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C.C.I.R.

REPORT No. 65

Revision of Atmospheric Radio Noise Data

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REPORT No. 65 *

REVISION OF ATMOSPHERIC RADIO NOISE DATA

(Recommendation No. 120 — Study Programme No. 96 (VI))

(Warsaw, 1956)

1. *Introduction.*

The determination of the minimum signal level required for satisfactory radio reception in the absence of other undesired radio signals necessitates a knowledge of the noise with which the desired signal must compete at the receiving location. Studies of radio noise levels have been in progress for a number of years.

The initial research leading to the first publication of predictions of world-wide radio noise levels was carried out in 1942 by a group in the United Kingdom at the Interservices Ionosphere Bureau and in the United States at the Interservice Radio Propagation Laboratory (1).

Predictions of world-wide radio noise have been published subsequently in R.P.U. Technical Report No. 5 (2) and NBS Circular 462 (3). In these publications noise grade maps and prediction curves were given, indicating the noise level in terms of the minimum required signal strength to assure radiotelephone communication for ninety per cent of the time in the presence of atmospherics.

A more recent publication, NBS Circular 557 (4), presents the same noise grade maps as used in the previous publications. However, the prediction curves have been revised to show the expected median levels of radio noise during four-hour time blocks for each season instead of the required field strength for 90 per cent intelligibility. The method of interpreting the earlier predictions was not entirely clear and the present method of presenting that data has been used to remove the ambiguities so that further data can be compared with them more readily.

The compilation of more recent data indicates that, although the predictions presented in Circulars 462 and 557 have been found useful by many administrations, large discrepancies appear between measured values and the expected values from the predictions for some locations and times. For this reason, the preparation of entirely new predictions was undertaken.

These new predictions show primarily the expected values of a selected parameter of the atmospheric noise passed by a narrow-band filter. Values are given on a world-wide basis for all frequencies from 10 kc/s to about 30 Mc/s for all times of the day and night and all seasons of the year.

In preparing this report, slightly more emphasis was placed on data recorded during periods of high sunspot activity than on data recorded during periods of low sunspot activity when both were available. Also, the expected effect of high sunspot activity was to a small extent considered in determining the diurnal variations of the noise at locations where no data were available. Since a period of high sunspot activity is approaching, this method should give the best estimates of the expected noise in the near future. While it is felt that the phase of the sunspot cycle will affect the amount of received noise, it has not been possible to show satisfactory sunspot correlation with the available noise data. Therefore, no further account, other than the above, has been taken of the phase of the sunspot cycle.

* This Report was adopted unanimously.

Wherever possible, the predictions are based on actual measurements. Unfortunately, even measurements in recent years have been made by a number of different methods and many are difficult to interpret. Also, measurements are often vitiated by the presence of man-made noise or by lack of sensitivity in the equipment.

2. *The basic parameters.*

The basic parameter, F_a (4), used to describe the noise is related to the noise power available from a short, vertical, grounded, loss-free aerial. If the aerial is short compared with the wavelength, the available power is independent of its length.

The noise power shows large, rapid fluctuations, but if it is averaged over several minutes, the average values are found to be nearly constant during a given hour; the variations of the average seldom exceed 2 or 3 db except during sunrise or sunset periods or during a local storm. The basic parameter used is, therefore, the median value of the average power during a period of one hour—called the hourly value. In using the noise measurements where the noise was sampled for only a few minutes each hour, it is assumed that the result represents the hourly value.

The hourly value, in terms of F_a, is expressed in decibels relative to the thermal noise power which would be available from the aerial if it were at a specified temperature, T. F_a may, therefore, be regarded as an effective aerial noise figure. The reference power level is kTB watts where:

k = Boltzmann's constant $= 1.38 \times 10^{-23}$ Joules per degree Kelvin,
T = reference room temperature = 288°K,
B = effective noise bandwidth in cycles per second.

In this report, the value of T has been chosen as 288°K so that with the value of k given above, $10 \log_{10} kT$ will equal 204 db below 1 Joule per c/s. If the noise figure measurements are made at significantly different temperatures, they can be adjusted to this value for convenience and uniformity.

Since the available noise power from all sources is assumed to be proportional to bandwidth, as is the reference power level, F_a is independent of bandwidth.

F_a in db is simply related to the r.m.s. field strength at the aerial by the following equation:

$$E_n = F_a - 65.5 + 20 \log_{10} f$$

where

E_n = the r.m.s. field strength for a 1 kc/s bandwidth in db above 1 μV/m
f = the frequency in Mc/s

It should be noted particularly that this is an effective field strength; the conformation of the incident waves may be complex, and cannot be deduced from measurements on a single vertical aerial. Therefore, E_n represents only the vertically polarised component.

3. *The plotted parameters.*

It is not practicable to quote the hourly values F_a and E_n for all times and places. The presentation of the data has been simplified by considering the four seasons and six four-hour periods of the day. The time period defined by a given four-hour period of the day and a season is a time block. Thus, there are, in the year, 24 time blocks each consisting of about 360 hours (four hours on each of about 90 days).

For the purpose of this report, the year has been divided into four seasons of three months each, as follows:

Months	Seasons Northern Hemisphere	Seasons Southern Hemisphere
December, January, February	Winter	Summer
March, April, May	Spring	Autumn (Fall)
June, July, August	Summer	Winter
September, October, November	Autumn (Fall)	Spring

The plotted parameter is the median hourly value for each time block, and the variations in this parameter show the diurnal and seasonal variations of the noise. In the present state of our knowledge, the variations of the hourly values within a time block must be treated as random, and their extent is indicated by the ratios of the upper and lower decile values to the medians (see Section 6).

4. *Factors involved in the predictions.*

For convenience, the factors involved in the preparation of the predictions are summarised below:

(a) Type of aerial

A vertical grounded monopole, short compared with the wavelength, is assumed.

(b) Basic parameter

The hourly median value of the available noise power expressed in terms of an effective noise figure, F_a, is used as the basic parameter. The effective field strength at the aerial, E_n, is also given.

(c) Plotted parameter

The plotted parameters used in these predictions are the median values of F_a and E_n, denoted by F_{am} and E_{nm}, for a time block. The time block is defined as the aggregate of all hours within a given four-hour period of the day and a given season.

(d) Time variations

As an indication of random variations of the hourly values within a time block, typical figures are given for the ratios of upper and lower decile values to the median.

(e) Location

Results of actual noise measurements are available for only a few places. The data used were obtained from references 4, 5, 6, 7, 8 and 9. Additional data were obtained from the following reports:

Herman V. Cottony, " Memorandum report on observations of atmospheric radio noise in arctic regions ", U.S. Department of Commerce, National Bureau of Standards, C.R.P.L., Jan. 1948.

H. E. Dinger, W. E. Garner, G. E. Leavitt, " Measurements of some low and very low frequency atmospheric noise in the Alaskan area ", N.R.L. Report No. 3958.

Statements of K. A. Norton, R. Bateman, C. A. Ellert; Ship Power Hearing, Federal Communications Commission, Report No. 30539, November 14, 1938.

Edward W. Allen, Jr., Report of Committee No. 1, Part III, FCC Clear Channel Hearing, Docket 6741, February 15, 1946.

Data were also used from additional measurements made in the United States by the Central Radio Propagation Laboratory and in the United Kingdom by the Radio Research Station. Values for other parts of the world are deduced by interpolation, based on a knowledge of thunderstorm distribution (10) and of radio propagation characteristics.

(f) Frequency

The charts are drawn with contours of estimated noise at 1 Mc/s. Values at other frequencies are obtained from those for 1 Mc/s by means of sets of curves.

(g) Bandwidth

Values of F_a are independent of bandwidth. Values of E_n are for a 1 kc/s bandwidth and it may be assumed that the r.m.s. noise field is proportional to the square root of the bandwidth.

5. *Description of the data.*

Figures 1 to 20 inclusive are of charts showing the estimated median values of F_a in db at a frequency of 1 Mc/s for each of the 24 time blocks of the year. Corresponding values of E_{nm} in db above 1 μV/metre may be derived by subtracting 65.5 db from the plotted values. The differences between the time blocks 0000 to 0400 and 2000 to 2400 do not appear to be significant, as far as is known at present. Therefore, one chart is used for these two time blocks for each season.

Noise values at frequencies other than 1 Mc/s are derived by the use of figures 21 and 22 for F_{am} or figures 23 and 24 for E_{nm}; the 1 Mc/s noise grade is obtained from a chart and the curves are used to extrapolate to the desired frequency. Figures 21 or 23 are used for daylight at the receiving point and figures 22 or 24 for night-time. While the variation of noise with frequency is found to vary to some extent from place to place, these curves appear to represent the variations as well as is justified by the accuracy of the data available at present.

