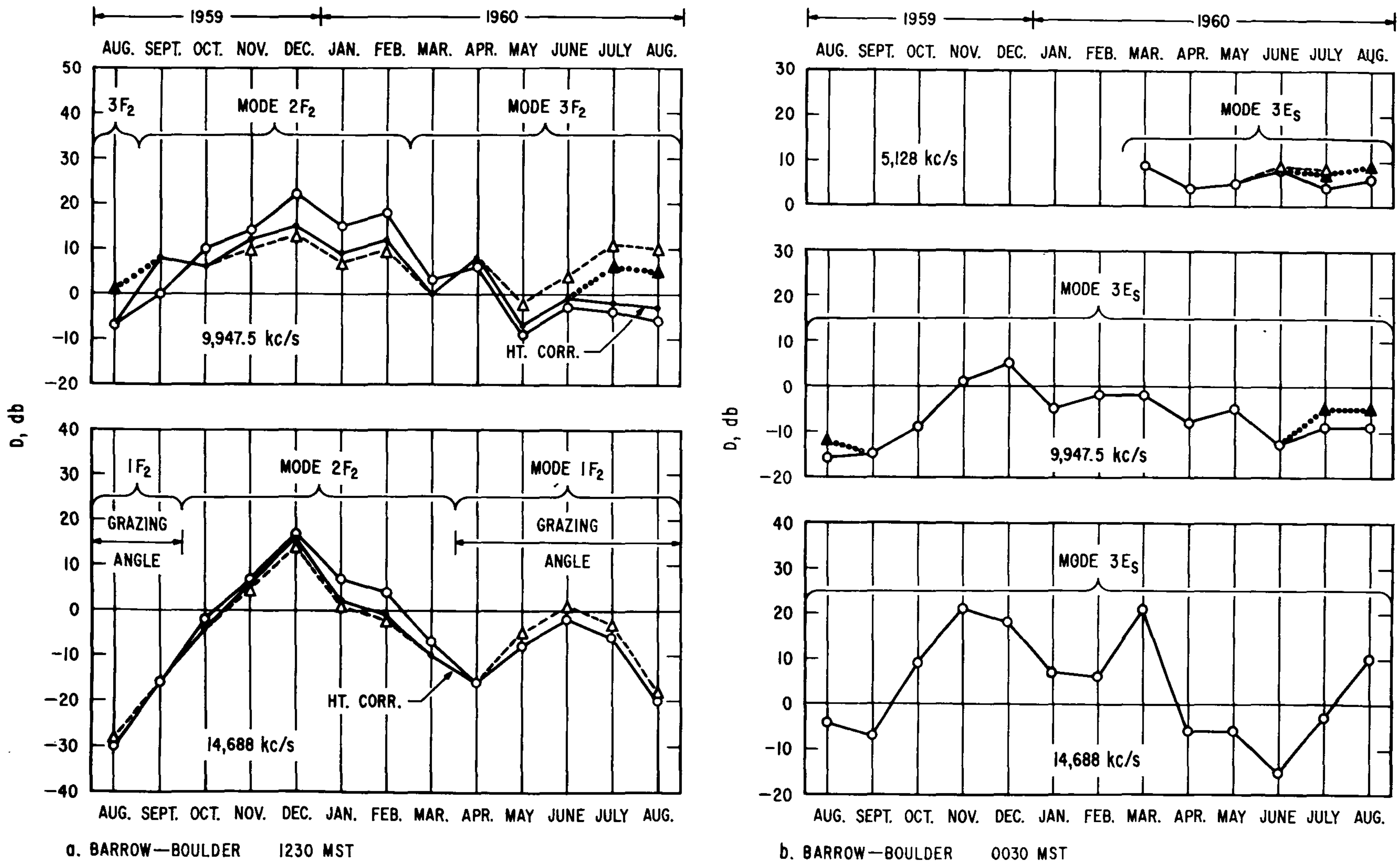


Figure 22. Increment D to be added to Absorption Prediction for Observed "Undisturbed" Value

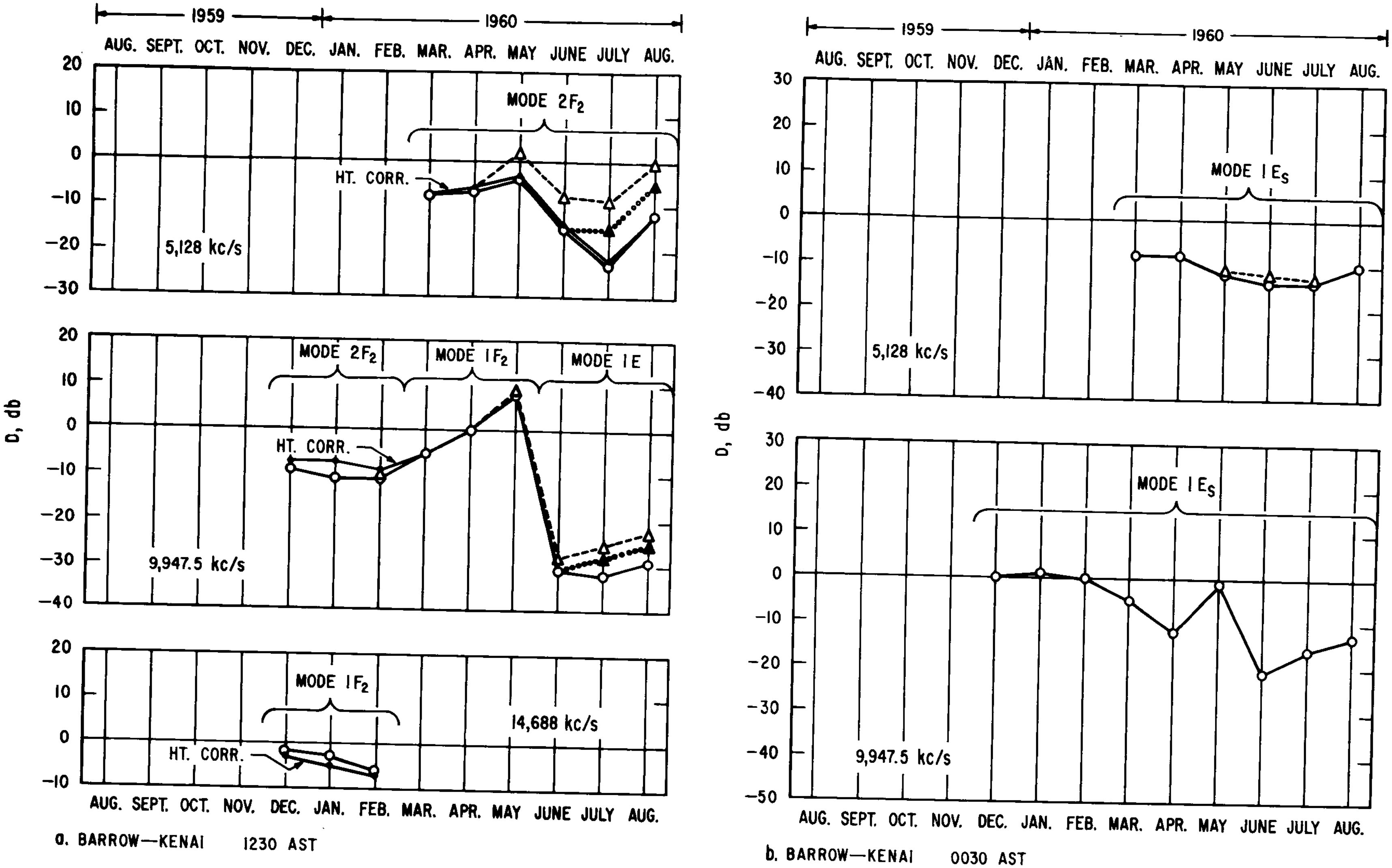


Figure 23. Increment D to be added to Absorption Prediction for Observed "Undisturbed" Value

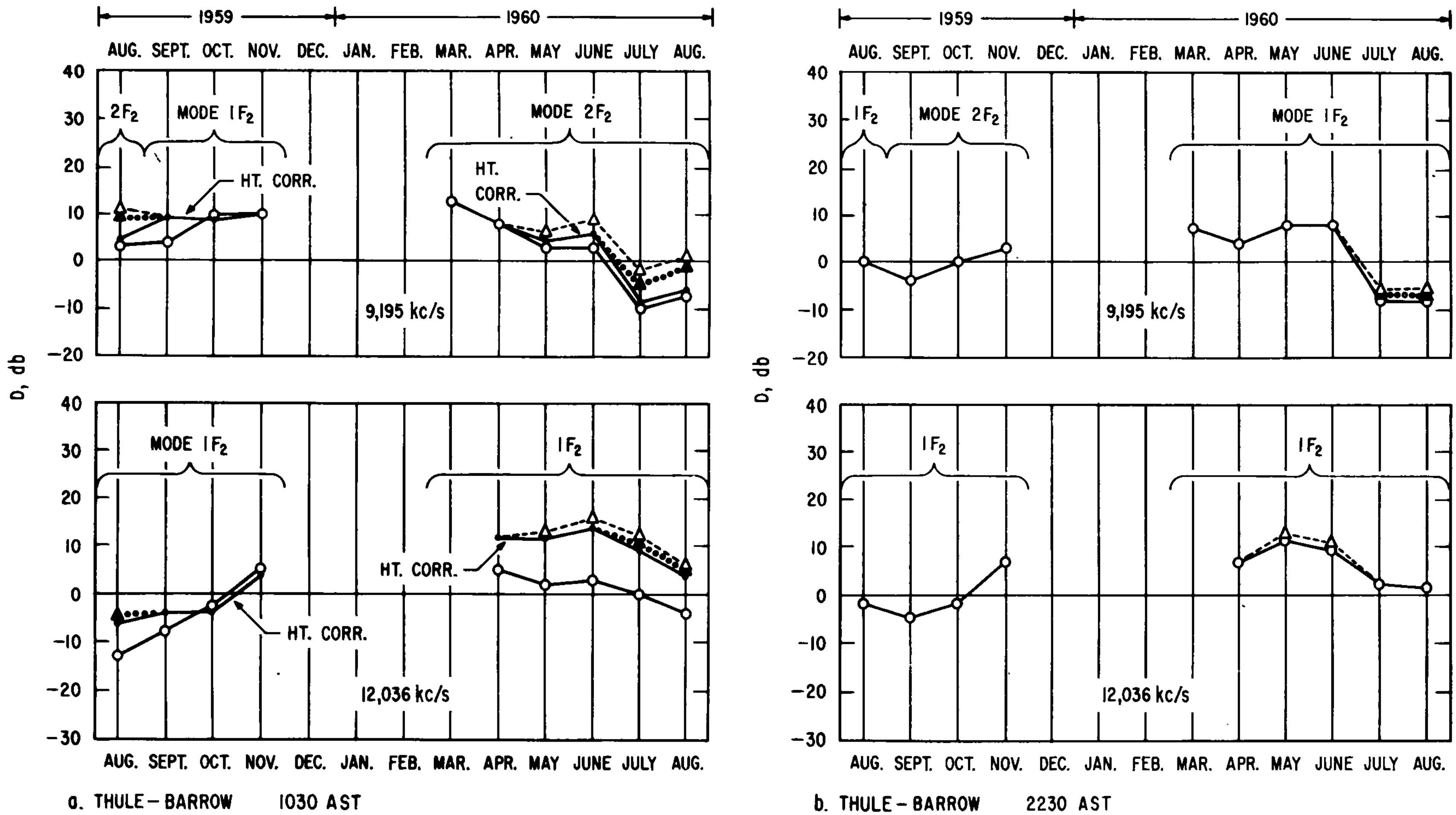


Figure 24. Increment D to be added to Absorption Prediction for Observed "Undisturbed" Value