The differences between the law for day-time and night-time frequency curves result primarily from changes in propagation conditions, and these have been allowed for by using different sets of curves according to the predominance of daylight or darkness during a given time block. The sunrise (0400 to 0800) and sunset (1600 to 2000) times have varying percentages of daylight and darkness depending on latitude and season, and this complicates the presentation of the data. However, it has been decided that the existing data do not justify subdivision of these time blocks into dark and daylight hours and, therefore, the daylight curves are used for the whole time block in spring and summer and the night-time curves for autumn and winter. Further comments on the use of the curves for these periods, and on the particular difficulties involved at the equator are given in Section 8.

A curve of galactic noise at frequencies above 1 Mc/s is shown (4). There are small variations with time about this curve, but they are less than $\pm$ 2 db. Galactic noise is significant only at frequencies above the vertical-incidence critical frequency at any given time, which is normally much higher than 1 Mc/s except in polar regions.

In many locations man-made noise will be a limiting factor in radio communication for at least part of the time. Although this type of noise must depend on local conditions, a curve of expected values at a quiet receiving location has been added. The values plotted are typical of the lowest values at sites chosen to insure a minimum amount of man-made noise and much lower values will seldom be found at sites which are not several kilometres from power lines and electrical machinery. Man-made noise may arise from any number of sources such as power lines, industrial machinery, ignition systems, etc. with widely varying characteristics. Propagation of man-made noise is principally by conduction over power lines or by ground wave and is thus relatively unaffected by diurnal or seasonal changes in the ionosphere. However, there is experimental evidence that man-made noise may also be received from distant sources by ionospheric propagation; for example, values of man-made noise of a few decibels above kTB at 2 Mc/s have been attributed to a large city at a distance of 65 kilometres (40 miles) when the receiving site was exceptionally free from local man-made sources and very few atmospherics and radio signals were being received (11). The only trend considered in this report is the variation with frequency; the level decreases with increasing frequency, owing partly to the characteristics of the radiated spectrum and partly to propagational factors.

It will be observed that values of noise at 1 Mc/s are indicated which are below the expected levels of man-made and galactic noise. These values should be used with caution, as they represent only rough estimates of what atmospheric noise would be recorded if other types were not present. They are useful mainly as reference levels for low-noise locations, a 1 Mc/s noise grade being assigned by plotting data at other frequencies on the noise curve.

6. *Noise level variations within a time block.*

The hourly values for a given time block vary from hour to hour and from day to day. The extent of these variations is shown in figure 25, on which are plotted the ratios in db of the upper decile to the median values, D_u, and of the median to the lower decile values, D_l. These ratios depend on a number of parameters, but the frequency has been found to be the most significant. D_u has its highest values at sunrise and sunset owing to the change from daytime to night-time propagation conditions and also during the afternoons owing to the occurrence of local storms.

Figure 26 is an example of the distribution of the hourly values within a time block. It may be noted that the curve, typical of a large number of curves of this type, can be represented on normal probability paper with reasonable accuracy by two straight lines, one of which passes through the upper decile and median and the other passes through the median and lower decile. Thus, a knowledge of these three values which can be obtained from the predictions will enable a good estimate to be made of any percentile value between 1% and 99%.

At those locations where man-made noise from local sources has been studied, it has been found that the variations are similar in extent to those of atmospheric noise.

7. *The fine structure of atmospheric noise.*

The variations of the noise envelope in periods of the order of milliseconds depends on the bandwidth of the receiver. The noise is partly impulsive, and the wider the bandwidth the higher and narrower are the peaks. The following remarks, therefore, apply to bandwidths normally used for radio services—say 300 c/s at a frequency of 10 kc/s increasing to several kc/s for frequencies of 300 kc/s and above.

At the lowest frequencies the noise consists largely of impulses separated by periods of relatively low noise. The larger peaks have a shape characteristic of the pass-band of the receiver, but the smaller ones, which are more numerous, run into one another and constitute more continuous noise. The large peaks, though relatively few in number, contribute substantially to the noise power, which could, therefore, be much reduced by amplitude limitation in the receiver. Such amplitude limitation will often take place in operational types of receivers in current use.

The structure of atmospheric noise at medium and high frequencies is more complex. In temperate latitudes, noise at 10 Mc/s consists of bursts, of the order of 10 to 100 milliseconds long, with relatively quiet periods in between. The noise during a burst closely resembles fluctuation noise. In the periods between bursts the noise may be mainly of galactic origin, around mid-day, but at other times the minimum atmospheric noise level is above that of galactic noise.

8. *Use of the data.*

The data may be used in the form of either the r.m.s. noise field strength E_n, or noise figure, F_a. In Recommendation No. 161 (12), the required signal-to-noise ratios for various services under steady conditions are given, the noise being expressed as the r.m.s. value in a 6 kc/s bandwidth. The noise values for a 1 kc/s bandwidth given in this report should be increased by 8 db to give the noise in a 6 kc/s bandwidth.

Since the signal-to-noise ratios in Recommendation No. 161 are for steady conditions, allowance must be made in practical problems for the random temporal variations of noise. Intensity fluctuation factors are given in Recommendation No. 164 where the upper decile intensity of noise is assumed to be 10 db above the median. From figure 25, it is seen that the allowance should be a function of frequency and that it should be greater than 10 db in the MF (hectometric) band but less than 10 db in the HF (decametric) band.

Considering shorter-term variations, reference has already been made to the variations over an hour of the noise averaged over a period of a few minutes (Section 2). These variations are normally of only two or three decibels and are small compared with the allowances for fading of the signals (see Report No. 27). It is also found that fluctuations of noise averaged over periods of the order of ten seconds are small compared with fluctuations in signals, if these follow the Rayleigh distribution.

The difficulties in presenting the data for the sunrise and sunset periods (0400 to 0800 and 1600 to 2000) have already been mentioned. These are periods when large changes in noise level occur at some frequencies and the median value may be expected to depend rather critically on whether the receiving point is in daylight for more or less than half the period. In practical problems it will usually be necessary to reconstruct the diurnal curve of noise level and if this is done, having regard to both the median levels derived from the curves and the times of occurrence of sunrise and sunset, the final values should not be much in error. The equator, which has no seasons in the sense in which they are defined here, presents a special problem. To obtain uniformity in interpretation it is suggested that the average of the two values derived from the daylight and the night-time curves be used for locations on the equator. In future revisions of the data, it may be possible to deal with this problem in a more elegant manner, but the necessary data do not at present exist.

If a more complete analysis of a receiving installation is required, for example to determine whether or not reception is limited by external noise or by noise sources within the receiving system, the method described in references 4 and 13 may be used as follows.

Figure 27 is a block diagram in which the various elements that contribute to the resultant noise level are shown. Block A represents a loss-free antenna receiving external noise with an effective noise figure F_a. The losses in the antenna and associated circuit are represented in block C, whose noise figure is F_c. Similarly, the transmission-line loss will determine a noise figure, F_t, for the transmission line. The receiver noise figure is designated by F_r. Using Friis' (14) method of combining the noise figures (expressed as power ratios) of several networks in cascade, the effective noise figure (also expressed as a power ratio) at the input of the aerial is given by

$$F = F_a - 1 + F_c F_t F_r$$

The minimum signal power available from the aerial that is required to provide satisfactory reception is:

$$P = F + R - 204 + 10 \log_{10} B$$

where P = available signal power in db above 1 watt

F = overall effective noise figure in db

R = required signal-to-noise ratio in db

B = bandwidth in c/s.

For example, using values of R given in Recommendation No. 99 where B is taken as 6 kc/s, then

$$P = F + R - 166$$

In making a system evaluation as described above, the value of F_a that is used can be the median, upper decile, or some other percentile, depending upon the protection required.