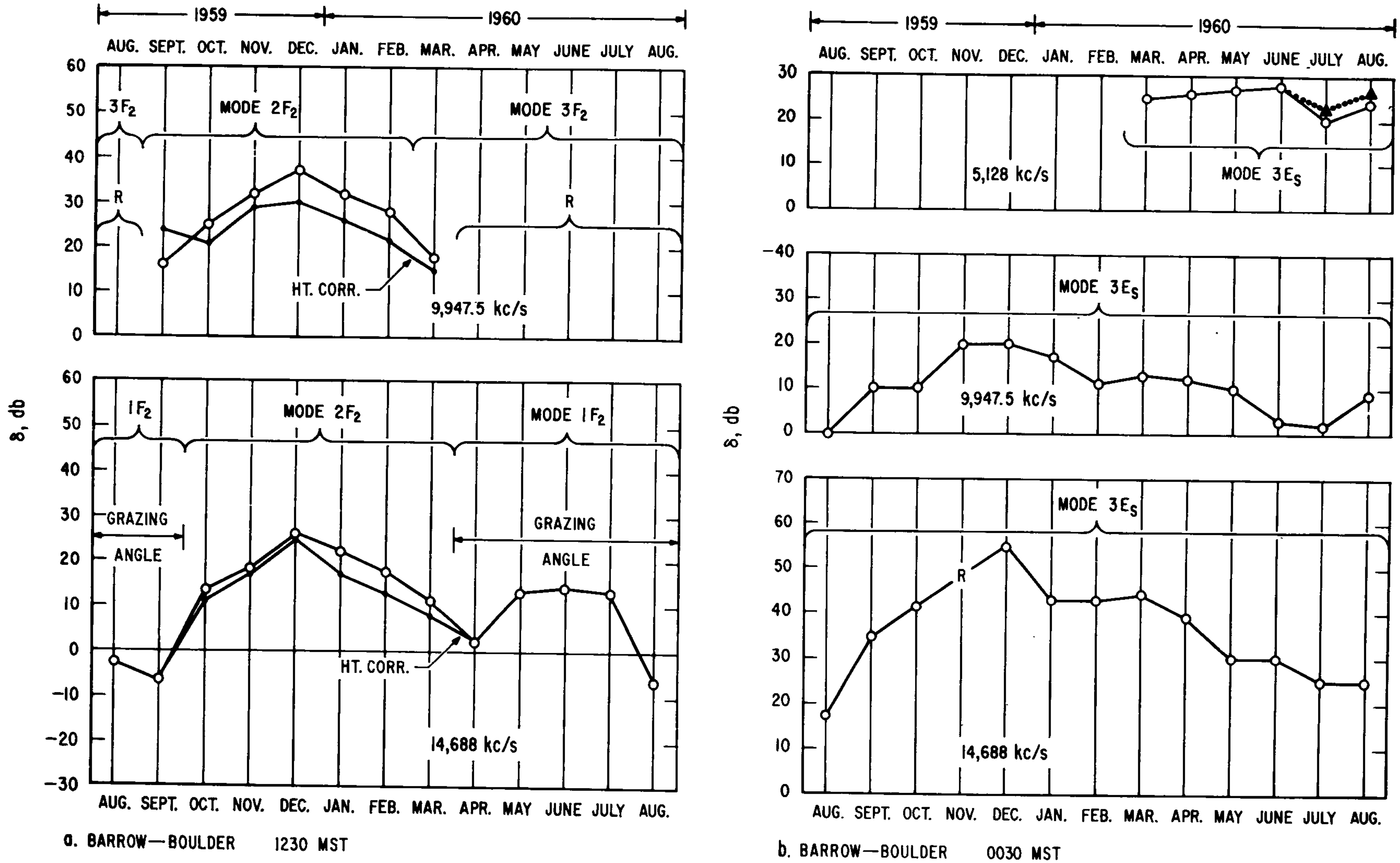


Figure 25. Increment δ to be added to Absorption Prediction for Median

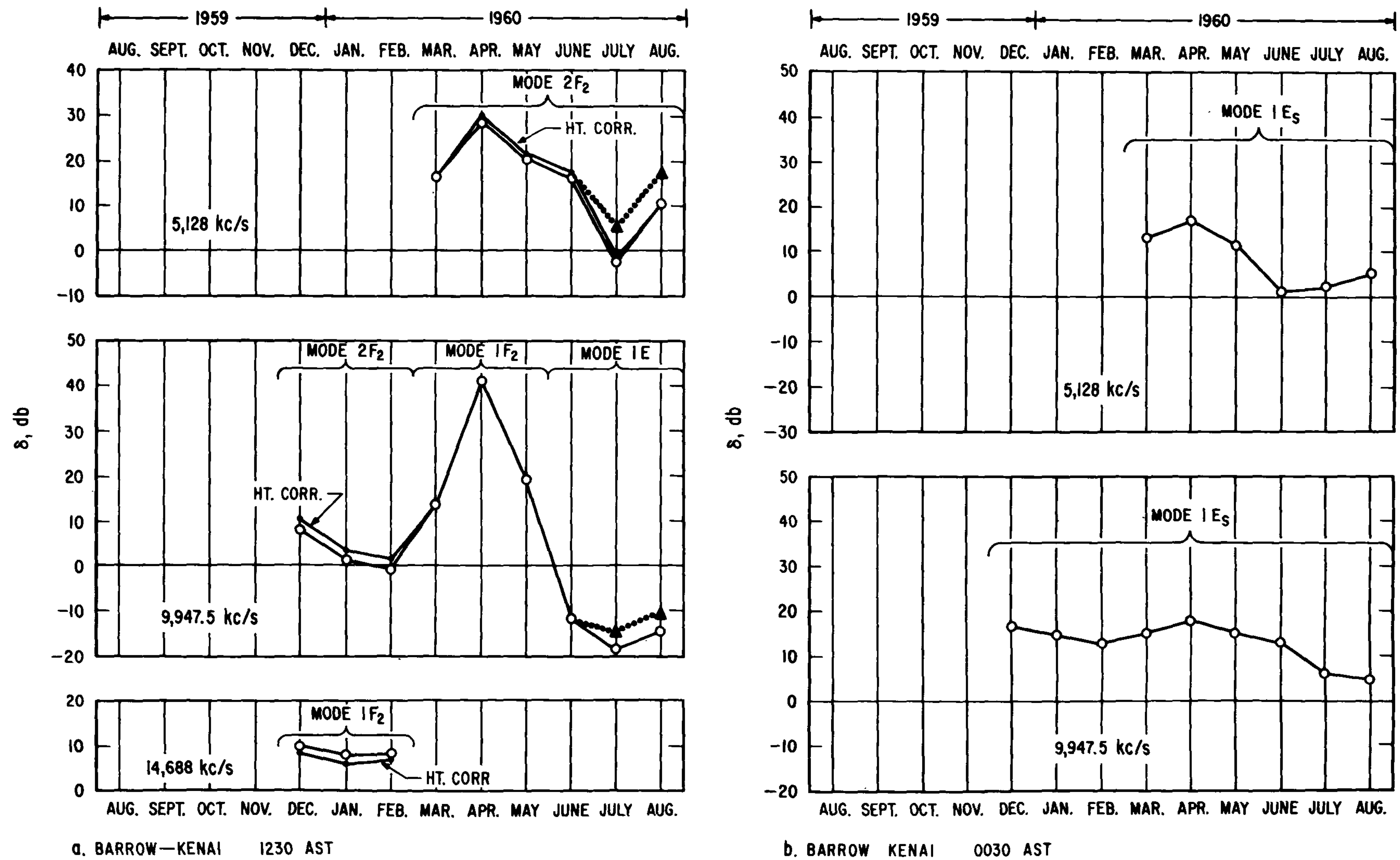


Figure 26. Increment δ to be added to Absorption Prediction for Median

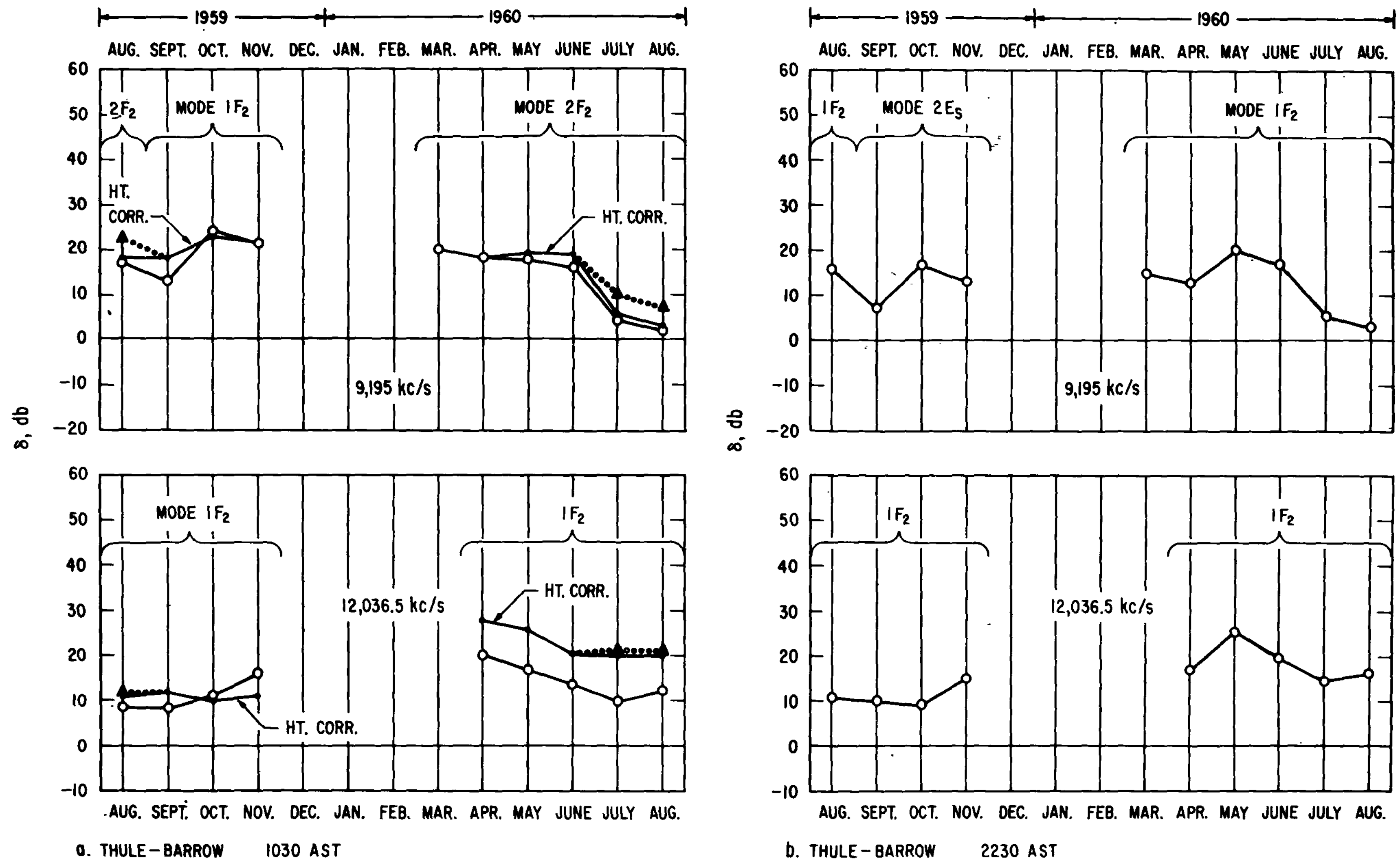


Figure 27. Increment δ to be added to Absorption Prediction for Median

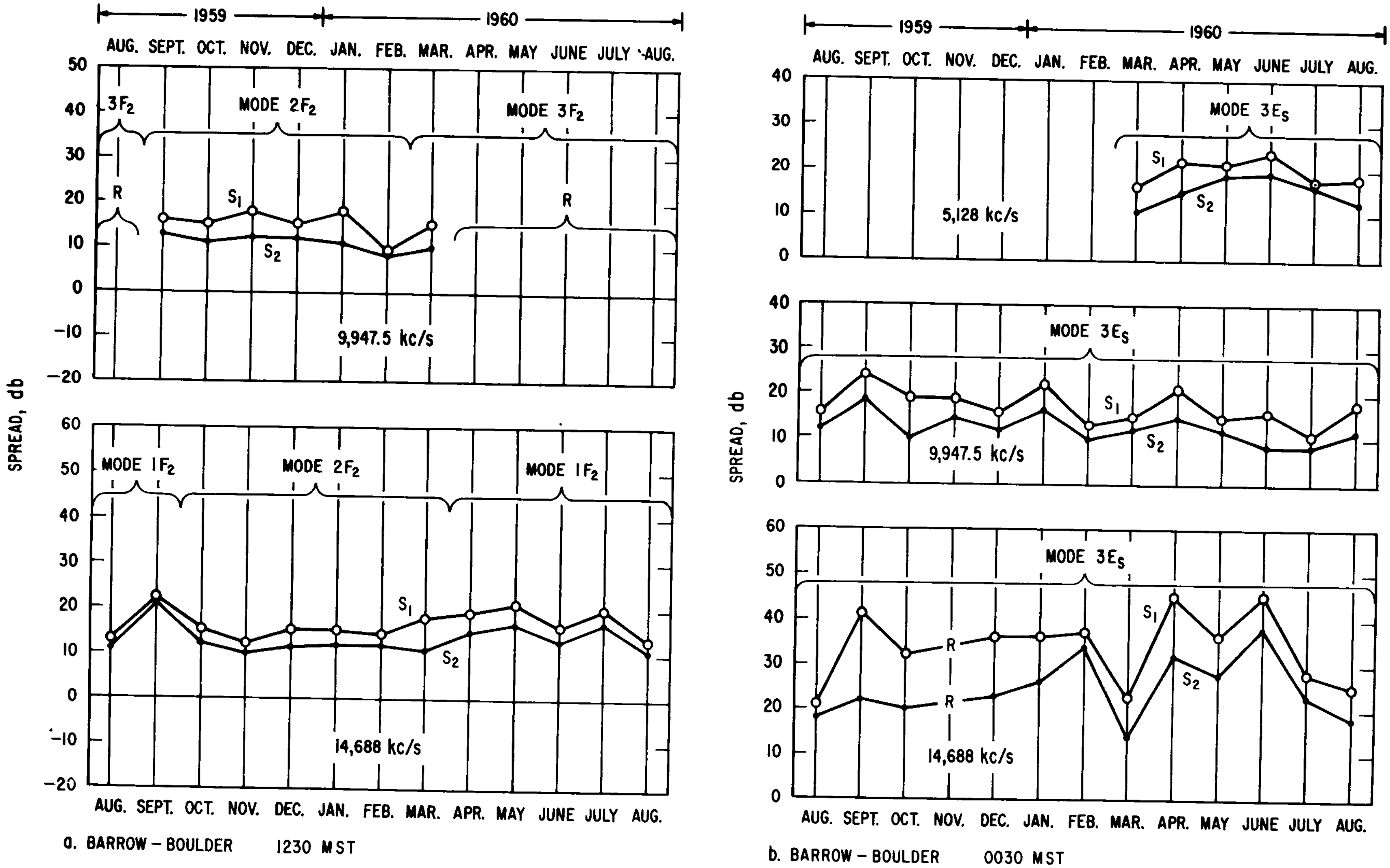


Figure 28. System-Loss Spreads Below Median

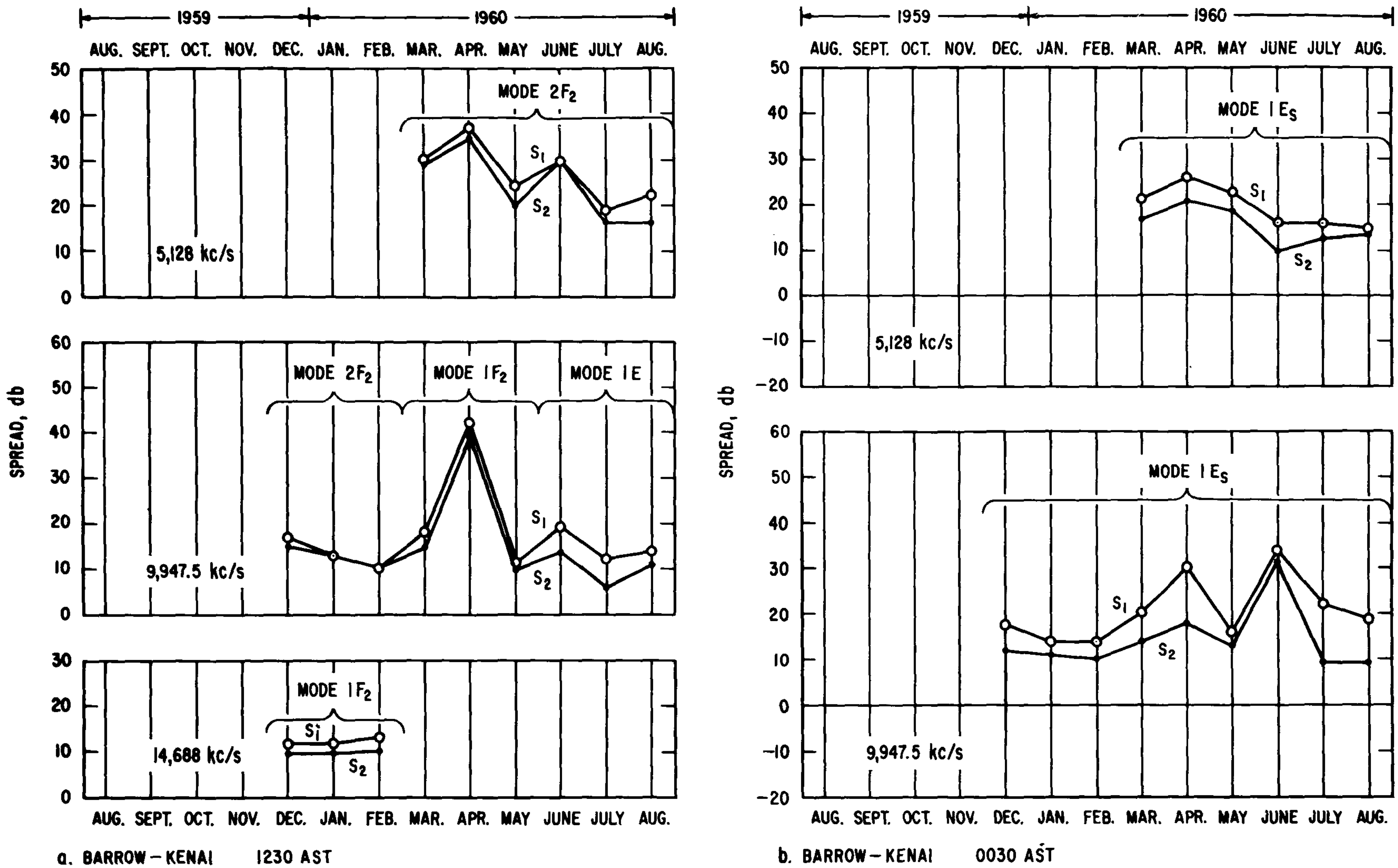


Figure 29. System-Loss Spreads Below Median

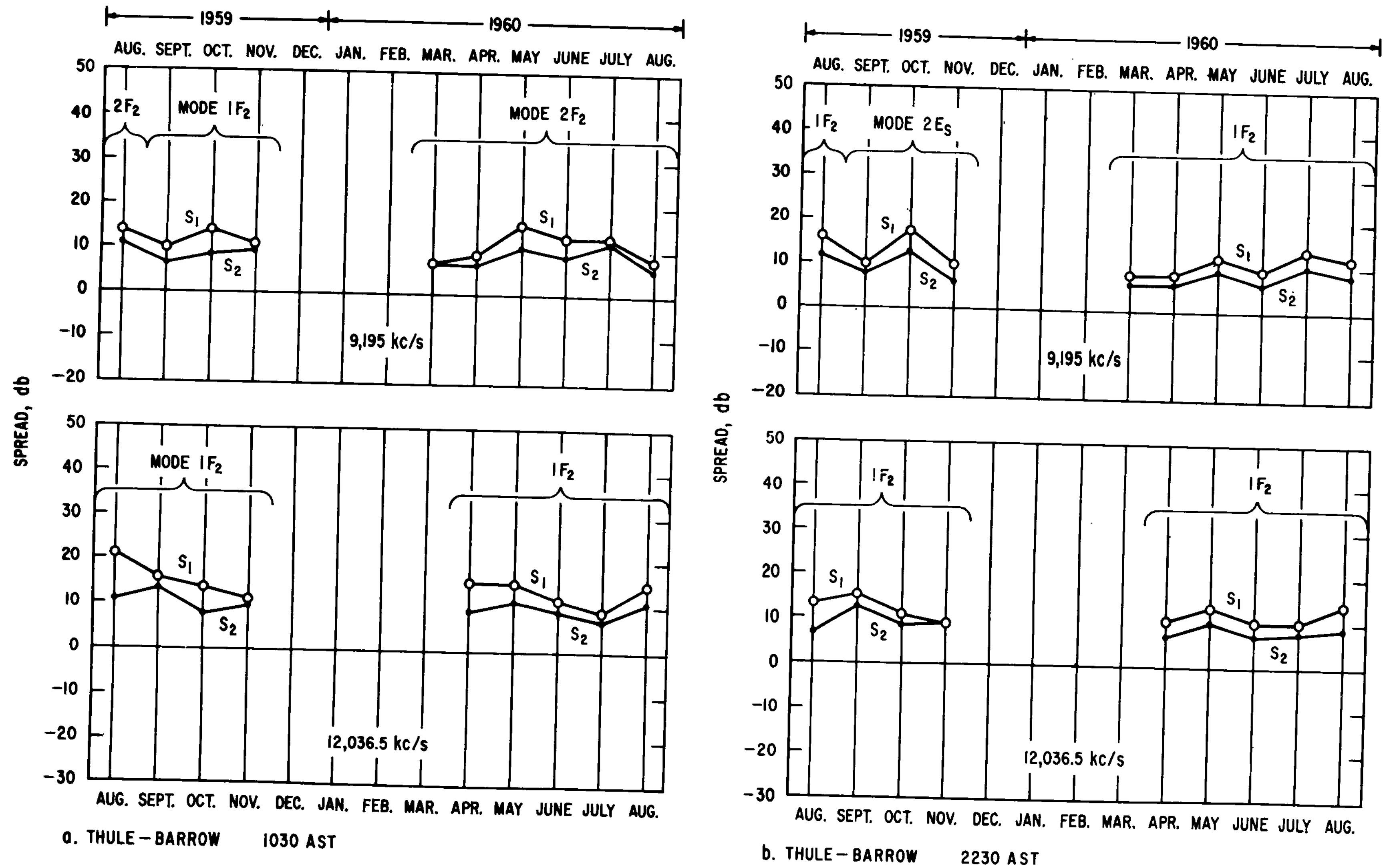


Figure 30. System-Loss Spreads Below Median

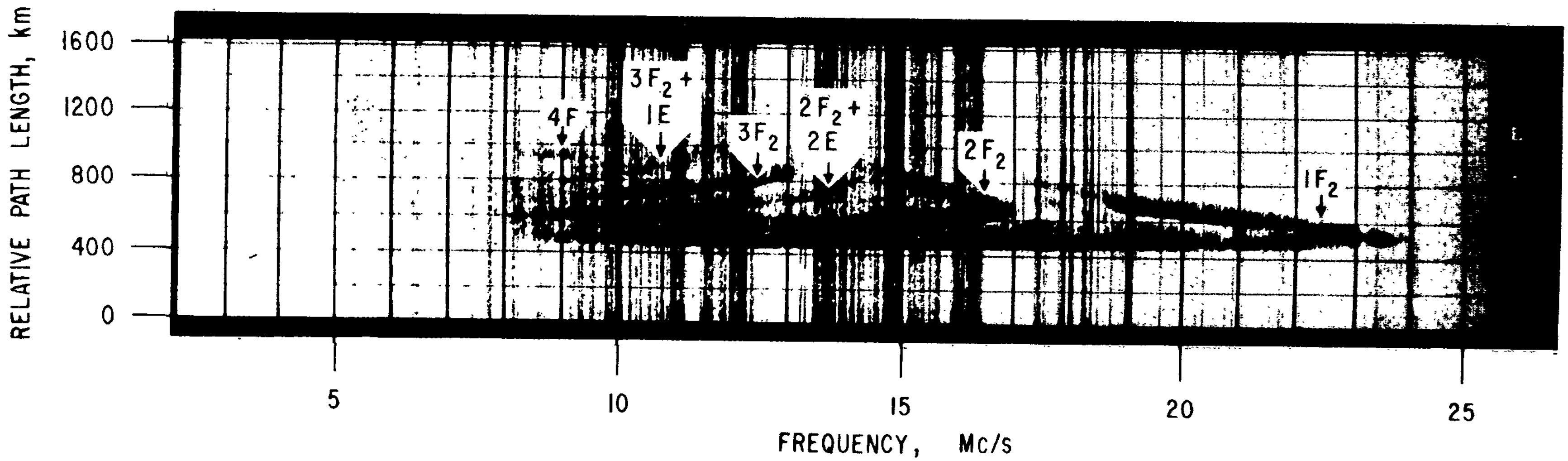


Figure 31. Typical Mode Structure Observed Under Quiet Conditions Over a Point-to-Point Path, Barrow, Alaska, to Boulder, Colorado 2 June 1960, 2306 MST

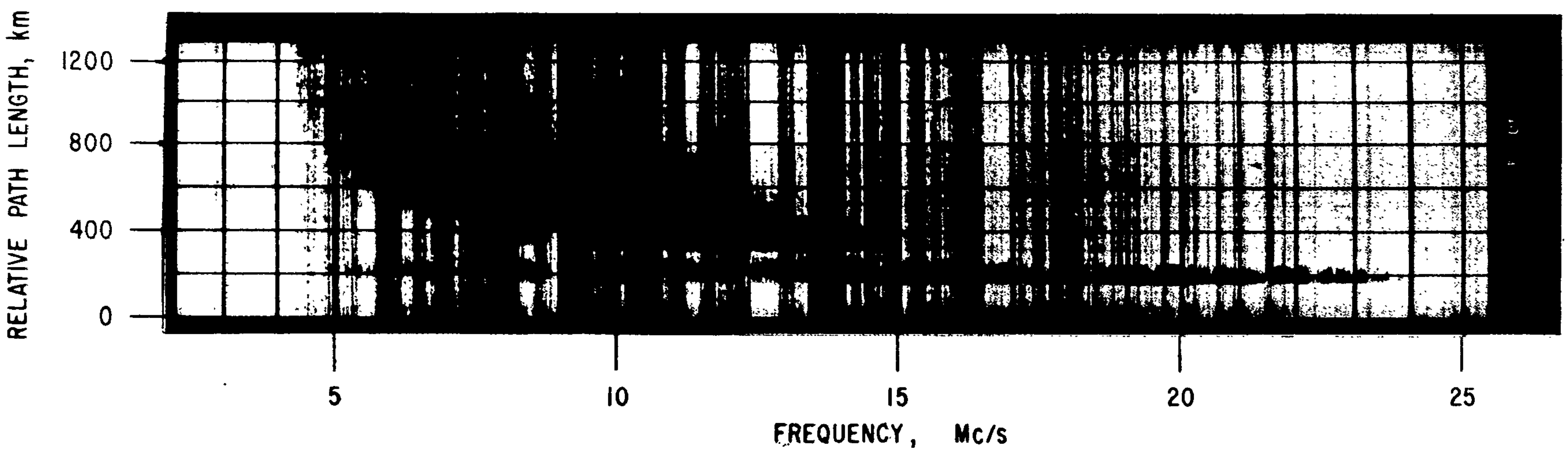


Figure 32. Mode Structure Observed Over a Path Through the Auroral Zone During a Season and Time of Day of Moderate Disturbance, Barrow, Alaska to Boulder, Colorado, 14 April 1960

Table 1

Data on Experimental System

Path, Km	Frequencies, kc/s	Period Covered to date	Transmitter Corrected Nominal Input to Transmission line, kw	Transmitting Antenna Characteristics	Receiving Antenna (all $\lambda/2$ doublets across path) height	Approximate Receiver Noise Bandwidth c/s
Barrow-Boulder, 4470	5128	Mar. 4-Aug. 31, 1960	2	$\lambda/4$ unipole	90'	35
	9947.5	Aug. 1-Aug. 31, 1960	2	$\lambda/4$ unipole	λ	35
	14688	Aug. 1-Aug. 31, 1960	2	$\lambda/4$ unipole	λ	35
	19247	Aug. 1-Aug. 31, 1960	2	$\lambda/4$ unipole	λ	35
Barrow-Kenai 1220	5128	Mar. 4-Aug. 31, 1960	2	$\lambda/4$ unipole	90'	700
	9947.5	Dec. 1959	2	$\lambda/4$ unipole	$\lambda/2$	700
	14688	Dec. 1959	2	$\lambda/4$ unipole	$\lambda/2$	700
	19247	Dec. 1959	2	$\lambda/4$ unipole	$\lambda/2$	700
Thule-Barrow 2240	9195	(1) borrowed FSK transmissions Aug. 1959, Sept.1959, 19-31 Oct. 1959, 1-14 Nov. 1959 (2) controlled CW transmissions Mar. 1959 - Aug. 31, 1959	2	$\lambda/2$ doublet across path	70'	700
	12036.5	(1) borrowed FSK transmissions same as for 9195 (2) controlled CW transmissions Mar. 1959 - Aug. 31, 1959	2	$\lambda/2$ doublet across path	52'	700

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
9,195 kc/s	1959	CT	30	30	30	30	30	30	29	29	30	29	28	31	30	29	28	29	30	29	30	30	29	29	29	30
	AUGUST	90%	129	132	134	135	137	139	138	141	143	147	142	143	144	144	143	141	139	137	133	133	133	130	130	131
		50%	146	146	147	150	153	152	153	156	157	155	156	155	155	153	154	152	150	147	145	143	142	145	140	143
		10%	161	162	164	175	170	174	176	175	175	174	182	176	170	171	168	167	162	161	161	167	159	159	159	159
		% R																								
9,195 kc/s	1959	CT	29	28	29	29	28	28	27	27	28	28	28	28	28	28	28	27	28	28	28	28	28	28	28	28
	SEPTEMBER	90%	128	131	130	131	132	134	137	137	141	140	140	140	141	142	136	136	130	126	127	125	124	126	126	125
		50%	134	138	137	137	142	142	144	143	148	148	146	148	147	147	145	144	140	138	138	136	133	134	136	131
		10%	151	150	160	151	164	163	170	170	173	173	174	167	169	167	167	159	157	152	154	156	149	148	150	150
		% R																								
9,195 kc/s	1959	CT	18	18	18	18	17	18	18	17	17	17	17	17	17	17	18	20	20	20	20	20	21	21	21	21
	OCTOBER	90%	136	131	131	136	136	139	139	138	143	142	143	144	141	141	139	138	137	131	135	131	131	128	131	131
		50%	144	144	143	141	144	144	148	151	152	154	153	149	149	147	148	149	147	149	148	144	141	142	143	145