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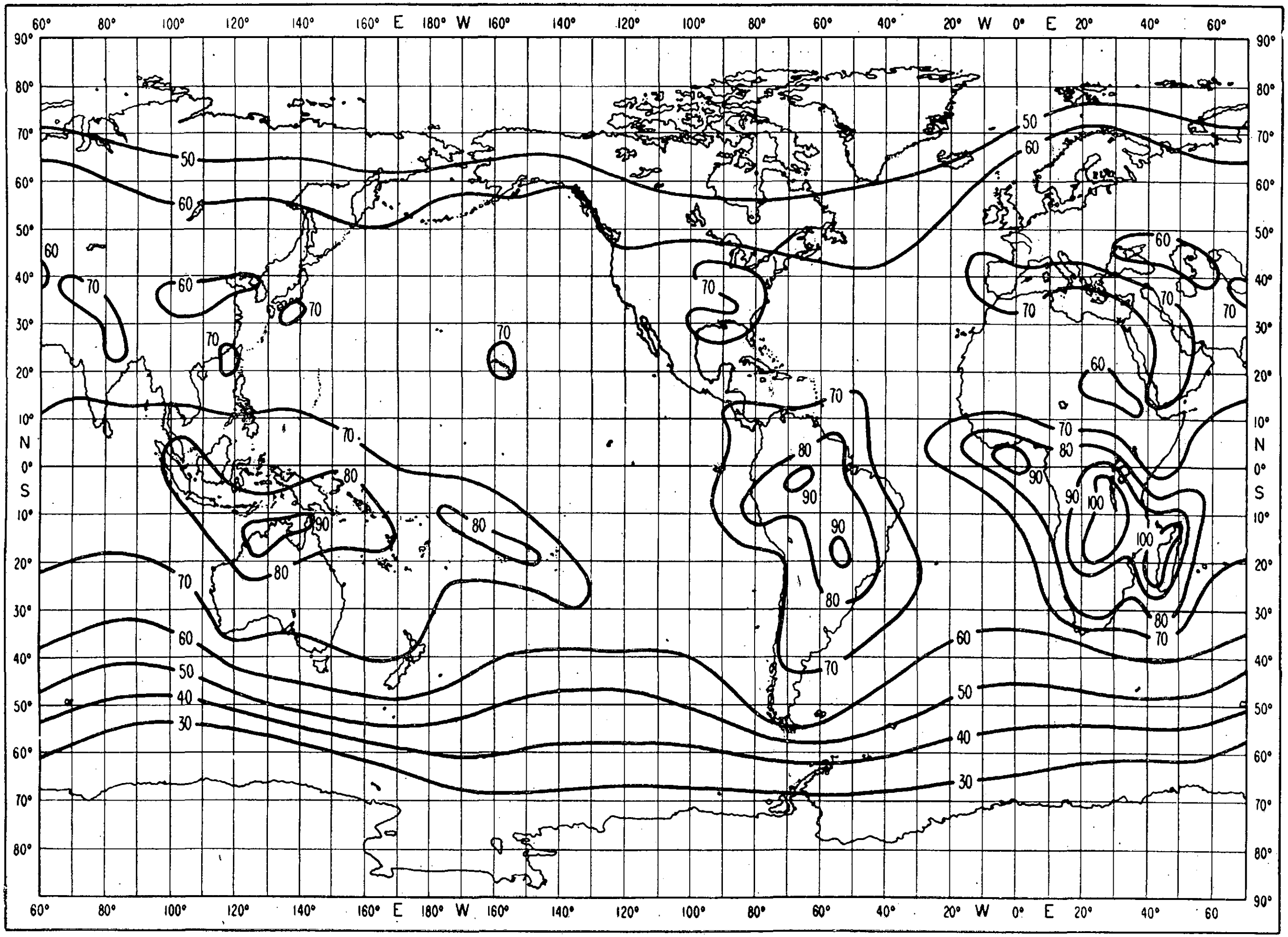


FIGURE 1

Expected values of radio noise F_a (in db above kTB) at 1 Mc/s, from 0000—0400 hrs and from 2000—2400 hrs, for December, January and February

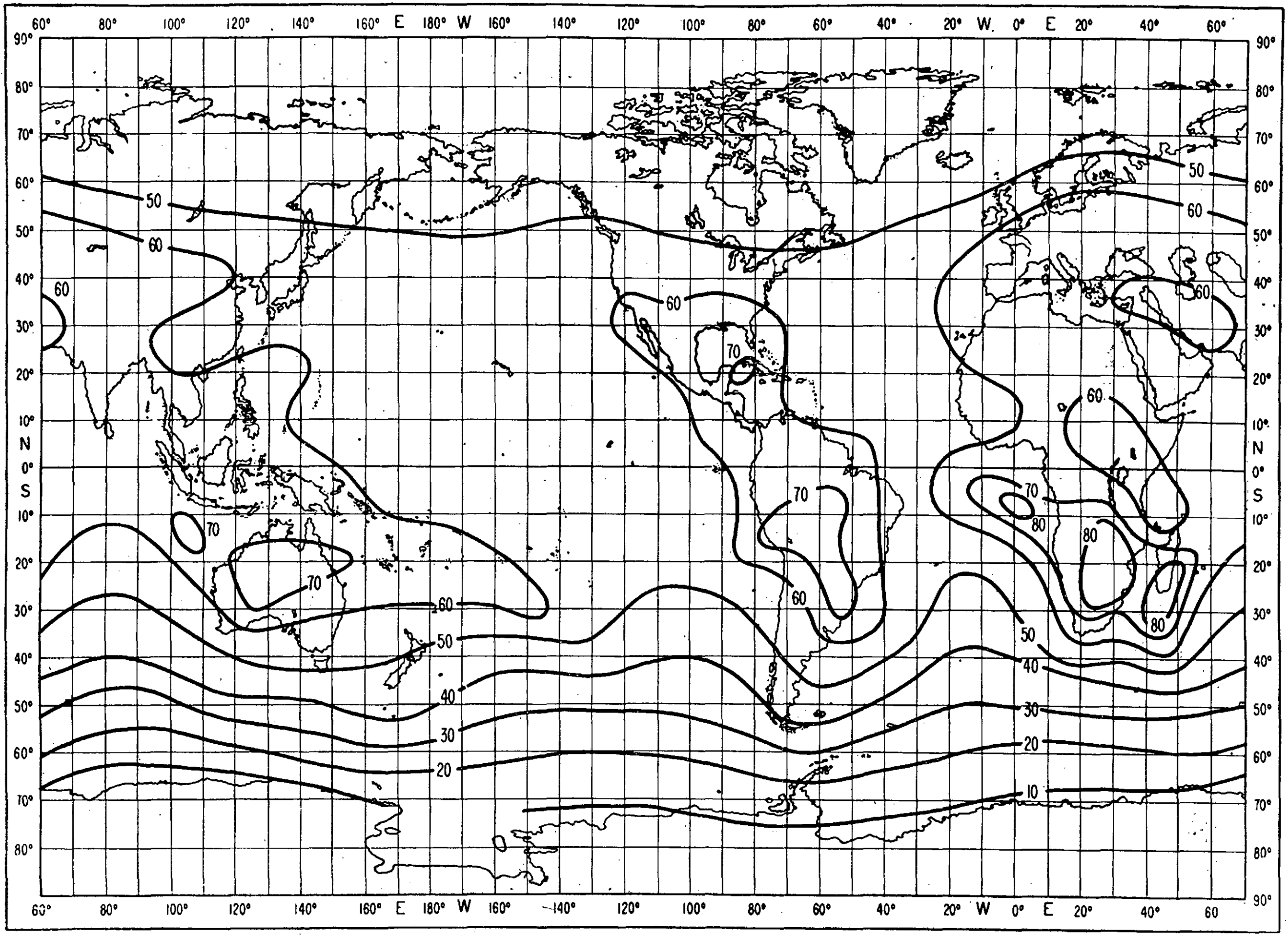


FIGURE 2

Expected values of radio noise F_a (in db above kTB) at 1 Mc/s, from 0400—0800 hrs, for December, January and February

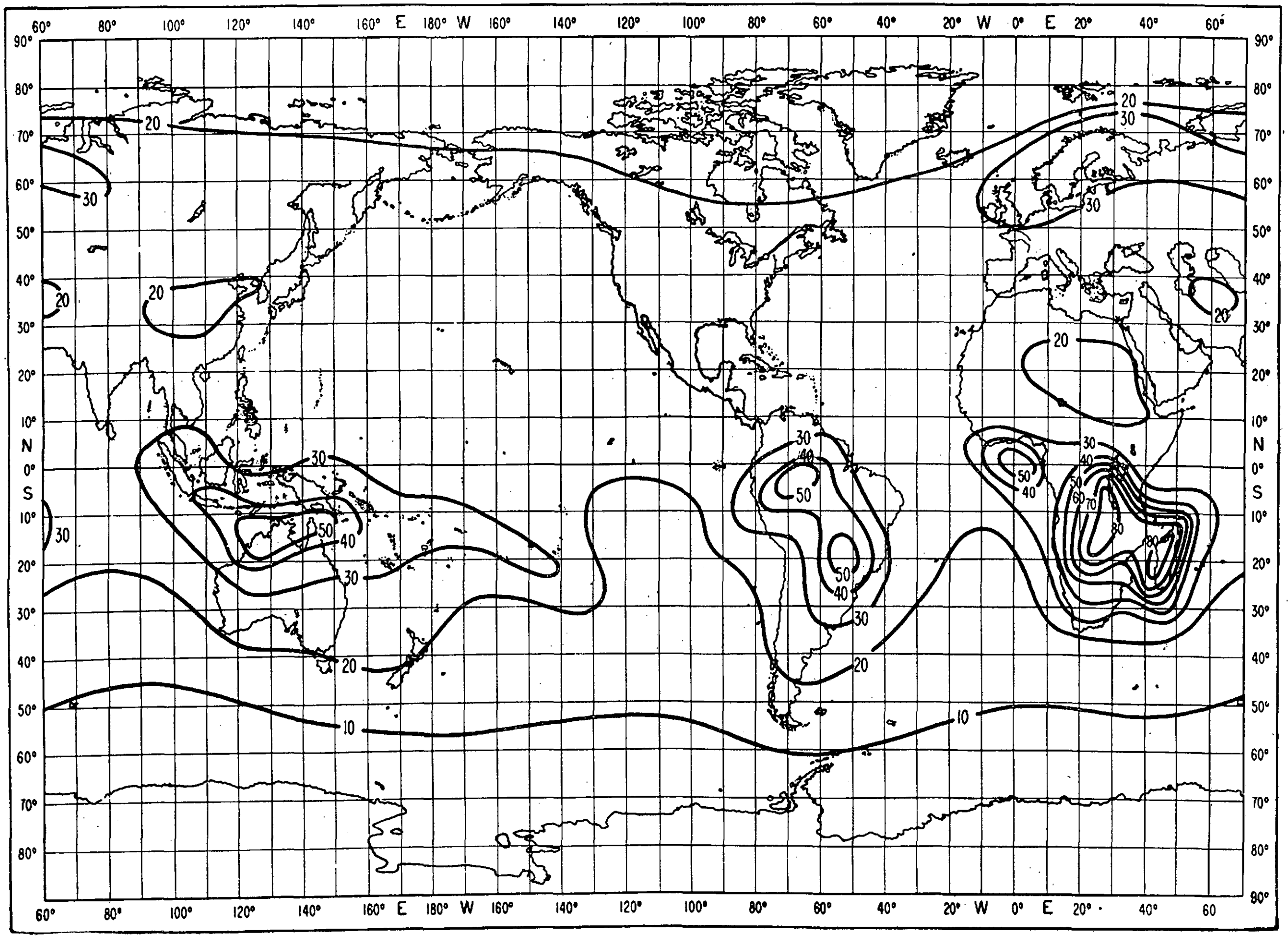


FIGURE 3

Expected values of radio noise F_a (in db above kTB) at 1 Mc/s, from 0800—1200 hrs, for December, January and February

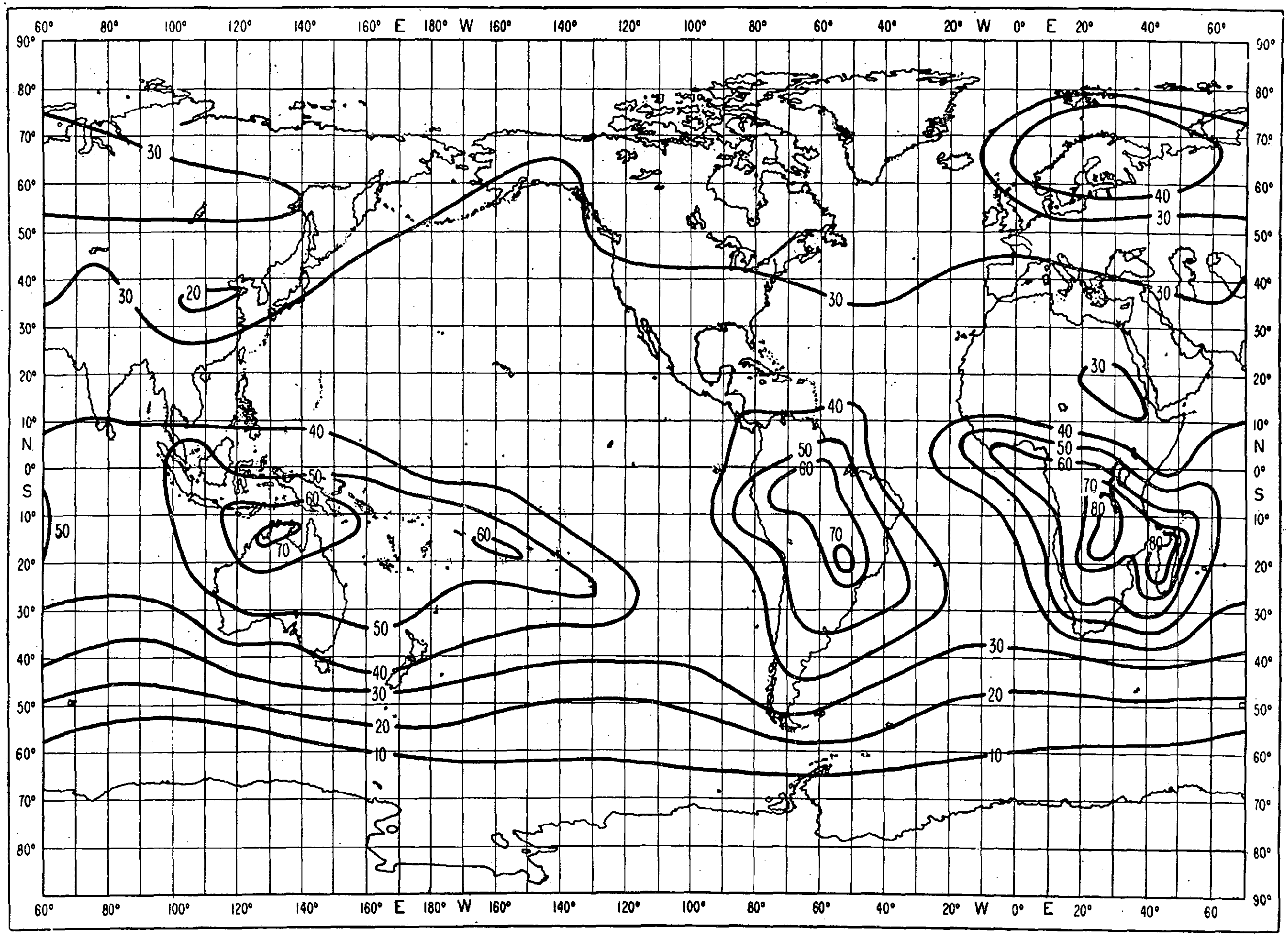


FIGURE 4

Expected values of radio noise F_a (in db above kTB) at 1 Mc/s, from 1200—1600 hrs, for December, January and February