		10%	168	167	166	164	166	167	170	173	176	180	180	196	189	187	172	171	170	169	170	168	167	167	166	167
		% R																								
9,195 kc/s	1959	CT	15	15	14	13	14	14	14	14	13	14	15	14	15	14	13	14	14	14	14	14	14	14	14	14
	NOVEMBER	90%	137	135	132	129	133	132	132	131	135	135	135	137	136	137	129	131	134	134	131	130	133	131	133	136
		50%	144	143	140	137	138	136	136	139	141	143	145	148	148	146	142	138	136	137	140	140	138	137	140	142
		10%	160	153	153	161	147	145	150	152	161	155	155	170	165	168	166	152	145	143	144	142	146	144	150	159
		% R																								
9,195 kc/s	1960	CT	12	13	13	13	13	12	12	12	11	11	11	13	13	13	14	15	15	14	14	15	15	15	15	13
	MARCH	90%	133	133	132	133	135	139	136	138	143	142	141	141	140	140	139	138	137	137	134	133	134	131	132	132
		50%	139	137	138	140	142	144	145	149	148	149	148	148	145	144	143	144	142	140	139	140	137	137	138	137
			R	R	R	R	R	R	R	R	R	R	R	R	R	R										R
		10%	184	194	184	184	184	184	189	184	184	184	184	192	192	192	180	171	174	176	173	173	174	172	187	190
		% R	8	8	8	8	8	8	17	8	9	9	9	8	15	8			7	7	7	7	7	7	7	15
9,195 kc/s	1960	CT	30	30	30	30	30	29	30	30	30	30	29	29	29	29	30	29	30	30	30	30	30	30	30	30
	APRIL	90%	132	132	133	134	134	138	138	136	141	145	145	143	142	143	142	141	141	139	136	135	131	129	132	134
		50%	139	138	142	142	144	145	148	150	152	153	153	149	153	147	147	146	145	145	142	139	137	139	136	138
			R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
		10%	184	192	192	194	194	194	194	194	194	193	194	194	194	194	184	184	184	184	184	193	194	186	194	190
		% R	17	20	17	20	20	21	20	23	30	17	21	24	28	21	17	17	17	17	13	17	17	10	20	17
9,195 kc/s	1960	CT	31	30	30	31	31	30	30	31	31	31	29	30	30	30	30	31	31	31	31	31	31	31	31	31
	MAY	90%	142	144	143	146	149	149	148	146	149	150	147	148	149	149	144	145	143	142	143	142	140	139	139	141
		50%	153	153	156	155	157	158	158	158	162	163	163	166	163	159	157	156	155	152	151	152	149	148	150	149
			R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R	R	R
		10%	200	190	194	200	203	204	204	203	202	201	200	203	200	196	194	202	204	203	201	204	199	197	200	199
		% R	10	10	10	10	10	10	13	13	13	16	14	17	20	17	10	13	13	13	6	10	10	10	13	13
9,195 kc/s	1960	CT	30	29	29	29	29	30	30	30	30	30	28	29	30	30	29	29	29	30	30	30	30	30	30	30
	JUNE	90%	144	144	142	146	146	148	149	147	148	150	149	148	149	147	147	146	147	144	143	143	140	142	143	143
		50%	149	150	152	152	155	157	155	157	163	162	164	161	160	157	157	153	154	152	152	150	146	146	150	151
		10%	167	165	162	168	170	178	181	184	188	186	186	185	180	182	180	179	173	173	179	172	173	171	170	170
		% R						3	3	3		3														
9,195 kc/s	1960	CT	29	29	28	28	27	27	27	27	27	27	26	27	27	28	29	29	29	29	29	29	29	29	29	29
	JULY	90%	126	130	131	133	135	137	137	138	139	142	137	139	137	135	130	129	130	131	130	127	125	125	124	127
		50%	139	140	140	138	139	141	[illegible]	146	150	150	148	150	146	145	145	141	138	137	138	135	135	136	134	136
		10%	147	152	152	150	151	154	154	154	158	161	159	161	154	154	153	150	152	149	147	144	144	144	149	147
		% R																								
9,195 kc/s	1960	CT	28	29	29	29	29	29	29	30	30	30	30	30	30	31	29	29	29	29	29	29	29	29	29	29
	AUGUST	90%	126	126	128	129	129	131	132	132	135	140	135	136	136	134	131	129	128	128	129	125	123	121	122	123
		50%	133	133	135	137	139	140	140	140	144	145	144	142	142	140	138	135	135	133	133	130	129	127	129	134
		10%	145	144	144	147	147	153	154	158	156	159	158	157	153	148	149	146	148	140	142	142	140	141	149	144
		% R																								

HOURS ALASKA STANDARD TIME (150° W)