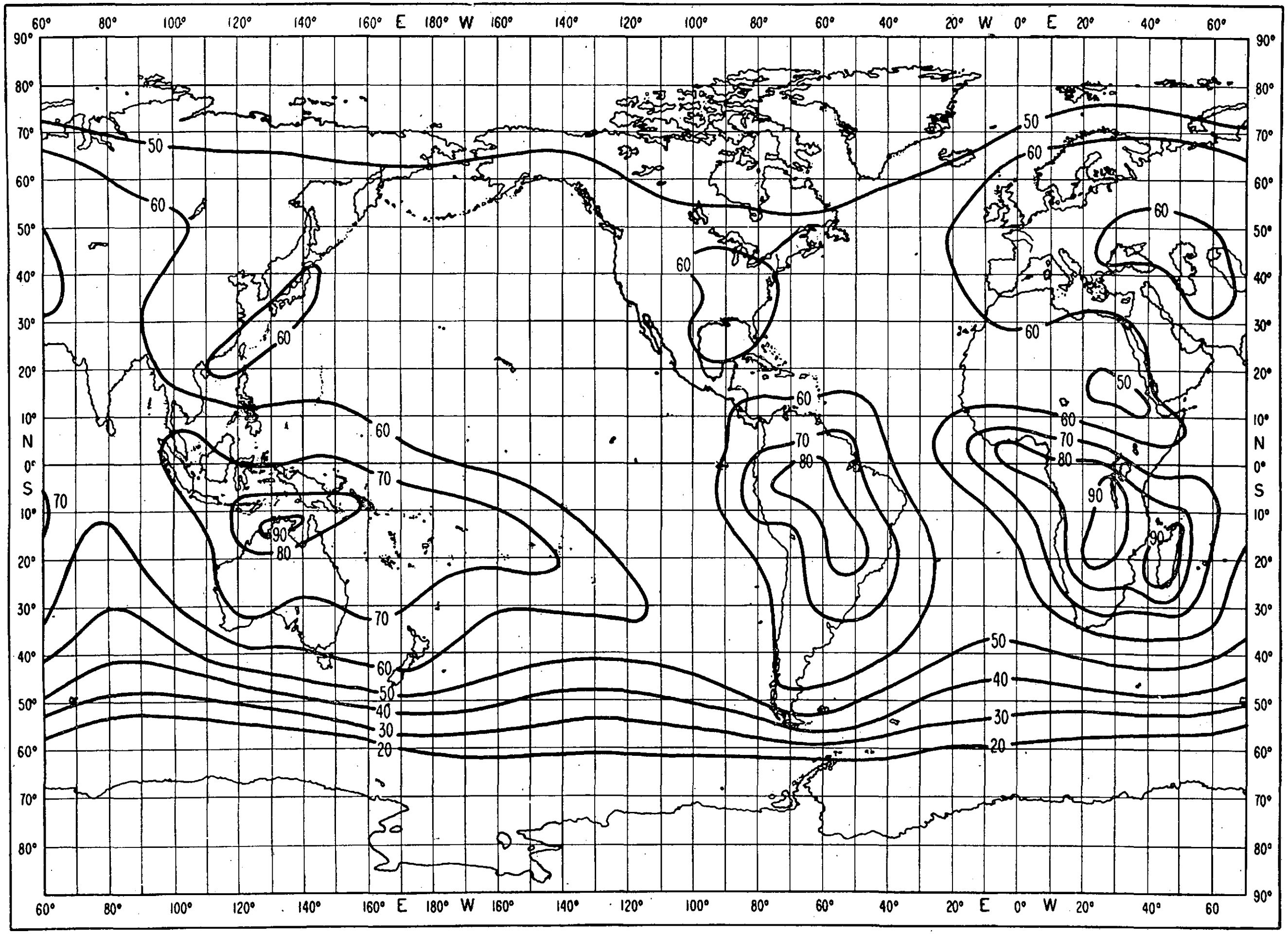


FIGURE 5

Expected values of radio noise F_a (in db above kTB) at 1 Mc/s, from 1600—2000 hrs, for December, January and February

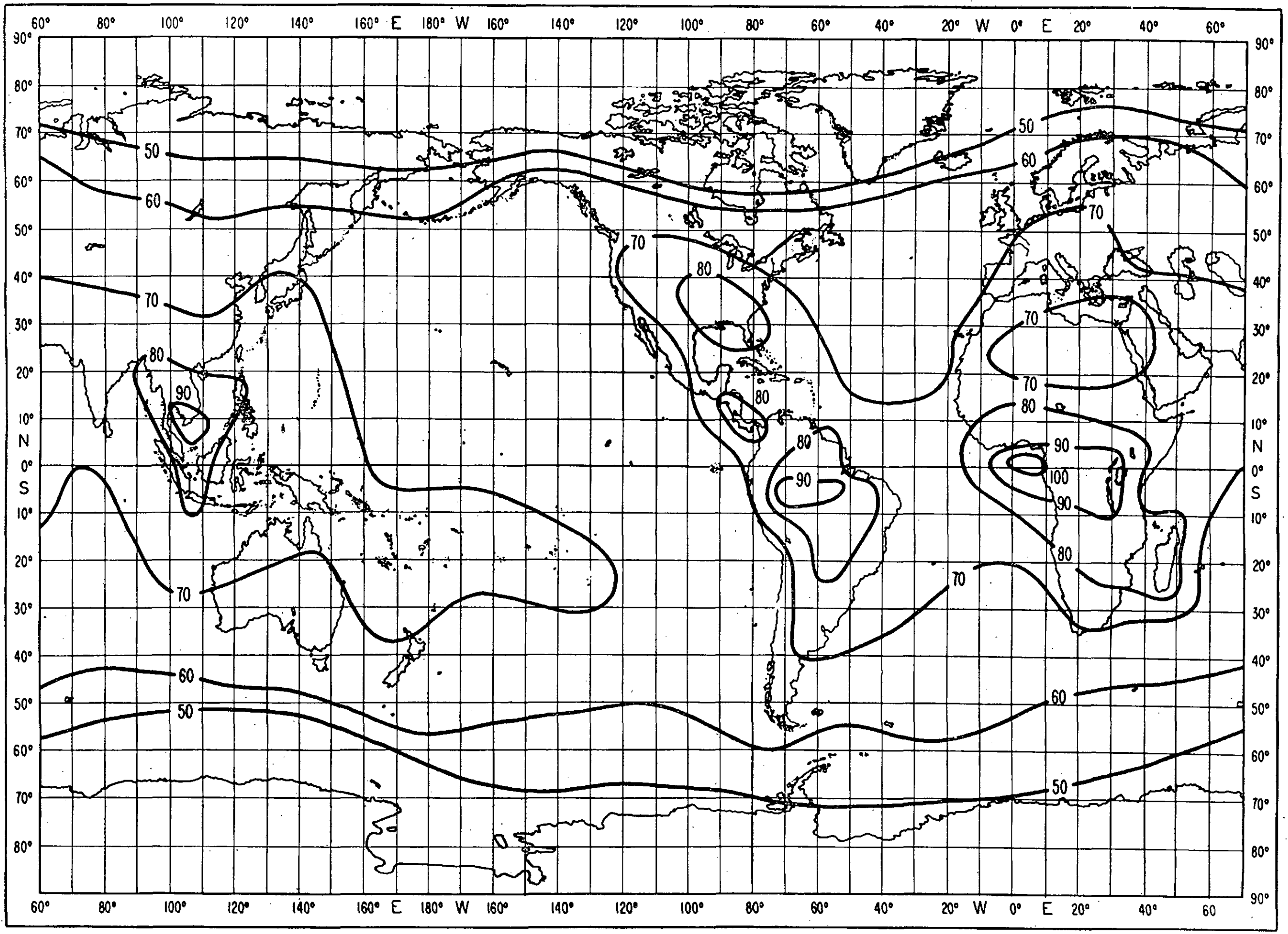


FIGURE 6

Expected values of radio noise F_a (in db above kTB) at 1 Mc/s, from 0000–0400 hrs and from 2000–2400 hrs, for March, April and May