Table 2a. Monthly Diurnal Variation of System Loss and Percent Time Signal Below Noise, Thule-Barrow 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
			HOURS ALASKA STANDARD TIME (150° W)																							
12,036.5 kc/s	1959	CT	25	25	26	26	26	26	26	26	26	26	26	26	26	25	25	27	28	27	28	28	28	27	27	26
	AUGUST	90%	130	129	131	130	128	133	136	129	134	130	129	130	130	127	129	128	129	129	130	129	127	130	128	129
		50%	141	139	140	141	142	141	145	143	140	141	141	141	143	142	141	138	138	136	136	138	136	135	136	137
		10%	168	175	178	174	160	164	162	157	161	160	162	157	156	153	154	151	148	154	164	178	168	157	164	154
		% R																								
12,036.5 kc/s	1959	CT	29	28	28	29	29	29	29	29	27	30	30	29	29	29	28	29	28	29	29	29	29	29	29	29
	SEPTEMBER	90%	120	122	124	126	127	128	126	126	127	125	123	125	126	128	125	124	125	121	121	120	120	119	120	120
		50%	131	132	134	139	138	138	138	138	139	138	138	139	140	138	138	137	134	134	135	133	132	135	133	131
		10%	160	171	146	149	175	161	159	161	152	154	160	157	157	155	147	160	156	161	177	176	164	159	170	170
		% R																								
12,036.5 kc/s	1959	CT	25	25	24	24	24	24	24	24	24	25	27	26	26	28	28	28	28	28	28	28	27	28	28	28
	OCTOBER	90%	126	124	124	124	125	126	125	126	126	127	128	131	126	127	123	121	123	123	121	122	121	121	122	124
		50%	131	132	131	130	131	133	134	134	135	138	136	137	136	134	133	131	132	130	133	129	129	130	131	132
		10%	142	147	138	142	141	140	143	142	141	147	146	145	151	143	138	141	144	144	154	155	154	156	158	156
		% R																								
12,036.5 kc/s	1959	CT	14	13	14	14	15	15	15	15	14	15	15	15	15	14	13	13	14	14	14	14	14	14	13	13
	NOVEMBER	90%	133	128	136	132	133	129	129	130	131	130	129	128	128	135	126	124	125	125	128	126	129	126	130	130
		50%	141	140	143	139	137	136	137	138	139	140	137	140	141	137	138	137	136	135	135	133	139	136	137	139
		10%	160	167	156	155	154	149	156	147	143	146	152	152	159	148	150	154	152	157	152	160	175	170	171	178
		% R																								
12,036.5 kc/s	1960	CT	4	4	5	5	5	5	5	5	5	6	7	8	8	8	7	6	6	6	6	5	5	5	5	5
	MARCH	90%			131	136	136	136	136	138	142	134	131	138	138	131	134	135	132	134	134	129	135	137	136	134
		50%			138	141	141	142	140	141	144	138	139	141 R	142 R	139 R	143 R	145 R	145 R	146	142	141	137 R	142 R	140	136 R
		10%			147	149	151	162	169	171	162	189	190	196	195	195	193	196	195	194	177	176	192	191	180	190
		% R												12	12	12	14	17	17				20	20		20
12,036.5 kc/s	1960	CT	29	29	29	29	29	29	29	29	28	29	28	28	28	28	30	29	29	29	30	29	29	29	29	29
	APRIL	90%	134	133	137	138	137	140	140	142	143	142	140	143	137	137	137	137	137	135	136	132	131	132	134	136
		50%	143 R	146 R	143 R	144 R	146 R	149 R	150 R	151 R	151 R	151 R	151 R	151 R	147 R	146	144 R	147 R	143 R	144 R	143 R	141 R	140 R	142 R	141 R	141 R
		10%	193	197	196	197	197	199	204	204	203	202	203	200	195	183	195	195	196	195	198	200	203	199	198	195
		% R	14	17	17	17	17	17	21	17	14	14	14	11	11	7	10	10	14	14	13	17	17	17	17	14
12,036.5 kc/s	1960	CT	31	31	31	31	31	31	31	31	31	31	30	30	30	30	30	31	31	31	31	30	30	31	31	31
	MAY	90%	141	145	144	146	147	146	145	144	140	142	145	146	140	142	139	141	141	139	139	139	141	141	141	143
		50%	153 R	152 R	151 R	154 R	158	157	157 R	157 R	158 R	158	156 R	154	151	150	151	153	149	147	149	150	150	150	152 R	152 R
		10%	199	202	203	204	201	198	200	202	201	194	205	191	199	195	194	189	195	190	190	173	178	193	194	192
		% R	10	16	16	10	6	6	10	13	10	3	10	3	3	3	3	6	6	6	3	7	3	3	6	6
12,036.5 kc/s	1960	CT	28	28	29	29	29	29	29	29	29	29	27	28	29	29	29	28	29	28	29	29	29	28	28	28
	JUNE	90%	142	146	146	145	146	145	147	144	144	146	143	142	145	138	141	142	143	143	139	139	141	142	141	140
		50%	148	149	152	155	153	156	155	158	159	157	157	153	151	150	148	149	150	152	150	148	148	147	148	149
		10%	164	160	168	166	171	169	169	176	176	172	170	175	171	169	167	162	166	165	160	163	158	161	168	168
		% R			3	3	3	3																		
12,036.5 kc/s	1960	CT	27	27	26	26	26	26	25	26	26	23	25	26	27	26	26	26	27	26	27	28	27	27	27	26
	JULY	90%	133	136	133	137	139	137	135	135	135	136	136	136	137	136	137	137	138	136	135	131	131	131	131	135
		50%	143	142	143	143	144	145	147	149	150	149	149	147	147	145	144	143	144	142	142	139	138	140	140	142
		10%	149	148	150	149	151	151	153	155	154	158	157	153	153	151	153	149	151	148	148	149	147	163	152	156
		% R														4		4	4							
12,036.5 kc/s	1960	CT	28	29	31	31	30	31	28	29	28	29	29	29	30	30	29	30	29	29	30	30	30	30	29	28
	AUGUST	90%	136	137	138	138	136	135	136	135	137	140	141	138	137	131	134	132	134	133	132	132	129	131	131	134
		50%	142	142	144	145	145	146	145	144	144	147	147	146	148	144	144	143	144	143	141	140	142	142	140	141
		10%	156	165	173	159	159	160	160	155	158	156	158	158	156	157	154	152	153	149	150	165	173	172	163	151
		% R																	3	3	3	3			3	4

Table 2b. Monthly Diurnal Variation of System Loss and Percent Time Signal Below Noise, Thule-Barrow 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
			HOURS ALASKA STANDARD TIME (150° W)																							
5,128 kc/s	1960 MARCH	CT	26	25	25	25	24	26	26	25	24	25	24	26	21	23	25	24	26	28	28	28	26	25	27	26
		90%	119	117	118	119	119	120	125	127	135	140	144	146	146	142	144	139	133	125	115	113	113	112	114	119
		50%	135	131	130	131	126	127	136	145	152R	151R	154R	158	166R	164R	157R	157R	146	131	126	122	120	125	133	139
		10%	149	153	152	154	141	140	160	182	201	203	198	195	203	203	203	198	185	167	168	159	155	146	152	159
		%R	4	4	4					8	25	12	12	8	24	17	16	12	8	7	7	7	8			
5,128 kc/s	1960 APRIL	CT	30	30	30	29	29	28	28	28	23	25	23	26	23	21	27	27	27	29	29	29	30	30	30	30
		90%	118	118	119	122	121	123	130	141	148R	150R	158	154	153R	146	150	146	139	136	130	123	120	117	115	118
		50%	135	142	138R	140R	141R	143R	147R	166R	188R	196R	183R	179R	191R	189R	180R	172R	163R	157R	146R	144R	139R	137	139	141
		10%	172	178	199	198	194	203	203	203	204	204	204	204	204	204	204	204	204	198	192	204	199	186	179	176
		%R	7	7	10	14	14	25	18	21	52	52	30	35	52	48	33	30	22	17	10	14	17	7	7	7
5,128 kc/s	1960 MAY	CT	25	25	24	21	21	21	20	20	14	21	15	24	16	24	22	25	26	25	24	24	23	24	24	25
		90%	119	124	121	122	125	133	139	141	151	150	158	164	164	163	154	159	153	148	137	131	125	119	118	119
		50%	138	141	147R	148R	152R	155R	155R	166R	171R	170R	174R	179R	187R	184R	189R	176R	171	161R	150	146R	141R	138	141	139
		10%	173	173	175	184	185	188	204	204	202	203	203	204	204	204	204	204	186	203	191	193	187	171	175	161
		%R	8	8	12	14	14	10	25	15	21	19	27	33	38	29	32	36	8	12	8	12	9	8	8	8
5,128 kc/s	1960 JUNE	CT	26	26	26	28	28	28	28	28	28	28	28	27	27	23	24	23	25	27	27	26	29	28	28	27
		90%	125	125	127	127	130	134	139	142	145	151	156	155	152	153R	156	152	148	147	150	140	135	130	122	125
		50%	134	134	139	139	139	140	147	155	162R	167R	172R	172R	187R	194R	180R	181R	174R	170R	165	150R	145	141	139R	138
		10%	171	181	177	168	155	158	171	169	199	204	204	199	204	204	204	204	194	194	191	190	161	172	177	175
		%R	4	8	4	4	4				11	18	14	19	37	52	42	26	16	11	7	12	7	7	7	4
5,128 kc/s	1960 JULY	CT	22	22	21	20	20	19	17	17	19	22	21	21	20	21	19	22	22	21	20	19	20	21	21	21
		90%	121	116	118	119	120	127	130	137	141	143	142	143	146	146	144	143	144	135	131	132	127	124	116	121
		50%	132	131	129	131	128	134	140	143	151R	154	156R	159R	164R	170R	160R	164R	160R	157	154	146	141	134	133	133
		10%	139	147	159	157	144	141	144	186	194	180	193	198	200	198	198	187	188	187	176	157	157	149	145	143
		%R			5					6	11	5	10	19	20	19	16	9	9	5					5	
5,128 kc/s	1960 AUGUST	CT	27	28	26	27	27	28	28	28	28	29	30	31	30	30	31	31	31	31	30	31	31	31	31	30
		90%	116	115	116	118	125	128	134	143	150	153	156	152	156	151	150	148	146	141	134	128	121	116	117	114
		50%	128	126	128	130	131	136	144	155R	170R	172R	169R	172R	169R	166R	164R	169R	164R	155	147	144	137	132	129	132
		10%	136	153	156	159	161	169	177	192	199	204	204	204	204	204	204	202	201	187	169	161	157	157	147	146
		%R	4	4	4	4	4	7	4	11	21	28	30	19	17	17	19	16	13	3	3	3	3	3	3	3
9,947.5 kc/s	1959 DECEMBER	CT	30	30	29	29	30	30	30	30	30	30	29	25	29	29	29	29	26	28	29	29	30	31	31	31
		90%	133	136	134	138	137	134	130	138	138	126	123	126	126	124	122	122	123	124	125	134	128	131	132	130
		50%	147	147	147	152	151	151	150	155	156	152R	139R	144	141	135	134	133	130	133	146	146	140	140	141	142
		10%	164	167	166	167	169	164	170	169	172	180	179	167	162	149	147	146	147	160	171	166	165	168	167	165
		%R									3	10	7	4												
9,947.5 kc/s	1960 JANUARY	CT	30	30	29	29	30	29	28	28	26	24	24	25	27	29	30	29	31	31	30	29	29	29	28	30
		90%	134	132	136	134	137	134	127	121	119	120	123	123	122	121	121	119	121	119	119	121	124	128	128	130
		50%	142	147	145	151	145	149	156	148	148	133	129	130	136	132	130	127	126	124	134	151	143	136	140	140
		10%	161	173	164	170	167	168	166	170	170	156	162	166	162	160	145	140	142	148	161	166	170	166	164	163
		%R																								
9,947.5 kc/s	1960 FEBRUARY	CT	25	25	25	24	23	23	22	21	19	20	21	22	26	26	25	23	20	26	25	26	26	25	24	24
		90%	131	135	134	135	134	133	133	124	124	121	123	126	127	127	126	121	121	118	119	117	127	130	129	128
		50%	139	146	146	150	144	149	150	154	149R	135	135R	131	135	134	131	129	126	125	124	126	140	140	137	139
		10%	160	162	161	162	168	167	165	178	183	175	188	181	175	163	148	149	136	146	138	145	167	166	165	162
		%R									16		10													
9,947.5 kc/s	1960 MARCH	CT	28	26	26	26	26	26	26	26	27	26	25	26	23	29	29	30	30	31	30	30	28	27	28	29
		90%	130	122	125	136	136	134	134	132	119	119	118	120	120	119	124	120	120	119	118	118	118	131	131	134
		50%	143	142	143	143	141	143	151	151R	149R	144	144	137	136R	132	130	129	127	125	127	129	136	140	142	144
		10%	166	163	157	157	158	165	184	188	188	174	172	178	173	168	165	154	141	150	149	155	159	161	159	162
		%R							4	15	15	4	4		4											
9,947.5 kc/s	1960 APRIL	CT	30	30	30	30	30	29	29	28	24	24	22	27	20	20	25	25	27	29	29	29	29	29	29	30
		90%	131	134	131	127	132	120	120	124	147	131	127	127	123	126	126	121	121	118	121	122	121	121	119	120
		50%	147	143	144	146	150R	153R	155R	163R	174R	163R	164R	155R	174R	164R	153R	148	141	139	138R	143R	140	142	143	148
		10%	164	169	171	182	191	213	213	203	213	208	213	198	203	200	203	182	179	183	189	188	182	180	172	169
		%R	3	3	3	7	10	17	21	25	25	21	23	19	15	20	12	8	7	7	10	10	7	7	3	3
9,947.5 kc/s	1960 MAY	CT	21	22	22	21	20	21	20	21	15	18	14	21	14	20	16	21	20	22	22	22	22	22	22	22
		90%	132	130	133	132	137	137	130	122	136	126	130	135	134	129	127	122	121	122	120	122	119	122	129	134
		50%	147R	145R	151	150	154	156R	161R	152R	149R	140R	146R	147	145	137	139	134	135R	138	136	135	134R	142R	145R	144R
		10%	180	182	161	168	173	181	191	203	208	203	203	181	193	177	165	160	179	162	163	173	181	174	173	181
		%R	10	9	5	5	5	10	20	14	20	17	14	5	7	5	6	5	10		5	5	9	9	9	9

Table 3a. Monthly Diurnal Variation of System Loss and Percent Time Signal Below Noise, Barrow-Kenai 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
			HOURS ALASKA STANDARD TIME (150°W)																							
9,947.5 kc/s	1960	CT	26	29	29	29	28	27	25	26	27	27	26	23	22	18	23	19	26	30	28	26	29	27	28	26
	JUNE	90%	112	114	115	117	119	126	134	172	120	121	123	126	126	123	122	121	118	118	118	118	116	114	115	112
		50%	148	143	148	147	145	142	143	140	134	134	133	140	140	137	134	132	127	131	140	136	141	137	143	143
		10%	166	171	164	162	164	168	171	173	175	162	165	161	162	153	148	151	142	153	157	157	159	162	162	158
		%R									4	4	4												4	
9,947.5 kc/s	1960	CT	28	28	27	26	26	26	24	24	27	30	29	27	28	29	27	29	30	29	28	28	28	28	28	28
	JULY	90%	128	131	129	127	128	121	119	116	117	119	120	125	126	126	122	121	116	114	113	116	114	116	115	126
		50%	137	139	141	143	138	135	135	128	130	131	131	130	132	133	131	127	126	129	132	132	135	134	139	136
		10%	155	156	158	152	151	156	158	168	170	163	159	156	154	155	142	143	146	142	144	148	150	151	156	148
		%R									4															
9,947.5 kc/s	1960	CT	28	27	28	28	28	28	28	28	27	28	28	29	28	27	27	29	28	30	30	30	30	30	30	29
	AUGUST	90%	125	125	127	128	131	125	120	120	119	121	123	123	123	120	121	118	115	116	113	115	113	115	113	126
		50%	133	136	138	141	146	147	143	147	144	140	132	133	134	132	130	126	136	135	134	137	136	137	135	134
		10%	149	148	144	154	164	161	162	167	177	176	156	153	156	152	151	155	151	153	152	154	150	151	152	144
		%R									7	4														
14,688 kc/s	1959	CT	30	29	28	29	29	28	27	27	29	29	29	29	28	31	31	31	31	31	28	29	29	28	29	31
	DECEMBER	90%	133	133	134	138	140	145	146	153	161	159	146	120	122	121	120	119	121	136	153	138	133	134	131	131
		50%	146	146	150	154	158	156	163	166	172	169	162	160	131	131	128	124	148	164	172	172	169	158	142	144
		10%	174	173	170	166	168	174	179	180	185	R 191	187	180	169	174	165	166	171	180	183	R 187	R 186	181	R 184	176
		%R			4	3					3	17	7	7	4					3	4	14	14	7	14	
14,688 kc/s	1960	CT	26	27	28	27	26	27	25	20	18	20	19	20	23	27	26	28	30	28	28	27	28	30	29	25
	JANUARY	90%	135	137	135	134	139	143	142	146	149	122	118	119	119	119	115	114	116	119	130	154	137	136	132	132
		50%	152	149	150	152	157	160	156	166	164	160	155	136	129	128	124	123	122	149	165	171	173	165	148	150
		10%	180	178	174	176	170	178	176	178	R 187	180	184	178	176	165	152	155	160	167	181	183	186	187	185	177
		%R	4								11		5									4	7	7	3	4
14,688 kc/s	1960	CT	27	26	26	24	24	24	22	22	20	24	22	24	27	26	25	21	19	23	26	27	27	27	26	26
	FEBRUARY	90%	131	132	136	139	136	139	135	148	153	149	123	122	118	120	120	120	117	116	121	139	132	133	131	131
		50%	144	150	155	145	159	158	159	162	167	166	165	159	131	127	126	126	123	121	154	160	165	162	162	140
		10%	177	175	172	166	170	R 179	R 182	R 183	179	182	R 191	178	177	173	168	167	167	144	165	174	178	R 183	178	179
		%R		4		4		12	9	9	5	8	9	4	4									7		8
14,688 kc/s	1960	CT	28	26	26	25	23	23	23	24	25	24	24	26	24	28	28	29	29	30	29	28	27	25	26	28
	MARCH	90%	139	136	138	141	136	143	145	154	158	165	164	130	155	133	120	121	117	118	118	135	139	136	132	133
		50%	147	146	153	150	156	162	170	169	171	169	175	173	173	170	166	160	158	154	152	161	165	166	145	145
		10%	169	168	177	181	180	182	R 186	183	179	R 185	R 189	189	184	182	180	176	172	165	165	172	179	175	175	177
		%R		4					4	4	8	8	17	8												
14,688 kc/s	1960	CT	28	29	30	28	27	27	27	26	23	24	23	26	20	21	25	25	26	28	28	28	28	29	29	29
	APRIL	90%	135	139	137	146	148	147	146	158	165	160	155	156	157	147	155	161	154	149	154	141	136	136	136	138
		50%	153	150	152	163	159	165	170	174	177	174	174	173	184	186	174	175	171	172	168	166	161	157	151	154
		10%	172	176	172	181	173·	184	R 193	R 193	R 198	R 192	R 196	R 198	R 202	R 198	R 193	R 193	R 193	190	188	178	180	183	177	177
		%R	7	7	7	4	4	7	15	19	26	21	22	27	30	33	24	28	27	7	7	4	7	7	3	7
14,688 kc/s	1960	CT	30	29	29	27	27	27	26	26	19	26	18	28	19	25	27	27	28	31	31	30	29	31	31	30
	MAY	90%	133	138	141	141	137	137	136	139	138	140	143	139	139	140	143	144	143	140	138	137	138	137	133	133
		50%	148	150	154	155	155	152	154	154	158	159	161	152	153	151	160	164	169	169	168	166	165	166	159	153
		10%	175	172	176	R 183	R 189	R 184	R 185	183	R 192	178	R 191	174	R 191	183	180	R 185	R 188	R 186	184	178	173	173	174	175
		%R			3	11	15	11	12	4	11	8	17	4	11	8	7	11	14	10	6	7	3	3	3	
14,688 kc/s	1960	CT	29	29	29	30	29	29	29	29	29	29	26	24	23	23	26	22	29	29	29	27	29	28	29	29
	JUNE	90%	135	139	140	136	135	133	136	135	136	137	134	135	134	134	137	138	146	144	139	137	132	137	136	134
		50%	153	149	149	146	146	143	146	150	151	150	145	143	144	146	146	157	162	169	160	149	153	152	153	149
		10%	167	169	166	163	174	163	166	165	162	160	167	157	172	174	168	177	176	182	178	173	175	171	167	168
		%R													4	4	4				3					
14,688 kc/s	1960	CT	27	27	26	26	26	26	24	24	26	29	28	25	25	26	27	29	29	28	28	27	29	28	28	28
	JULY	90%	129	132	132	133	135	129	133	135	137	135	132	132	134	134	135	137	141	142	138	132	134	132	132	128
		50%	137	137	146	145	143	145	148	156	152	148	143	139	138	140	148	151	161	165	164	161	161	161	148	146
		10%	152	166	165	170	169	167	170	165	166	156	156	163	166	155	163	172	179	176	172	167	173	168	165	165
		%R																3	7	4	4					
14,688 kc/s	1960	CT	29	29	29	29	29	29	28	28	27	28	28	28	28	29	28	29	30	30	30	30	30	30	30	30
	AUGUST	90%	131	134	131	136	137	141	139	144	146	141	143	138	138	135	141	147	161	155	144	139	133	132	130	128
		50%	138	141	140	145	149	151	155	156	161	160	155	154	150	152	158	165	168	166	165	162	157	152	150	137
		10%	166	174	168	173	170	171	169	171	172	176	167	167	174	174	179	182	180	175	173	173	173	169	170	167
		%R									4					3		3	3							

Table 3b. Monthly Diurnal Variation of System Loss and Percent Time Signal Below Noise, Barrow-Kenai 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
			HOURS ALASKA STANDARD TIME (150°W)																							
19,247 kc/s	1959 DECEMBER	CT	30	30	30	30	30	30	30	30	31	31	31	31	29	30	31	31	31	31	31	31	31	31	31	31
		90%	135	133	136	133	139	140	150	142	167	168	166	161	135	115	118	133	156	163	165	146	141	135	132	134
		50%	150	145	146	156	167	158	171	174	178	178	173	169	164	159	157	159	165	169	179	177	177	177	167	167
		10%	179	179	179	179	179	179	179	179	179	179	179	179	179	179	179	179	179	180	189	184	181	179	179	179
		% R	30	27	23	27	43	43	60	70	90	94	61	48	28	20	16	16	19	32	81	77	81	77	55	48
19,247 kc/s	1960 JANUARY	CT	26	26	26	26	26	26	24	24	23	24	24	23	23	23	25	24	27	27	27	26	26	27	26	26
		90%	133	133	137	133	133	140	148	157	163	165	159	117	113	112	110	112	115	154	159	174	157	148	134	131
		50%	176	163	170	163	176	177	179	179	179	173	167	163	161	121	120	140	156	163	173	179	179	179	179	178
		10%	180	180	180	180	180	180	180	180	180	180	180	180	180	180	174	174	174	179	180	180	180	180	180	180
		% R	54	38	58	42	50	65	71	83	87	50	42	39	39	22	8	12	11	15	56	92	88	89	69	62
19,247 kc/s	1960 FEBRUARY	CT	28	28	28	27	27	26	26	26	26	26	24	26	26	26	25	24	20	25	23	26	27	28	28	27
		90%	135	134	136	137	136	145	141	139	156	157	165	155	119	120	120	118	117	117	151	157	146	141	142	138
		50%	166	153	153	166	174	162	168	177	179	179	179	176	166	166	162	160	157	156	162	175	179	179	179	175
		10%	182	182	182	182	182	179	182	182	182	182	182	179	181	181	179	179	179	176	179	182	189	187	184	187
		% R	43	39	29	30	37	31	39	50	62	58	58	38	27	23	24	21	20	8	9	31	67	64	57	56
19,247 kc/s	1960 MARCH	CT	29	27	27	27	27	27	27	28	29	29	30	30	26	28	28	30	30	31	30	29	28	29	29	29
		90%	141	148	144	144	148	152	157	160	162	169	176	174	173	171	169	164	163	163	165	167	160	150	142	141
		50%	176	175	171	168	182	182	182	189	187	187	191	186	187	179	177	173	172	171	170	177	179	184	182	172
		10%	192	192	190	192	192	192	192	192	192	192	197	202	197	202	197	192	188	184	187	192	192	197	197	192
		% R	28	30	30	26	44	52	52	62	52	55	67	43	46	39	21	10	7	6	10	21	36	45	45	34
19,247 kc/s	1960 APRIL	CT	26	26	25	26	26	26	25	25	22	23	22	22	21	19	22	24	24	25	26	26	26	26	26	26
		90%	148	148	150	157	150	155	158	157	167	169	176	186	186	181	187	187	180	175	167	172	157	150	148	148
		50%	180	164	162	181	182	190	189	190	192	192	192	202	201	197	199	197	194	192	189	188	187	179	170	176
		10%	197	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202	202
		% R	42	38	36	46	46	62	56	60	68	74	73	91	95	89	86	83	62	64	54	54	54	42	31	35
19,247 kc/s	1960 MAY	CT	23	23	21	20	20	20	20	20	19	19	19	19	20	18	19	18	21	21	22	21	22	23	24	23
		90%	146	145	145	145	147	143	146	151	155	179	167	178	182	182	182	178	148	159	147	142	169	160	154	143
		50%	164	170	157	158	159	167	164	184	187	187	188	188	189	188	187	187	187	187	184	181	183	186	182	177
		10%	189	187	187	188	188	192	192	192	192	192	192	192	192	192	192	192	192	192	192	192	191	192	189	187
		% R	39	35	29	25	25	35	30	50	74	89	89	89	95	94	95	89	67	71	64	38	50	65	54	48
19,247 kc/s	1960 JUNE	CT	22	23	24	24	24	24	24	24	24	24	23	21	21	15	17	19	21	21	21	21	21	22	22	22
		90%	146	139	139	141	136	148	144	149	151	160	166	151	165	152	145	179	162	151	149	145	153	150	149	144
		50%	155	151	156	154	155	163	159	167	178	182	183	184	184	187	187	187	186	182	176	175	179	176	178	171
		10%	185	184	182	180	184	184	186	186	187	189	190	189	190	189	189	191	191	187	187	184	187	187	186	183
		% R	14	13	17	8	17	21	38	33	38	46	52	57	71	67	71	79	62	62	33	24	48	36	27	27
19,247 kc/s	1960 JULY	CT	28	28	27	26	26	26	24	24	27	30	29	27	28	29	27	28	29	29	28	28	29	28	28	28
		90%	136	137	140	140	145	142	144	148	159	155	169	147	153	156	160	153	153	171	162	161	161	148	149	144
		50%	152	150	149	150	157	163	165	180	181	182	184	184	185	185	186	186	184	184	182	180	182	182	180	169
		10%	181	184	184	186	184	185	186	185	187	187	188	188	191	190	190	191	189	188	188	187	187	187	187	186
		% R	11	11	22	27	19	27	38	29	56	53	55	56	57	55	63	75	66	59	46	36	41	50	37	29
19,247 kc/s	1960 AUGUST	CT	29	29	29	29	29	29	29	29	28	29	30	31	30	30	29	31	31	31	31	31	31	31	31	30
		90%	138	141	142	142	142	148	146	148	150	160	161	171	174	177	179	182	178	177	173	160	147	144	143	141
		50%	154	160	151	161	157	166	178	178	182	183	187	187	188	187	188	188	187	184	185	182	176	176	174	157
		10%	187	186	186	185	187	187	187	187	187	188	189	189	190	190	190	190	190	189	189	189	188	189	188	188
		% R	14	17	17	17	31	38	38	24	39	48	63	68	70	78	86	81	71	48	48	42	42	26	26	20

Table 3c. Monthly Diurnal Variation of System Loss and Percent Time Signal Below Noise, Barrow-Kenai 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
			HOURS MOUNTAIN STANDARD TIME (105°W)																							
5,128 kc/s	1960 MARCH	CT	25	26	26	26	25	25	25	25	27	27	26	26	26	24	26	22	22	25	26	26	28	28	28	27
		90%	151	156	155	156	150	146	147	161	187	199	203	203	203	204	203	196	183	182	168	156	145	139	141	146
		50%	162	161	167	163	160	155	157	175	198	208	210	212	212	210	208	208	203	187	177	168	160	159	160	163
		10%	179	179	181	180	179	177	172	193	206	217	217	217	217	217	217	217	212	197	192	184	174	175	179	178
		% R	4	8	12	8	8	4	8	12	81	100	100	100	100	100	100	100	95	80	50	15	7	7	7	11
5,128 kc/s	1960 APRIL	CT	30	30	30	30	30	30	29	29	29	29	29	24	25	23	27	23	22	27	28	28	30	30	30	30
		90%	149	150	146	143	144	152	173	188	196	195	198	195	194	193	194	194	189	182	175	168	158	151	148	146
		50%	161	163	164	160	159	164	181	201	206	208	207	207	207	206	206	204	199	191	183	176	169	164	164	165
		10%	182	184	183	185	186	196	206	207	216	217	217	217	216	217	216	216	208	201	193	191	183	183	179	179
		% R	23	23	20	20	23	17	24	72	97	97	100	100	100	100	100	100	100	100	100	79	37	23	17	20
5,128 kc/s	1960 MAY	CT	26	26	26	25	25	24	22	22	22	21	20	14	21	15	24	16	24	24	26	26	26	24	24	23
		90%	145	143	150	155	164	172	186	205	205	205	203	196	187	154	177	175	179	176	172	167	165	158	149	145
		50%	162	165	167	166	171	186	204	210	212	212	210	211	210	207	204	203	198	191	183	178	174	169	165	164
		10%	180	184	184	184	187	197	209	216	217	217	217	216	217	215	215	213	212	207	197	189	185	181	179	178
		% R	19	35	35	24	24	23	68	95	100	100	100	100	100	93	96	100	100	100	100	100	92	46	25	22
5,128 kc/s	1960 JUNE	CT	28	28	27	27	27	26	27	26	26	25	20	22	22	24	25	26	22	24	21	25	27	28	27	29
		90%	159	154	156	157	170	180	191	196	196	198	193	193	194	189	181	183	181	180	179	170	167	168	167	163
		50%	177	175	175	178	188	197	202	206	208	210	207	206	205	204	205	202	199	196	196	188	187	186	186	181
		10%	187	191	188	196	198	205	216	216	216	216	216	216	216	216	216	216	216	212	216	196	196	192	193	193
		% R	21	21	11	19	30	65	89	96	100	100	100	100	100	100	100	100	100	100	100	96	96	96	78	59
5,128 kc/s	1960 JULY	CT	19	19	19	19	18	17	17	18	17	15	16	16	20	18	19	16	21	19	22	22	20	19	20	20
		90%	150	148	148	156	157	171	180	182	193	203	202	201	190	182	181	183	176	176	173	169	165	165	158	159
		50%	167	165	165	165	171	185	198	206	208	208	209	206	203	201	197	196	190	184	180	174	169	169	168	167
		10%	189	191	184	186	201	216	216	216	216	216	216	216	216	216	216	211	211	205	204	199	197	197	190	190
		% R	21	16		5	17	35	71	83	88	93	100	100	100	100	100	100	95	100	100	100	95	79	55	40
5,128 kc/s	1960 AUGUST	CT	29	28	26	25	25	23	24	24	27	27	28	27	27	29	30	29	28	29	30	30	30	30	30	30
		90%	148	148	147	145	147	158	180	189	197	204	205	204	196	189	184	183	179	174	168	164	159	152	150	148
		50%	161	161	159	159	159	169	185	200	205	208	212	209	206	204	201	195	189	182	176	172	167	166	164	161
		10%	173	177	173	166	182	187	198	209	214	217	217	217	217	215	210	205	202	194	186	182	180	178	176	175
		% R	10	11	8	4	4	4	25	83	93	96	100	100	100	100	100	100	100	100	100	97	70	23	23	17
9,947.5 kc/s	1959 AUGUST	CT	29	29	28	28	28	28	28	27	27	26	26	29	28	27	25	30	29	26	27	27	29	27	30	29
		90%	131	131	136	136	136	136	145	152	154	162	171	176	176	176	176	173	168	159	154	146	136	132	129	132
		50%	144	144	144	146	145	145	149	157	167	176	181	187	184	184	182	181	176	172	167	156	147	143	142	141
		10%	165	166	154	164	153	157	163	168	179	185	191	199	195	191	190	190	183	179	178	174	164	153	163	157
		% R		3	4	4				4	4	4	12	31	36	44	48	60	48	23	11	4	3			
9,947.5 kc/s	1959 SEPTEMBER	CT	24	22	23	23	22	24	22	21	22	21	18	19	21	20	20	22	24	22	19	20	25	23	25	22
		90%	136	130	134	135	138	137	138	147	154	156	170	168	173	173	172	162	161	146	143	136	128	125	131	134
		50%	147	159	153	152	148	145	145	151	163	173	179	184	185	184	180	177	170	161	151	144	139	139	148	152
		10%	172	175	182	174	177	171	170	173	177	185	196	205	202	196	193	191	187	172	165	158	151	152	165	171
		% R					5						6	26	29	20	20	27	12	5						
9,947.5 kc/s	1959 OCTOBER	CT	29	30	30	30	31	31	27	30	29	30	29	29	28	26	29	28	29	29	29	29	30	28	30	30
		90%	143	144	143	146	145	142	141	143	152	162	166	172	174	172	169	162	154	147	141	137	135	134	138	143
		50%	153	155	158	159	156	157	148	154	168	176	182	182	185	185	179	176	166	158	154	152	148	146	148	151
		10%	172	177	172	180	180	176	159	170	179	188	192	195	197	197	196	193	186	183	170	160	158	160	169	180
		% R	3	3		3	6	3				3	7	17	21	31	24	25	17	7	3					3
9,947.5 kc/s	1959 NOVEMBER	CT	25	26	24	24	24	24	24	24	22	26	26	27	26	28	28	29	29	28	28	28	29	29	26	26
		90%	147	150	147	153	155	154	149	143	150	158	166	169	173	169	168	158	151	147	142	141	144	145	145	149
		50%	162	167	164	167	165	164	159	156	159	171	173	178	179	182	176	167	164	155	152	151	151	152	153	161
		10%	178	188	187	185	187	189	175	167	175	188	187	198	198	204	202	193	181	170	161	157	158	161	175	185
		% R	4	12	8	4	4	12	4			8		22	15	18	18	21	10	7						4
9,947.5 kc/s	1959 DECEMBER	CT	28	28	28	28	28	27	28	28	28	28	27	27	28	26	27	27	28	29	29	29	29	29	29	29
		90%	151	153	156	154	158	161	157	146	148	154	161	171	170	172	165	162	155	150	150	147	146	146	148	151
		50%	161	168	172	165	166	168	167	160	162	168	175	181	186	183	180	171	166	161	159	155	154	155	157	161
		10%	182	185	190	190	188	180	176	173	182	182	190	189	193	191	194	184	174	169	170	164	164	162	165	175
		% R				4	4	4			4	4	7	4	11	8	19									
9,947.5 kc/s	1960 JANUARY	CT	31	31	31	30	31	30	31	31	31	31	31	30	31	31	31	31	31	31	30	31	31	31	30	30
		90%	144	143	152	150	152	148	147	139	142	145	155	165	169	172	167	157	147	143	142	141	139	141	139	141
		50%	158	164	162	163	160	160	160	152	155	167	172	176	181	181	180	171	162	156	155	153	149	151	151	158
		10%	175	183	182	181	178	174	172	164	172	173	187	202	198	198	196	186	178	174	170	162	162	159	167	165
		% R		10	10	3	6		3		3			13	10	13	16	10	6	6	3	3				