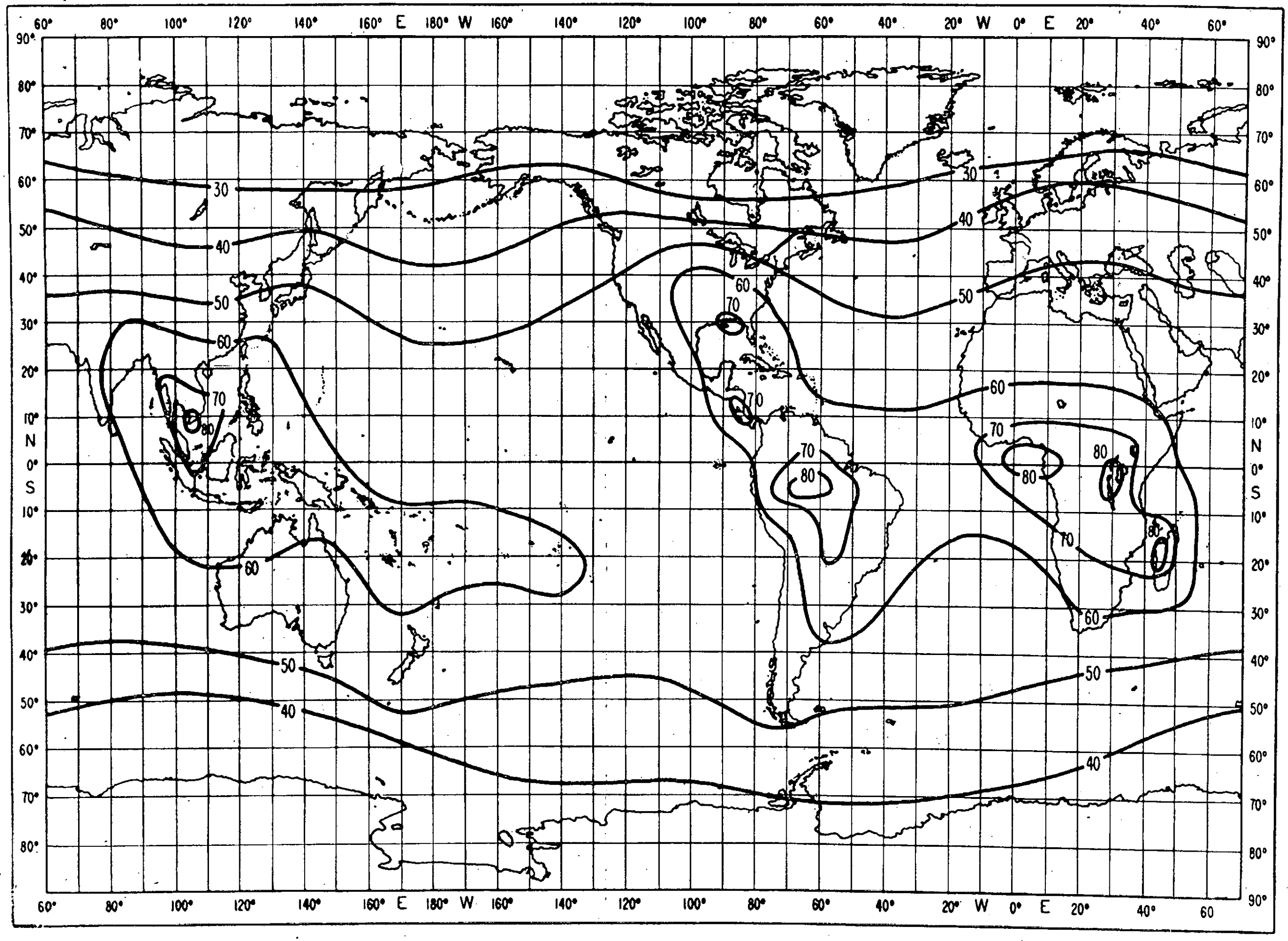


FIGURE 7

Expected values of radio noise F_a (in db above kTB) at 1 Mc/s, from 0400—0800 hrs, for March, April and May

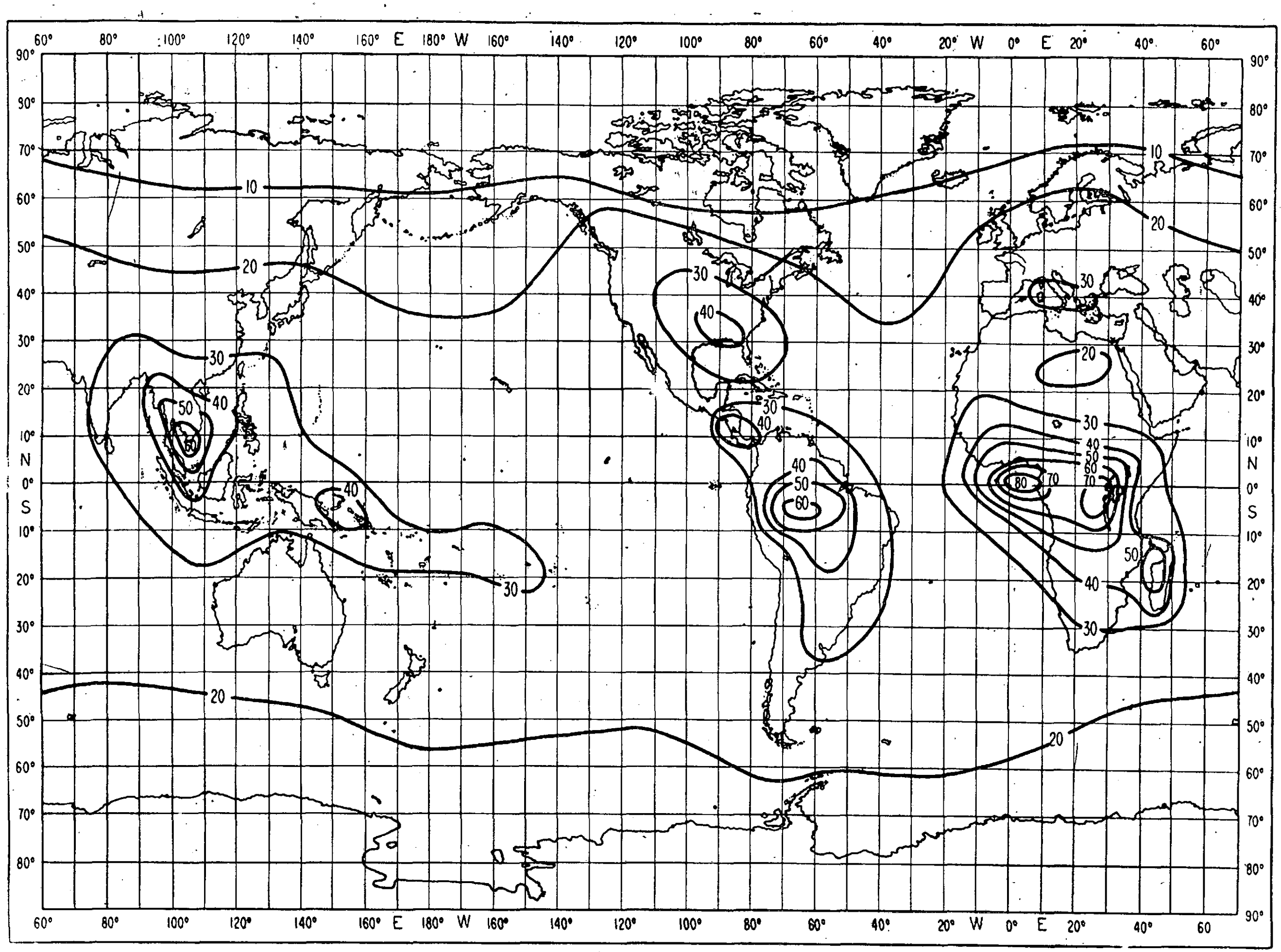


FIGURE 8

Expected values of radio noise F_a (in db above kTB) at 1 Mc/s, from 0800—1200 hrs, for March, April and May.

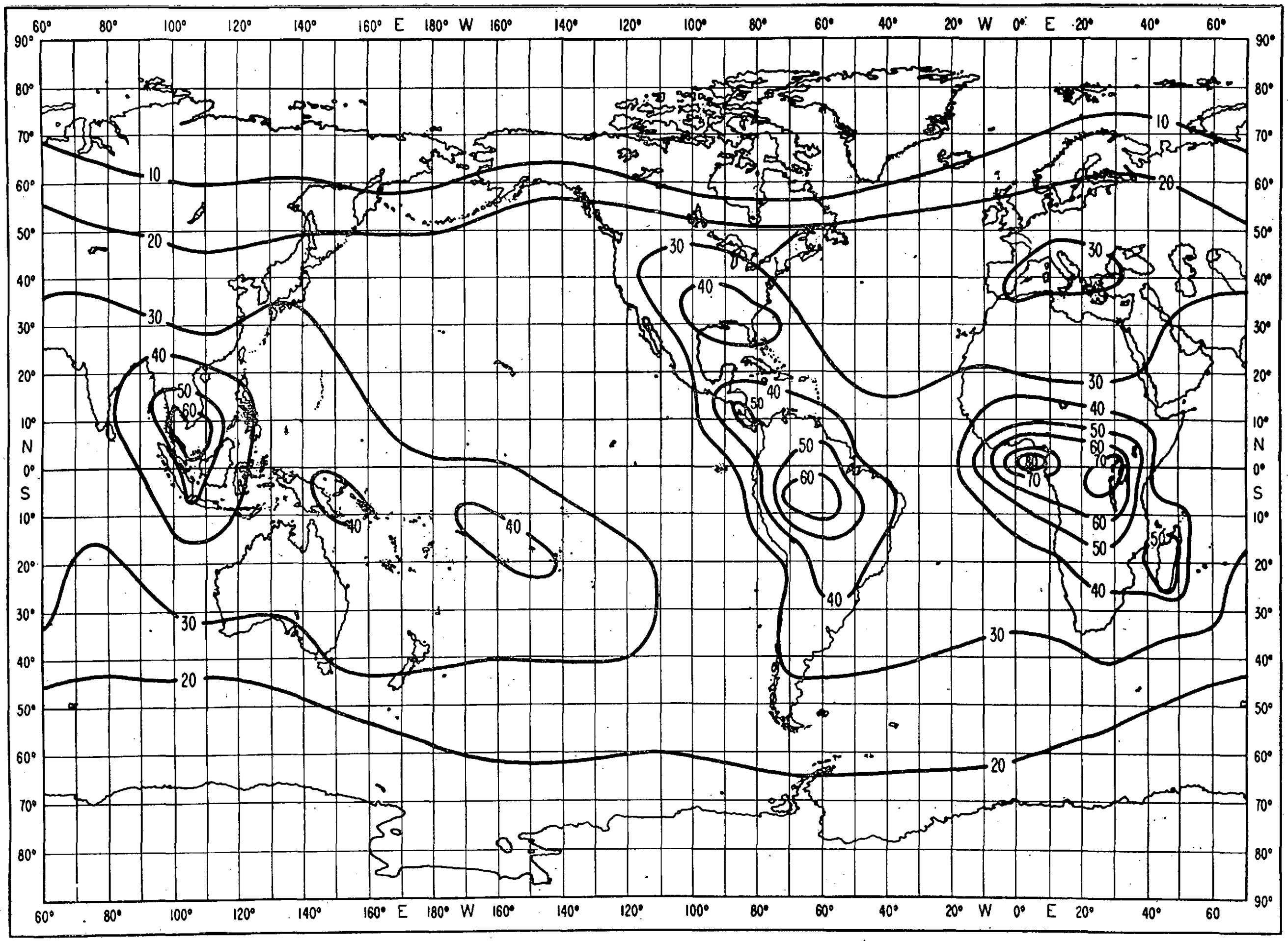


FIGURE 9

Expected values of radio noise F_a (in db above kTB) at 1 Mc/s, from 1200—1600 hrs, for March, April and May