Table 4a. Monthly Diurnal Variation of System Loss and Percent Time Signal Below Noise, Barrow-Boulder 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
			HOURS MOUNTAIN STANDARD TIME (105° W)																							
9,947.5 kc/s	1960	CT	26	26	25	25	25	25	24	22	23	23	23	22	23	22	23	24	24	25	24	21	26	26	26	26
	FEBRUARY	90%	144	142	145	144	152	152	148	144	143	155	165	170	174	175R	174	166	158	148	140	138	139	138	139	144
		50%	153	157	161	162	161	160	159	148	161	168	175	179R	182R	188R	184R	178R	168	158	157	148	147	146	149	151
		10%	167	171	186	186	183	183	167	168	177	183	184	196	195	196	193	189	176	171	166	160	157	156	153	157
		% R			4		4	4	4					18	26	41	26	25	8							
9,947.5 kc/s	1960	CT	28	29	30	29	27	27	26	26	26	27	28	28	30	29	29	27	30	29	30	30	30	30	30	29
	MARCH	90%	144	147	148	145	148	144	138	144	155	164	170	175	173	179	178	172	163	154	147	141	137	135	133	140
		50%	153	163R	162	161	157	159	153	153	165	172	178R	184R	185R	187R	189R	180R	171R	163R	157R	153	147	146R	146R	151
		10%	172	176	177	178	183	178	159	163	173	188	191	196	198	198	197	195	190	180	173	167	167	168	177	179
		% R	4	3	3	3	15	11	4	4	12	7	11	21	23	34	48	37	23	7	7	3	3	7	10	10
9,947.5 kc/s	1960	CT	30	30	29	29	29	28	29	29	29	29	28	24	24	22	26	19	22	26	28	28	30	30	30	30
	APRIL	90%	141	139	140	140	141	139	145	148	158	165R	172	183R	187R	186R	179R	180R	167R	161	153	148	141	139	139	141
		50%	156R	154R	155R	152R	151R	148R	154R	160R	170R	175R	182R	197R	197R	194R	190R	190R	179R	174R	165R	159R	152	151R	153R	156R
		10%	189	185	193	193	194	189	184	186	186	196	204	205	205	205	201	202	195	185	179	180	171	177	177	183
		% R	23	20	17	17	17	18	21	24	31	28	25	58	54	41	42	58	50	38	25	18	10	10	13	20
9,947.5 kc/s	1960	CT	31	31	31	30	30	29	27	27	27	26	26	19	24R	19R	28R	19R	28	28	31	31	30	31	31	31
	MAY	90%	139	141	141	147	147	147	152	157	166	172	180	180R	186R	172R	180R	171R	174R	169R	161	153	148	142	139	142
		50%	155R	154R	159R	159R	156R	160R	163R	167R	178R	189R	193R	196R	194R	192R	193R	189R	180R	176R	172R	166R	159R	152	150R	150R
		10%	181	185	184	187	184	186	176	184	195	201	201	202	201	202	198	198	195	190	184	178	177	163	178	179
		% R	10	16	13	13	13	14	15	19	30	38	46	53	62	58	82	84	50	39	32	23	17	6	10	10
9,947.5 kc/s	1960	CT	29	30	30	30	30	30	30	30	30	30	30	28	29	27R	25	26	21	24	21	25	27	25	23	27
	JUNE	90%	140	141	140	142	142	147	152	151	162	171	175	182R	181R	180R	181R	178R	177R	172	161	156	153	148	144	142
		50%	148	153	152R	150	150	152	157R	164	172	178R	182R	191R	189R	190R	187R	184R	180R	177R	167R	164	160	157R	149R	150R
		10%	163	178	182	176	170	169	169	173	185	194	196	201	200	199	193	190	186	184	180	175	177	164	164	169
		% R	7	7	7	10	3		13	10	7	13	17	29	52	56	52	38	38	29	19	12	11	12	9	11
9,947.5 kc/s	1960	CT	27	27	27	27	27	26	25	24	24	23	24	25	29R	27R	26R	26R	28	27	30	29	28	28	27	27
	JULY	90%	139	138	143	144	140	144	148	154	161	172	179	183R	179R	181R	178R	177R	175R	168	162	155	147	144	142	140
		50%	148	147	148	152	149	150	154	162	172	181R	186R	189R	188R	186R	184R	182R	180R	176R	169R	163	157	150	148	149
		10%	179	172	160	171	163	169	166	170	184	192	196	195	195	193	190	186	185	184	180	172	162	159	160	165
		% R	7	4				4			4	17	46	60	62	63	62	54	57	37	17	3			4	
9,947.5 kc/s	1960	CT	30	29	28	27	27	27	27	27	27	27	27	26	27	29	30R	28	27	28	29	30	29	29	29	29
	AUGUST	90%	140	142	139	140	140	141	146	155	161	168	176	179R	182R	183R	180R	178R	169	162	156	151	143	138	136	139
		50%	153	155R	160	155	154	148	154	161	170	179R	185R	191R	192R	189R	188R	185R	179R	171R	164	159	154	150	146	149
		10%	182	182	180	181	178	160	167	168	180	190	199	197	197	195	191	188	185	180	176	167	160	156	170	177
		% R	7	10	4	4	4	4				11	30	50	63	66	63	46	33	21	7	3	3	3	7	7
14,688 kc/s	1959	CT	28	28	28	27	27	27	27	27	27	26	26	27	27	26	27	27	25	27	27	26	28	29	28	28
	AUGUST	90%	147	148	150	151	148	142	137	138	141	149	149	149	148	148	147	146	143	140	138	137	133	131	131	141
		50%	166	167	169	173R	163	153	148	149	150	160	161	160	159	160	156	152	149	147	145	146	144	145	148	156
		10%	190	188	189	192	189	183	170	170	171	172	171	175	183	177	168	164	161	154	158	156	152	171	178	182
		% R	4		7	4		4	4						4	4										
14,688 kc/s	1959	CT	25	25	25	25	25	25	25	24	23	22	22	22	22	21	25	27	26	25	24	24	24	25	25	25
	SEPTEMBER	90%	164	163	154	166	151	153	145	142	143	146	151	146-	145	141	146	139	139	140	137	134	133	131	144	148
		50%	181	181R	184R	186R	181R	182	173	171	168	169	165	168	164	163	161	160	153	145	143	144	146	153	175	178
		10%	193	196	198	196	197	194	199	193	187	183	186	187	179	175	171	172	165	161	156	160	171	180	188	189
		% R	8	16	16	20	4	4	4	8																
14,688 kc/s	1959	CT	30	30	30	30	30	30	30	30	28	30	28	31	30	28	31	30	31	31	31	31	31	31	30	30
	OCTOBER	90%	173	171	173	157	156	158	155	150	150	151	153	152	151	151	147	145	144	142	139	137	138	143	150	156
		50%	187	188R	194R	196R	197R	188R	166R	163	163	163	164	165	164	162	159	157	154	151	147	146	149	156	178	185
		10%	203	204	204	204	206	201	196	196	178	184	181	178	175	178	186	186	175	168	164	156	177	191	199	204
		% R	7	13	23	27	23	13	7	7							3	3	3						3	7
14,688 kc/s	1959	CT	23	23	22	22	22	23	22	23	22	22	23	22	21	23	23	23	22	23	24	25	26	25	24	23
	NOVEMBER	90%	182R	180R	182R	178R	181R	176R	167	149	148	153	154	154	155	154	152	150	143	140	140	140	145	160	162	170R
		50%	203R	203R	204R	204R	204R	203R	200R	167R	164R	171	169	165	164	164R	163	158	155	146	147	147	159	179R	195R	198R
		10%	211	208	207	207	207	213	212	203	203	194	185	181	181	197	188	182	180	170	155	163	192	202	203	205
		% R	56	65	68	64	55	61	45	17	9	5				9	4	4						12	33	48
14,688 kc/s	1959	CT	30	30	30	30	30	30	30	30	29	30	29	30	29	29	31	30	31	31	31	31	31	31	31	31
	DECEMBER	90%	176R	176	173R	165R	173R	175R	171R	161	146	147	155	160	158	160	157	153	146	144	145	142	149	154	174	174R
		50%	198R	199R	200R	200R	201R	201R	198R	182	161R	162	166	170	171	169	167	162	155	153	151	153	166	186R	192R	198R
		10%	204	205	205	206	206	206	205	198	200	192	180	175	182	179	181	173	167	162	162	167	195	202	204	205
		% R	43	47	43	47	57	60	47	7	10						3							16	32	45

Table 4b. Monthly Diurnal Variation of System Loss and Percent Time Signal Below Noise, Barrow-Boulder 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
			HOURS MOUNTAIN STANDARD TIME (105°W)																							
14,688 kc/s	1960	CT	30	30	30	30	30	30	30	30	30	31	31	28	30	30	30	30	30	30	30	30	30	30	29	29
	JANUARY	90%	161	169	171	174	173	164	159	154	145	147	149	153	155	154	153	148	144	141	140	138	140	144	156	160
		50%	185	199	201R	201R	199	195	194	177	165	165	163	167	166	166	162	161	153	149	148	148	154	169	179	183
		10%	204R	205R	204R	205R	204R	204R	204R	189	180	175	181	185	180	178	175	182	176	165	159	164	175	195	201R	199R
		%R	30	40	50	50	47	43	40	3	3			4											7	14
14,688 kc/s	1960	CT	28	27	27	27	27	27	26	25	26	26	25	25	28	27	27	28	26	26	24	23	27	28	28	27
	FEBRUARY	90%	158	155	159	157	160	161	156	153	150	152	152	153	156	152	151	148	145	140	137	136	136	139	148	154
		50%	189	194	196	196	201	199	191	160	162	161	161	164	168	166	158	156	152	148	147	141	144	151	167	185
		10%	203R	203R	203R	203R	202R	202R	200R	180	182	176	173	185	183	185	191	181	175	162	155	150	160	169	192	201
		%R	25	37	30	41	44	44	19	4	4			4	7											7
14,688 kc/s	1960	CT	27	27	29	28	26	26	26	26	26	27	28	28	30	29	31	28	31	28	29	29	30	29	29	28
	MARCH	90%	178	182	179	163	158	159	150	149	149	149	146	148	150	149	145	146	144	143	139	137	134	135	153	169
		50%	191	194	193	196	184	186	171	161	163	164	161	164	163	163	161	154	149	150	147	146	144	148	175	185
		10%	203R	202R	201R	202R	202R	199R	198R	195	184	183	178	182	181	182	184	180	178	172	163	164	175	187	192	197
		%R	15	19	17	25	23	19	15	4	4		4	4	3			4	3	4	3		3		3	4
14,688 kc/s	1960	CT	29	29	28	28	28	28	28	28	28	28	29	24	24	22	27	18	21	26	27	27	29	29	29	29
	APRIL	90%	151	161	162	162	167	149	140	141	144	145	149	159	154	153	154	155	148	143	142	140	133	135	136	147
		50%	184	188	192	187	190	186	174	170	167	167	170	174	171	166	164	172	166	155	154	153	153	167	179	183
		10%	199R	200R	201R	201R	202R	201R	201R	200R	199R	200R	200R	195R	197R	198R	191R	191R	197R	192R	198R	187R	194R	198R	199R	199R
		%R	24	31	25	29	29	25	21	14	21	18	17	25	17	18	11	17	19	15	15	7	14	17	24	31
14,688 kc/s	1960	CT	29	29	29	28	28	26	25	25	24	24	24	18	22	18	27	22	26	29	30	30	30	30	30	29
	MAY	90%	146	153	164	160	155	148	150	146	152	157	156	161	154	155	152	150	146	143	144	143	140	139	138	143
		50%	177	183	180	182	181	163	163	164	166	174	175	175	174	172	168	165	159	156	156	158	154	156	156	167
		10%	199R	199R	201R	201R	202R	203R	202R	197R	198R	201R	199	200R	204R	197	195	196R	193R	189	192	192R	193R	196R	197R	195R
		%R	14	14	[illegible]	18	21	31	16	20	17	12	12	11	5	6	4	9	12	3	3	10	10	10	13	10
14,688 kc/s	1960	CT	29	29	29	29	29	29	29	29	29	29	29	27	25	27	27	26	22	24	21	27	22	22	26	29
	JUNE	90%	140	143	146	154	148	141	142	144	146	150	153	158	156	153	153	151	149	142	138	137	136	137	135	135
		50%	177	185	184	176	164	158	157	161	161	164	169	173	167	167	162	159	156	156	148	150	148	148	155	171
		10%	194R	197R	197R	202R	199R	196R	184	175	178	178	183	192	191R	185	174	168	174	170	182	176	185	182	187	193R
		%R	10	14	14	21	17	14	7	3	3	3			4	4									4	7
14,688 kc/s	1960	CT	28	28	27	27	27	25	25	25	25	23	24	27	30	29	27	27	28	28	29	30	28	27	27	28
	JULY	90%	156	153	156	156	155	148	140	144	147	149	151	150	152	152	150	150	146	142	142	141	137	136	134	143
		50%	173	177	181	185	184	174	163	160	160	160	161	168	171	165	158	155	153	152	151	150	146	147	155	170
		10%	209R	208R	202	204R	209R	202	180	175	176	184	182	186	189	187	182	174	167	166	163	167	178	173	197R	202R
		%R	25	18	7	7	19	8							3	3							4	7	7	7
14,688 kc/s	1960	CT	30	30	29	29	29	29	29	28	28	28	29	28	28	29	29	29	29	29	30	30	30	30	30	30
	AUGUST	90%	166	169	169	159	161	151	141	143	146	151	152	155	155	155	150	147	144	142	141	139	137	136	138	152
		50%	181	184	187	186	190	179	169	163	164	163	165	166	166	165	161	158	154	148	148	146	148	148	155	177
		10%	199R	199	205R	205R	217R	206R	203R	186	178	178	178	181	180	178	171	164	162	165	165	162	185	184	195	203R
		%R	10	7	21	14	31	14	17	4													3	3	7	7
19,247 kc/s	1959	CT	27	27	26	27	27	27	26	27	27	26	28	27	27	25	25	25	26	28	28	28	29	28	27	27
	AUGUST	90%	168	163	175	172	172	158	149	142	146	142	141	142	141	140	143	142	137	135	135	140	140	139	145	171
		50%	194R	195	198	198R	199R	188	185	187	176	173	168	161	164	159	158	158	153	150	152	152	154	151	173	187R
		10%	204R	204R	205R	209R	209R	206R	203R	204R	201R	184	180	180	181	177	173	166	162	185	166	178	191R	191R	196R	202R
		%R	48	37	46	48	52	30	19	19	11									7		4	7	7	19	37
19,247 kc/s	1959	CT	26	26	26	26	26	26	26	24	25	26	24	22	24	24	26	26	26	28	27	27	27	27	27	27
	SEPTEMBER	90%	185	192	187	188	195	183	160	161	155	147	151	142	139	138	137	136	136	131	132	131	146	148	174	181
		50%	198R	199R	200R	200R	200R	198R	195R	194R	188R	180	168	167	165	159	154	154	151	146	148	154	169	181	189	194R
		10%	204R	206R	206R	206R	207R	206R	206R	208R	203R	200R	185	182	175	173	169	168	178	172	189	192	189	198R	200R	200R
		%R	69	77	69	77	69	62	54	58	44	23	8					4	8	7	4	4	4	15	30	48
19,247 kc/s	1959	CT	26	26	26	26	26	26	26	26	25	25	25	24	25	24	27	26	26	26	26	27	27	26	26	26
	OCTOBER	90%	191R	191R	192R	191R	193R	193R	185	160	149	149	146	146	140	142	140	140	136	135	134	133	142	159	171	191R
		50%	197R	198R	198R	199R	199R	200R	194R	185	177	170	160	157	152	150	155	150	146	144	144	146	167	190R	193R	196R
		10%	205R	205R	205R	207R	210R	206R	204R	202R	201R	200R	200	183	172	171	176	168	167	159	164	168	193R	203R	205R	205R
		%R	88	92	92	92	88	88	54	35	32	12	8	4									7	42	73	88
19,247 kc/s	1959	CT	27	27	27	27	27	27	27	27	27	28	28	28	27	27	29	29	28	28	29	28	28	28	28	27
	NOVEMBER	90%	198R	200R	199R	198R	201R	201R	200R	185	165	161	155	154	154	153	147	147	142	142	141	147	160	171	195R	197R
		50%	204R	205R	205R	206R	206R	206R	206R	202R	181	183	178	170	163	165	160	156	153	148	150	163	189	199R	202R	203R
		10%	215R	215R	215R	215R	215R	215R	215R	206R	205R	205R	202R	193	187	190	186	191	179	175	177	188	203R	205R	206R	210R
		%R	96	100	93	96	100	100	96	56	26	21	11				7	3					25	75	93	93

Table 4c. Monthly Diürnal Variation of System Loss and Percent Time Signal Below Noise, Barrow-Boulder 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
19,247 kc/s	1959	CT	30	30	30	30	30	30	30	30	29	30	30	31	31	29	31	31	31	31	31	31	31	31	31	31
	DECEMBER	90%	198	199	197	197	201	203	203	200	161	166	163	163	159	155	155	153	148	147	143	156	178	199	200	200
		50%	204	204	204	205	205	205	205	203	186	181	176	177	176	169	165	162	157	153	155	175	200	202	203	203
		10%	206	207	207	207	209	210	210	208	204	202	203	198	198	190	182	172	175	167	184	200	204	205	205	208
		%R	93	90	90	90	100	100	100	83	31	13	10		3							10	58	87	97	97
19,247 kc/s	1960	CT	26	26	26	26	26	26	26	26	23	23	23	23	24	24	24	24	24	25	25	26	26	26	25	25
	JANUARY	90%	199	202	202	202	203	203	201	185	159	158	153	152	155	152	151	148	144	140	139	142	157	181	195	194
		50%	204	205	205	205	206	206	205	203	178	175	170	166	164	161	155	154	152	148	147	157	188	201	202	203
		10%	211	210	210	211	211	211	212	209	204	195	194	193	185	179	179	171	166	165	166	183	203	205	209	209
		%R	88	96	92	96	96	100	88	73	22	4										4	42	77	88	84
19,247 kc/s	1960	CT	27	27	27	27	27	27	26	26	24	26	26	26	26	24	27	27	25	25	23	23	26	27	27	27
	FEBRUARY	90%	202	202	202	201	201	202	202	172	172	164	159	153	153	149	146	145	145	141	139	137	142	159	182	199
		50%	205	205	206	206	207	207	207	201	181	174	170	170	165	161	156	151	149	147	147	147	160	189	200	203
		10%	213	215	215	213	215	215	214	208	203	198	190	192	191	186	187	181	172	158	161	175	185	210	214	215
		%R	96	96	93	93	93	85	85	46	42	4		8	4		4							22	67	89
19,247 kc/s	1960	CT	27	27	27	27	26	26	26	26	26	26	27	28	29	30	31	29	28	28	30	30	31	30	30	29
	MARCH	90%	193	194	192	193	192	193	182	169	169	163	157	153	147	147	146	144	141	143	140	141	139	164	187	192
		50%	201	202	201	202	202	201	198	189	180	178	176	170	164	168	161	154	153	155	151	152	162	181	197	201
		10%	206	206	206	208	208	208	205	208	203	203	203	197	194	198	183	177	173	168	166	168	195	206	207	209
		%R	96	96	96	93	88	88	77	42	31	23	19	7	3	7	3	3	4		3	3	6	17	33	90
19,247 kc/s	1960	CT	26	26	25	25	25	24	25	25	25	24	25	22	23	23	22	21	19	23	24	24	25	26	26	26
	APRIL	90%	197	200	199	204	204	189	188	184	181	181	173	172	157	154	160	154	151	147	157	160	161	169	183	188
		50%	204	205	205	207	207	205	206	209	209	205	197	199	192	184	182	178	173	170	177	187	197	200	203	205
		10%	210	210	212	211	212	211	211	215	215	213	211	212	210	210	210	210	204	210	208	207	210	211	210	213
		%R	73	81	88	88	92	71	72	76	72	54	36	50	35	35	27	29	26	26	25	29	32	42	65	65
19,247 kc/s	1960	CT	23	23	23	22	22	20	19	19	19	19	18	18	18	18	17	19	17	19	21	21	21	22	22	22
	MAY	90%	165	173	188	199	188	175	162	161	175	172	168	171	158	154	160	155	148	153	152	157	155	158	162	157
		50%	204	205	207	206	208	202	205	204	199	195	189	184	178	179	179	168	171	169	168	168	169	175	187	197
		10%	214	214	215	215	215	211	214	213	215	212	210	211	215	215	202	194	203	204	207	209	207	207	209	209
		%R	56	74	78	74	68	50	68	58	47	16	11	11	11	11	6	5	12	16	24	24	14	23	36	32
19,247 kc/s	1960	CT	21	21	21	21	22	23	23	23	23	23	23	23	23	22	20	20	14	16	17	16	19	19	20	20
	JUNE	90%	184	177	172	182	182	158	152	158	155	152	160	158	152	153	152	154	149	145	149	152	151	152	154	159
		50%	201	204	205	206	205	203	200	204	188	178	176	176	174	172	169	170	162	154	157	161	159	180	197	198
		10%	205	206	208	209	209	209	208	209	208	194	183	191	191	194	186	182	171	201	200	201	203	204	205	205
		%R	43	57	67	76	55	48	26	52	17	4								19	12	19	21	26	30	35
19,247 kc/s	1960	CT	27	27	26	26	26	24	24	24	24	22	23	25	29	29	27	28	29	27	28	28	28	27	27	28
	JULY	90%	186	183	184	177	181	179	164	165	157	146	145	146	150	147	144	145	145	149	150	149	150	148	155	168
		50%	197	203	203	205	205	202	195	201	182	175	168	172	172	167	165	165	165	167	159	159	159	164	186	198
		10%	205	206	207	207	208	207	204	207	195	186	190	187	188	186	182	187	194	198	199	203	202	204	205	205
		%R	41	52	54	65	69	46	17	46							4	4	7	7	14	14	11	22	30	39
19,247 kc/s	1960	CT	31	31	30	29	29	29	29	29	29	29	29	28	29	30	31	30	30	30	31	31	31	31	31	31
	AUGUST	90%	187	197	200	202	202	184	163	166	162	152	152	153	149	148	146	146	142	145	149	151	151	150	166	181
		50%	205	207	207	208	207	204	201	203	196	183	177	176	175	170	167	163	156	160	161	161	161	191	197	204
		10%	210	210	210	210	210	209	208	208	207	203	196	193	191	192	193	190	187	196	199	201	204	207	208	209
		%R	68	84	77	83	86	62	45	52	31	14	3	4	3	3	6	3	7	17	10	10	13	19	39	55

Table 4d. Monthly Diurnal Variation of System Loss and Percent Time Signal Below Noise, Barrow-Boulder Path

FREQUENCY	YEAR	MONTH	SELECTED PERCENTAGES FROM MONTHLY 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
9,195 kc/s	1959	AUGUST	125	128	129	132	135	140	144	146	149	152	156	161	165	167	169	173	175	177	178	179	181	181	183	183
	1959	SEPTEMBER	123	124	124	126	128	133	136	139	142	144	147	151	156	159	164	166	170	173	174	174	174	175	178	178
	1959	OCTOBER		125	129	132	136	138	140	143	147	151	159	165	167	169	173	176	179	183	186	188	196	197	200	202
	1959	NOVEMBER	124	125	128	130	132	134	136	137	139	141	144	147	150	153	157	160	165	167	170	172	173	174	175	177
	1960	MARCH	129	129	131	132	134	136	138	140	142	144	147	152	164	177	182	183	R 189	R 191	R 192	R 192	R 193	R 193	R 193	R 193
	1960	APRIL	128	129	130	132	134	137	140	142	145	149	158	180	183	R 184	R 193	R 193	R 193	R 193	R 193	R 193	R 194	R 194	R 194	R 194
	1960	MAY	137	138	139	141	143	146	149	152	156	160	165	172	183	R 195	R 202	R 203	R 203	R 203	R 203	R 203	R 204	R 204	R 204	R 204
	1960	JUNE	139	139	141	142	144	146	149	152	154	158	162	166	170	175	179	182	185	187	189	190	R 191	R 192	R 195	R 196
	1960	JULY	122	123	125	127	130	134	136	139	141	143	145	148	150	152	153	154	157	160	162	163	163	164	165	165
	1960	AUGUST	119	120	121	124	126	129	132	134	136	139	141	143	145	147	150	152	155	157	158	160	164	165	167	169
12,036.5 kc/s	1959	AUGUST	119	122	123	126	129	131	134	136	138	141	145	149	153	157	163	166	173	177	178	179	181	182	183	184
	1959	SEPTEMBER		117	118	121	123	126	130	133	136	138	143	147	151	157	163	169	174	176	180	181	183	184	185	188
	1959	OCTOBER	118	119	119	121	123	126	128	130	132	134	136	138	141	144	147	150	155	158	162	165	167	169	170	172
	1959	NOVEMBER		123	124	125	128	131	134	136	137	139	142	146	151	154	156	161	168	170	175	177	177	177	177	178
	1960	MARCH		129	130	131	133	135	136	138	140	141	144	151	166	176	189	R 191	R 193	R 194	R 194	R 195	R 195	R 195	R 195	R 195
	1960	APRIL	128	129	131	133	136	138	141	143	145	149	157	177	192	R 194	R 199	R 203	R 213	R 213	R 214	R 214	R 214	R 214	R 214	R 214
	1960	MAY	132	135	137	139	141	145	147	149	152	156	159	167	177	190	R 197	R 201	R 204	R 204	R 204	R 204	R 204	R 204	R 204	R 204
	1960	JUNE	136	136	137	140	142	145	146	148	150	153	156	159	163	166	169	172	175	178	180	182	183	R 184	R 185	R 188
	1960	JULY		128	130	132	134	137	139	141	143	144	146	148	150	151	153	154	157	160	165	168	173	177	R 180	R 181
	1960	AUGUST	126	127	129	131	133	137	139	141	143	145	146	150	153	155	159	162	170	173	176	178	179	R 180	R 181	R 182

Table 5. System Loss at 24 Selected Percentages from Monthly Cumulative Distributions, Thule-Barrow Path

FREQUENCY	YEAR	MONTH	0.5	01	02	05	10	20	30	40	50	60	70	80	86	90	93	95	97	98	986	99.0	99.3	99.5	99.7	99.8
			SELECTED PERCENTAGES FROM MONTHLY CUMULATIVE DISTRIBUTIONS																							
5,128 kc/s	1960	MARCH		111	112	114	118	124	128	133	137	145	151	162	175	184	193	200	202	202	202	202	203	203	205	206
	1960	APRIL	113	114	116	119	123	133	141	148	156	167	177	195	201	202	203	203	203	203	203	203	203	203	203	203
	1960	MAY	114	115	117	124	131	139	147	153	160	167	173	185	191	201	202	203	203	203	203	203	203	203	203	203
	1960	JUNE	119	121	124	128	131	138	142	148	154	160	169	179	189	197	200	202	203	203	203	203	203	203	203	203
	1960	JULY	114	116	119	122	126	131	135	140	145	148	155	163	169	176	185	189	196	197	198	200	202	202	202	203
	1960	AUGUST	112	113	114	119	124	129	135	142	149	155	161	171	179	188	198	201	202	203	203	203	203	203	203	203
9,947.5 kc/s	1959	DECEMBER	118	120	121	124	126	131	136	139	142	147	153	159	163	165	166	169	171	174	178	178	180	184	188	195
	1960	JANUARY	115	117	118	120	122	126	131	135	139	144	149	156	160	163	166	169	172	174	176	178	178	179	181	181
	1960	FEBRUARY	116	117	118	120	123	128	131	134	138	143	147	155	160	164	166	169	178	180	182	185	187	188	189	189
	1960	MARCH		114	116	118	120	124	130	136	139	142	147	154	159	165	168	174	181	186	188	189	190	191	197	199
	1960	APRIL	115	115	117	120	124	133	138	143	148	155	163	174	185	192	201	205	210	211	211	212	212	212	213	213
	1960	MAY	118	119	120	122	125	132	136	141	145	149	153	161	168	179	183	192	199	202	205	208	210	211	212	212
	1960	JUNE		111	113	116	119	125	130	134	138	142	147	152	156	161	164	167	171	173	174	175	177	179	188	193
	1960	JULY	111	112	113	115	118	123	127	130	133	136	141	145	149	153	156	158	162	166	169	171	174	175	180	181
	1960	AUGUST	111	112	113	117	121	126	129	132	135	138	142	149	151	155	159	160	165	172	175	177	178	181	190	198
14,688 kc/s	1959	DECEMBER	116	118	119	122	126	135	142	150	158	162	167	172	174	178	180	182	185	187	188	189	190	190	191	191
	1960	JANUARY	112	114	115	118	121	128	138	147	154	158	165	171	175	177	180	182	184	186	187	188	189	189	190	190
	1960	FEBRUARY	115	116	117	120	122	128	137	143	153	159	165	170	173	177	178	181	184	186	188	188	190	191	192	192
	1960	MARCH	116	117	118	121	132	142	149	157	162	166	170	174	177	179	181	183	187	189	190	191	193	193	196	197
	1960	APRIL	130	134	135	139	144	151	157	163	167	171	176	184	189	192	193	198	201	202	203	203	203	203	203	203
	1960	MAY	129	130	132	136	139	143	148	153	158	163	167	171	175	179	184	188	191	191	192	192	192	192	192	193
	1960	JUNE	131	132	132	134	136	139	143	146	149	154	159	164	167	169	172	174	176	179	181	182	187	188	189	190
	1960	JULY	126	127	128	131	133	136	139	143	147	152	157	163	166	168	170	171	173	176	178	181	186	188	189	190
	1960	AUGUST	128	129	130	132	136	140	145	150	155	160	164	167	169	172	174	176	179	180	182	186	187	189	191	191
19,247 kc/s	1959	DECEMBER	116	118	124	133	138	150	158	165	168	171	177	179	179	179	179	181	186	188	188	189	189	189	189	189
	1960	JANUARY	109	110	112	117	124	144	158	166	173	178	177	179	180	180	180	180	180	180	183	185	187	188	189	189
	1960	FEBRUARY	113	115	117	122	137	149	158	165	170	177	179	179	179	182	182	184	187	187	189	189	189	190	190	190
	1960	MARCH	139	141	142	147	153	165	170	175	178	182	187	191	192	192	193	197	199	200	201	201	201	202	202	202
	1960	APRIL	141	144	147	150	155	169	180	187	190	192	197	202	202	202	202	202	202	202	202	202	202	202	202	202
	1960	MAY	139	142	143	146	150	157	174	181	186	187	187	189	191	192	192	192	192	198	199	200	201	201	202	202
	1960	JUNE	134	136	138	143	147	153	160	169	178	181	183	186	187	187	188	189	190	191	191	191	192	192	192	192
	1960	JULY	133	135	138	141	146	153	163	174	180	182	184	186	187	187	188	188	189	190	191	191	191	192	192	192
	1960	AUGUST	137	139	140	142	145	158	171	178	181	184	186	187	188	188	189	189	189	190	190	190	190	190	191	191