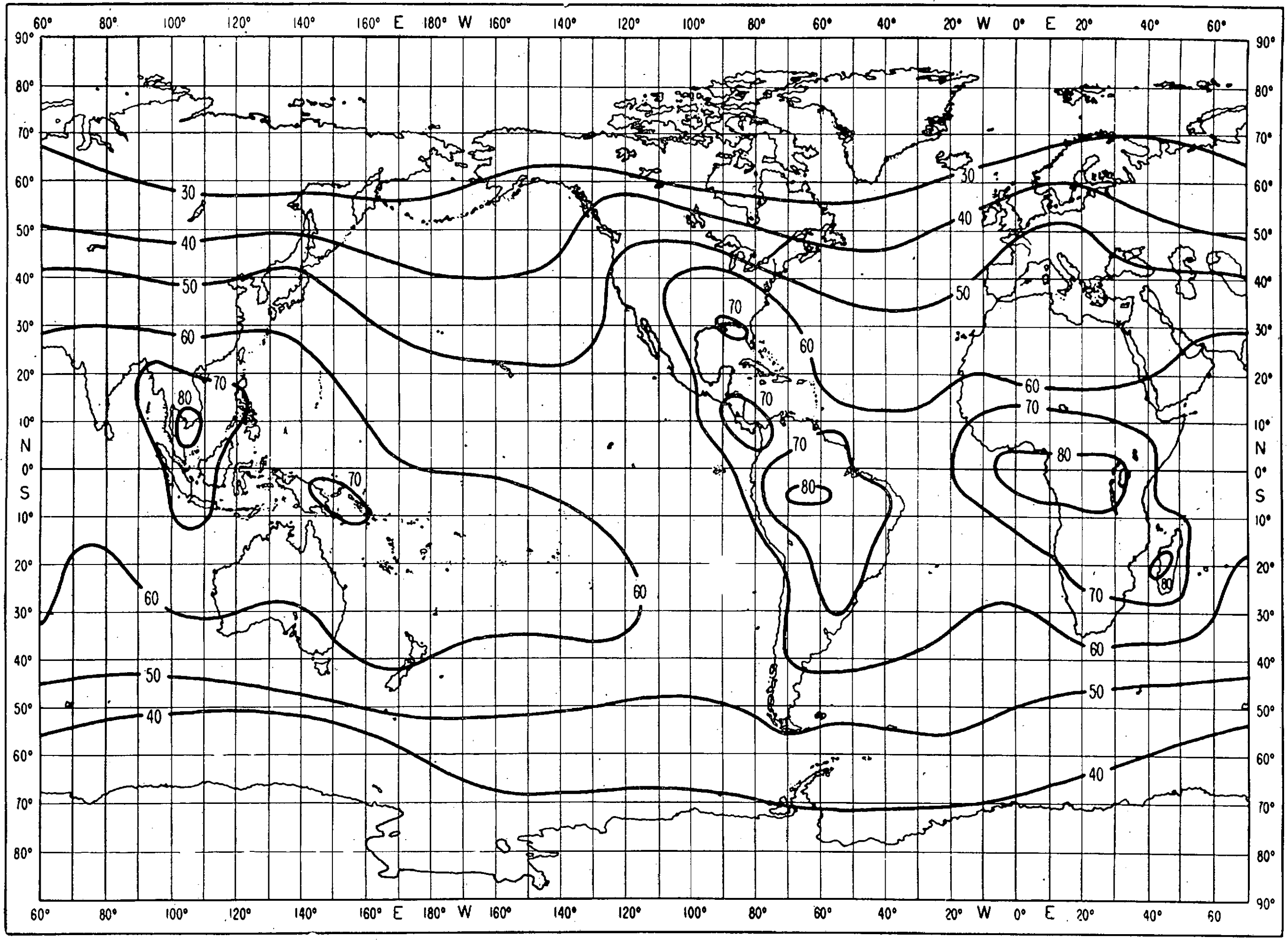


FIGURE 10

Expected values of radio noise F_a (in db above kTB) at 1 Mc/s, from 1600—2000 hrs, for March, April and May

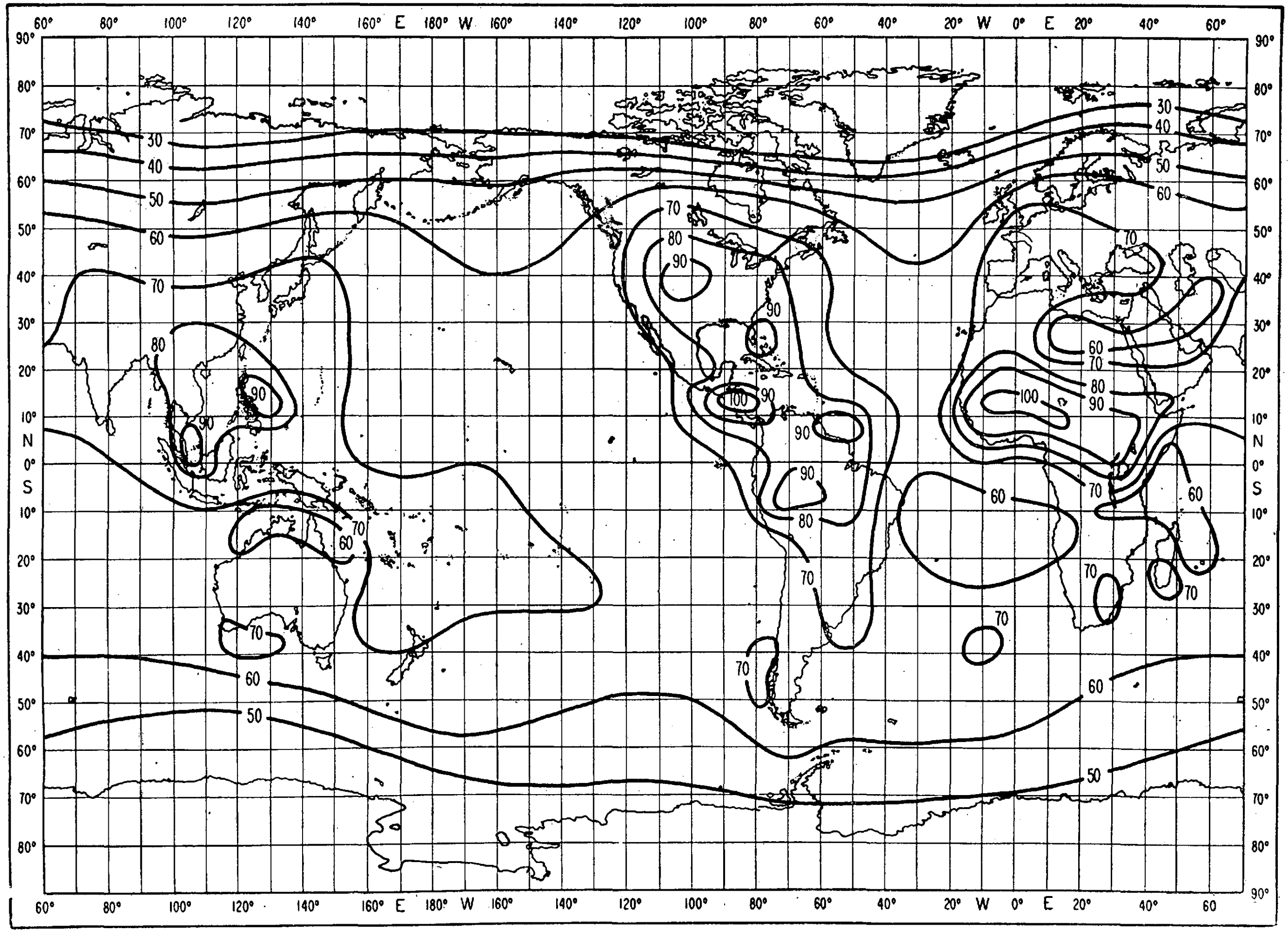


FIGURE 11

Expected values of radio noise F_a (in db above kTB) at 1 Mc/s, from 0000—0400 hrs and from 2000—2400 hrs, for June, July and August