Table 6. System Loss at 24 Selected Percentages from Monthly Cumulative Distributions, Barrow-Kenai Path

FREQUENCY	YEAR	MONTH	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
			SELECTED PERCENTAGES FROM MONTHLY CUMULATIVE DISTRIBUTIONS																							
5,128 kc/s	1960	MARCH	137	140	144	149	153	158	163	169	178	190	201	207	210	213	215	216	217	217	217	217	217	217	217	217
	1960	APRIL	141	142	143	149	153	163	171	178	185	194	201	205	207	210	212	215	216	217	217	217	217	217	217	217
	1960	MAY	141	143	147	153	160	167	174	180	186	197	205	209	212	213	214	215	216	216	217	217	217	217	217	217
	1960	JUNE	151	154	158	165	170	179	185	190	194	199	203	206	211	215	216	216	216	216	216	217	217	217	217	217
	1960	JULY	147	148	152	158	163	168	174	182	188	195	201	206	211	215	215	215	216	216	216	216	216	216	216	216
	1960	AUGUST	142	143	146	150	155	162	167	173	181	189	199	205	207	210	212	215	217	217	217	217	217	217	217	217
9,947.5 kc/s	1959	AUGUST	126	128	130	135	138	143	148	152	159	168	175	180	182	184	188	191	193	195	196	198	199	199	200	203
	1959	SEPTEMBER	125	127	128	134	137	143	148	152	160	166	172	178	182	187	189	191	196	201	205	208	211	212	214	214
	1959	OCTOBER	133	134	136	140	143	147	152	156	161	168	173	179	183	186	189	191	193	195	196	197	200	201	203	204
	1959	NOVEMBER	139	141	142	145	148	151	155	159	162	167	172	178	182	186	190	193	196	199	202	204	205	205	206	207
	1959	DECEMBER	142	145	146	148	151	155	159	162	166	169	173	179	182	185	187	189	191	192	194	195	198	200	201	202
	1960	JANUARY	136	137	138	141	145	150	153	157	161	164	169	174	178	182	187	190	195	196	198	201	202	203	205	206
	1960	FEBRUARY	137	138	139	141	144	148	152	156	161	166	171	177	182	185	188	190	193	194	194	195	196	196	197	197
	1960	MARCH	132	134	136	140	144	149	153	157	163	169	174	180	184	189	193	194	195	196	197	198	199	199	200	200
	1960	APRIL	135	136	138	140	145	150	154	161	169	177	183	189	193	196	198	199	202	204	205	205	206	206	207	207
	1960	MAY	137	138	140	144	148	153	159	164	172	178	184	190	193	196	198	200	201	201	202	202	202	202	203	203
	1960	JUNE	138	139	141	143	146	151	156	161	167	174	179	184	187	189	191	193	196	197	199	200	201	202	203	204
	1960	JULY	135	137	139	142	144	149	152	159	165	173	179	184	186	188	189	191	193	195	196	197	198	198	199	202
	1960	AUGUST	134	136	138	140	143	149	154	159	165	172	179	184	187	189	191	193	195	196	197	198	198	199	199	199
14,688 kc/s	1959	AUGUST	130	131	132	137	141	145	148	150	154	158	164	170	175	178	181	185	189	190	193	195	197	199	200	201
	1959	SEPTEMBER	131	131	134	138	142	148	153	159	165	171	176	182	187	190	193	195	197	199	200	200	203	204	204	204
	1959	OCTOBER	135	137	139	143	147	151	155	160	165	172	180	188	194	198	200	202	204	204	205	206	206	206	206	207
	1959	NOVEMBER	139	140	141	144	147	154	160	165	173	181	193	202	204	204	205	206	207	208	212	212	213	214	215	215
	1959	DECEMBER	142	143	145	147	152	157	163	167	173	182	194	199	202	203	203	204	205	206	206	207	207	207	207	207
	1960	JANUARY	138	139	140	143	147	153	158	163	168	174	182	193	200	202	203	203	204	205	205	205	205	206	206	206
	1960	FEBRUARY	135	136	137	140	145	151	154	158	163	169	178	191	197	200	201	202	202	203	203	203	203	203	203	204
	1960	MARCH	133	135	137	141	144	150	154	160	165	172	181	188	194	197	199	201	201	202	202	203	203	203	203	203
	1960	APRIL	132	134	136	141	146	153	161	166	171	179	187	195	197	199	200	201	202	203	203	204	204	205	205	205
	1960	MAY	137	139	140	143	148	154	157	163	168	174	181	189	195	197	199	201	203	203	203	204	204	205	206	206
	1960	JUNE		134	135	139	144	148	153	157	161	165	171	181	186	189	193	196	199	201	202	204	206	208	209	213
	1960	JULY	134	136	138	141	144	150	153	156	160	165	172	180	186	191	197	202	205	208	209	210	211	212	214	215
	1960	AUGUST	134	136	137	141	144	150	154	159	163	169	175	182	187	191	199	202	204	206	211	212	214	215	216	216
19,247 kc/s	1959	AUGUST	132	133	136	140	142	149	155	162	170	177	185	194	198	200	202	203	206	209	209	209	210	210	210	210
	1959	SEPTEMBER	130	131	133	137	143	151	159	168	178	188	195	198	200	201	202	203	206	210	214	214	214	215	215	215
	1959	OCTOBER	130	133	135	139	142	148	157	166	177	190	194	199	201	203	204	205	206	208	209	212	213	214	214	214
	1959	NOVEMBER	139	141	142	146	151	158	168	179	192	200	203	205	206	209	210	213	214	215	215	215	215	215	215	215
	1959	DECEMBER	142	145	147	152	156	165	173	183	197	201	203	204	205	205	206	207	209	210	210	212	213	214	214	214
	1960	JANUARY	138	139	141	145	151	157	165	172	186	200	202	204	205	206	208	209	212	214	214	215	215	215	215	215
	1960	FEBRUARY	137	139	140	143	147	153	161	171	182	198	203	205	207	208	209	212	214	214	215	215	215	215	215	215
	1960	MARCH	137	139	140	143	148	157	166	173	182	194	198	202	204	205	205	207	208	209	209	210	210	211	213	214
	1960	APRIL	146	149	151	159	165	178	188	197	203	204	206	208	209	210	212	213	214	214	215	215	215	215	215	215
	1960	MAY	147	148	150	155	160	166	174	183	192	199	203	207	209	210	212	213	214	214	215	215	215	215	215	215
	1960	JUNE	142	145	147	150	153	160	168	174	182	191	199	203	205	206	206	207	208	208	209	209	209	209	209	210
	1960	JULY	141	142	144	146	149	156	164	173	179	187	195	202	204	205	205	206	207	207	208	208	208	209	209	209
	1960	AUGUST	140	142	144	147	151	160	167	177	187	196	203	205	207	208	208	209	209	210	210	210	210	210	211	211

Table 7. **System Loss at 24 Selected Percentages from Monthly Cumulative Distributions, Barrow-Boulder Path**

April 1960 10 Mc/s 00-01 MST 01-02 MST

Date	F	1F2	2F2	3F2	4F2	1F1	2F1	E
1								
2								
3								
4	A							
5	AB							
6								
7	AB							
8								
9	AB							
10	AB							
11	A							
12	A							
13	B							
14	AB							AB
15	AB							
16	B							
17	AB							
18								
19								
20		AB	AB	A				
21			AB	AB				
22	B	A	A					
23		AB	AB					
24								
25	A							
26	AB							A
27	AB							AB
28								
29	AB							
30								

April 1960

Date	F	1F2
1		
2		
3		
4		
5	AB	
6		
7		
8		
9		
10		
11		
12		
13		
14	AB	
15		
16		
17		
18		
19		
20		AB
21		
22	B	A
23		AB
24		
25		
26		
27		
28		
29		
30		

April 1960 10 Mc/s 12-13 MST 13-14 MST

Date	F	1F2	2F2	3F2	4F2	1F1	2F1	E
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16				No Data				
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								

April 1960

Date	F	1F2
1		
2		
3		B
4		
5		
6		
7		
8		
9		AB
10		
11		B
12		
13		
14		
15		
16		
17		
18		B
19		A
20		
21		
22		A
23		
24		
25		B
26		
27		
28		
29		
30		

Table 8. CW-Signal Modes Deriv
Notes 1. F means Aurc
2. A is first hou
3. B is second h

1960 15 Mc/s 00-01 MST 01-02 MST

F	1F2	2F2	3F2	4F2	1F1	2F1	E
AB							
AB							AB
	AB						
		AB					
B	A						
	AB						
							AB

April 1960 20 Mc/s 00-01 MST 01-02 MST

Date	F	1F2	2F2	3F2	4F2	1F1	2F1	E
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								A
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								

April 1960 15 Mc/s 12-13 MST 13-14 MST

F	1F2	2F2	3F2	4F2	1F1	2F1	E
	B					AB	
		AB				AB	
	AB						
	B						
	B						
	A					AB	
	A						
	B						

April 1960 20 Mc/s 12-13 MST 13-14 MST

Date	F	1F2	2F2	3F2	4F2	1F1	2F1	E
1								
2								
3						AB		
4								
5		AB				AB		
6		B				AB		
7								
8								
9		B						
10						B		
11						AB		B
12								
13								
14								
15								
16								
17						B		B
18						B		
19		AB	B			B		
20		B						
21		B						
22		B						B
23			B					B
24								
25								
26								
27								
28								
29								
30								

s Derived from Sweep-Pulse Records, April 1960
ns Auroral Spread F
rst hour after noon or midnight MST
cond hour after noon or midnight MST

May 1960 10 Mc/s 00-01 MST 01-02 MST

Date	F	1F2	2F2	3F2	4F2	1F1	2F1	E
1								
2	A							
3	A	B	B					
4	B	AB	AB					
5								
6								
7								
8								
9								
10	A							
11								
12		A						
13								
14								
15								
16		B	AB	AB			B	
17								B
18		B						
19	AB							
20		AB	AB	A				
21	B		A					A
22		AB	AB	AB				
23		AB	AB	AB				AB
24	A							
25								AB
26	AB							
27								
28	AB							
29								
30	A							AB
31								B

May 1960 15 Mc/s 00-01 MST 01-02 MST

Date	F	1F2	2F2	3F2	4F2	1F1	2F1	E
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								B
11								
12								
13								
14								
15								
16		AB	AB					B
17								B
18		B						
19	AB							
20		AB						
21		A						
22		AB	AB					
23		AB	A					
24								
25								A
26								
27								
28	A							
29								
30								
31								AB

May 1960 10 Mc/s 12-13 MST 13-14 MST

Date	F	1F2	2F2	3F2	4F2	1F1	2F1	E
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16				No data				
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								

May 1960 15 Mc/s 12-13 MST 13-14 MST

Date	F	1F2	2F2	3F2	4F2	1F1	2F1	E
1								
2			B					
3							B	
4								
5								
6								
7								
8								
9								
10		B						
11								
12								
13								
14								
15		B						A
16		AB					A	B
17								
18								
19								
20								
21		B	B					
22		A	AB					
23		A	AB					B
24								
25								
26								
27		B						
28								
29								
30								
31	AB							AB

Table 9. CW-Signal Modes Derived from Sweep-Pulse
Notes 1. F means Auroral Spread F
2. A is first hour after noon or midnig
3. B is second hour after noon or midi

MST
MST

May 1960 20 Mc/s 00-01 MST
01-02 MST

E (cut off)	Date	F	1F2	2F2	3F2	4F2	1F1	2F1	E
	1								
	2								
	3								
	4								
	5								
	6								
	7								
	8								
	9								
B	10								
	11								
	12								
	13								
	14								
	15								
B	16		AB						
B	17								B
	18								
	19								
	20		A						
	21								
	22		AB						
	23		A						
	24								
A	25								
	26								
	27								
	28								
	29								
	30								
AB	31								

13 MST
14 MST

May 1960 20 Mc/s 12-13 MST
13-14 MST

E (cut off)	Date	F	1F2	2F2	3F2	4F2	1F1	2F1	E
	1								
	2						B		
	3		B				AB		AB
	4								
	5								
	6								
	7								
	8								
	9		B				A		A
	10								
	11								
	12		B						
	13								
	14								
A	15						B		AB
B	16		B				AB		AB
	17		AB				AB		AB
	18								
	19		B						
	20		B				B		
	21		AB				AB		
	22		AB						AB
B	23		AB						A
	24								
	25								
	26								
	27								
	28								
	29								
	30								
AB	31								

2

p-Pulse Records, May 1960

r midnight MST
or midnight MST

June 1960 — 10 Mc/s — 00-01 MST, 01-02 MST

Date	F	1F2	2F2	3F2	4F2	1F1	2F1	E
1								
2								
3								
4								
5								
6								
7								
8	AB							
9			AB					
10	B	A	A	A				AB
11								
12								
13								
14	AB							AB
15	B		A					
16			AB					
17		AB	AB					
18		B	AB					AB
19	AB							
20	AB							
21	AB							
22	A							A
23	AB							AB
24								
25	AB							
26	A							
27	AB							
28	A							
29								
30								

June 1960 — 15 Mc/s

Page	F	1F2	2F2	3F2
1				
2				
3				
4				
5				
6				
7				
8				
9		AB		
10	B	A	A	
11				
12				
13				
14				
15		A		
16		AB		
17		AB		
18		AB		
19				
20	B			
21				
22				
23				
24				
25				
26				
27				
28	A			
29				
30				

June 1960 — 10 Mc/s — 12-13 MST, 13-14 MST

Date	F	1F2	2F2	3F2	4F2	1F1	2F1	E
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18				No data				
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								

June 1960 — 15 Mc/s

Date	F	1F1	2F2	3F2	4F2
1					
2					
3					
4					
5					
6					
7		AB			
8					
9					
10					
11					
12					
13					
14					
15		AB			
16		AB			
17		AB			
18					
19					
20					
21					
22		AB			
23		AB			
24					
25					
26		AB			
27					
28					
29					
30					

Table 10. CW-Signal Modes Derived from Swe

Notes 1. F means Auroral Spread

2. A is the first hour after n

3. B is second hour after no

960 | 15 Mc/s | 00-01 MST / 01-02 MST

	1F2	2F2	3F2	4F2	1F1	2F1	E
1							
2							
3							
4							
5							
6							
7							
8							
9	AB						
10	A	A					B
11							
12							
13							
14							AB
15	A						
16	AB						
17	AB						
18	AB						AB
19							
20							
21							
22							
23							AB
24							
25							
26							
27							
28							
29							
30							

June 1960 | 20 Mc/s | 00-01 MST / 01-02 MST

Date	F	1F2	2F2	3F2	4F2	1F1	2F1	E
1								
2								
3								
4								
5								
6								
7								
8								
9								
10		AB						B
11								
12								
13								
14								
15								
16								
17								
18								A
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								

15 Mc/s | 12-13 MST / 13-14 MST

	1F1	2F2	3F2	4F2	1F1	2F1	E
1							
2							
3							
4							
5							
6							
7	AB						
8							
9							
10							
11							
12							
13							
14							
15	AB						
16	AB						
17	AB						
18					AB		B
19							
20							A
21							A
22	AB						
23	AB						A
24							
25							
26	AB						
27							
28							
29							
30							

June 1960 | 20 Mc/s | 12-13 MST / 13-14 MST

Date	F	1F1	2F2	3F2	4F2	1F1	2F1	E
1								
2								
3								
4								
5								
6								
7		A				AB		B
8						A		A
9								
10								
11								
12						AB		AB
13		AB				AB		A
14						AB		AB
15						AB		AB
16						AB		AB
17		AB				B		
18						AB		AB
19		B						
20								AB
21								
22		A						AB
23						B		AB
24								
25								
26								
27								
28								
29								
30						B		B

Derived from Sweep-Pulse Records, June 1960
Auroral Spread F
first hour after noon or midnight MST
ond hour after noon or midnight MST