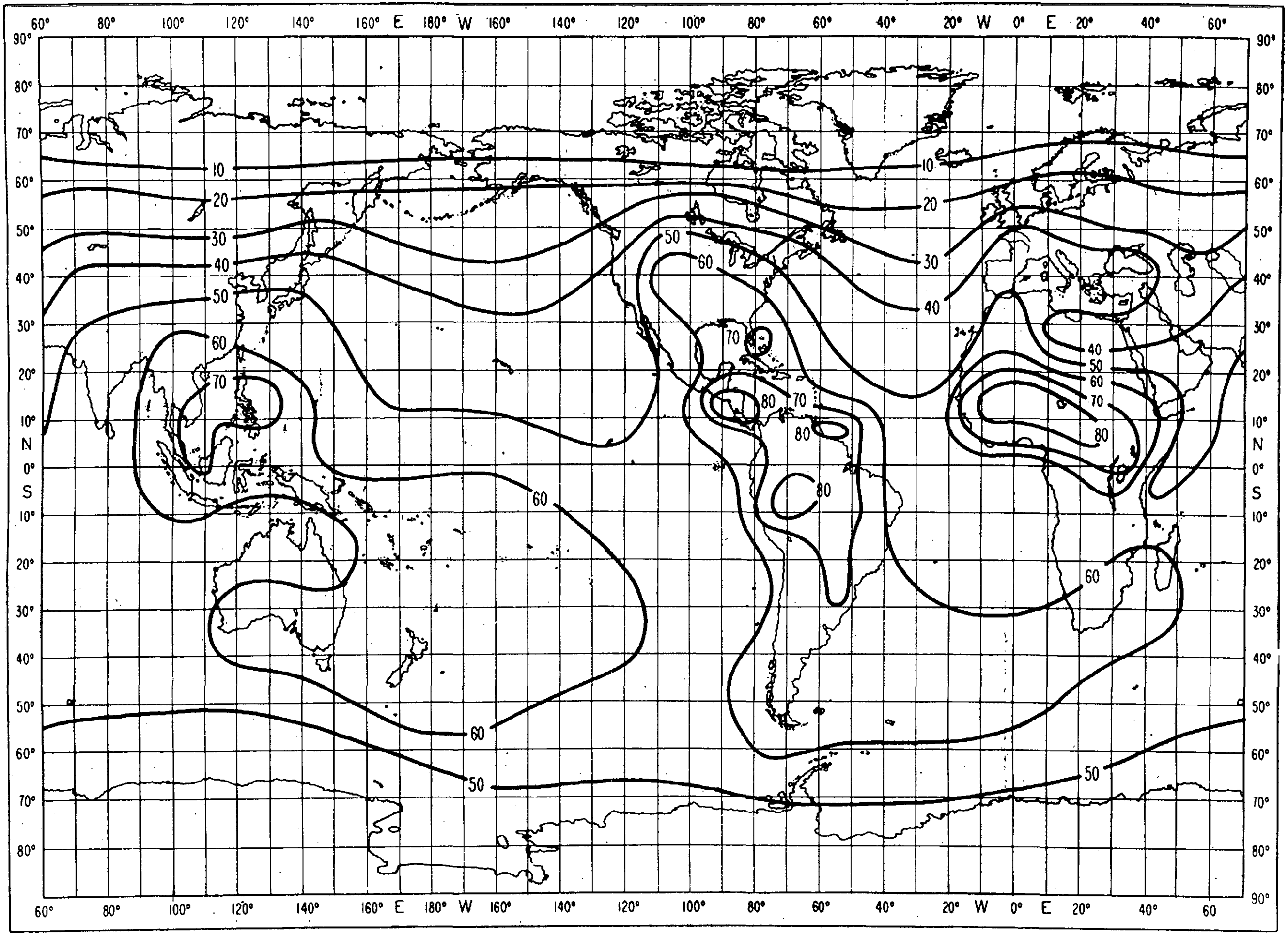


FIGURE 12

Expected values of radio noise F_a (in db above kTB) at 1 Mc/s, from 0400—0800 hrs, for June, July and August

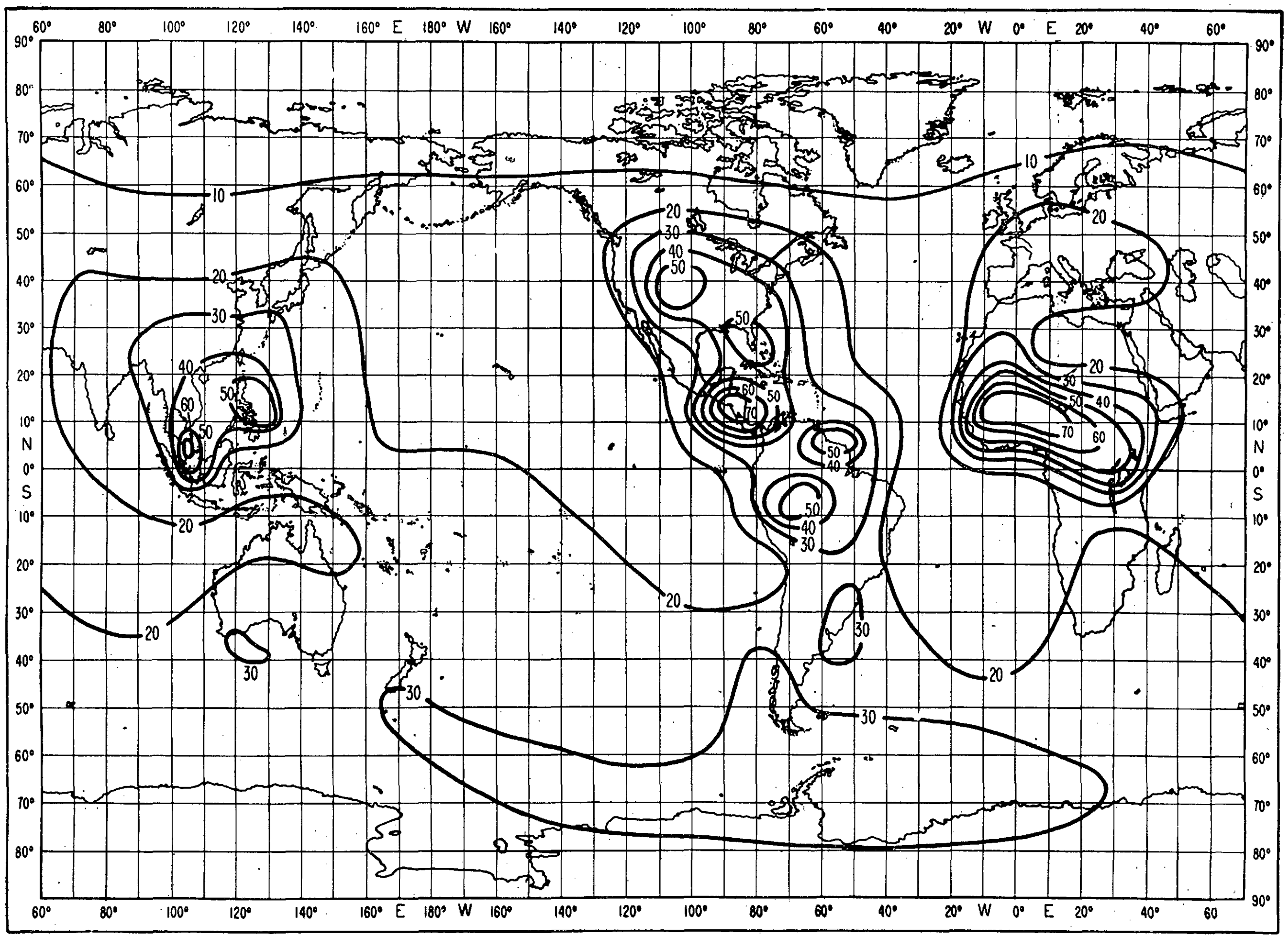


FIGURE 13

Expected values of radio noise F_a (in db above kTB) at 1 Mc/s, from 0800—1200 hrs, for June, July and August

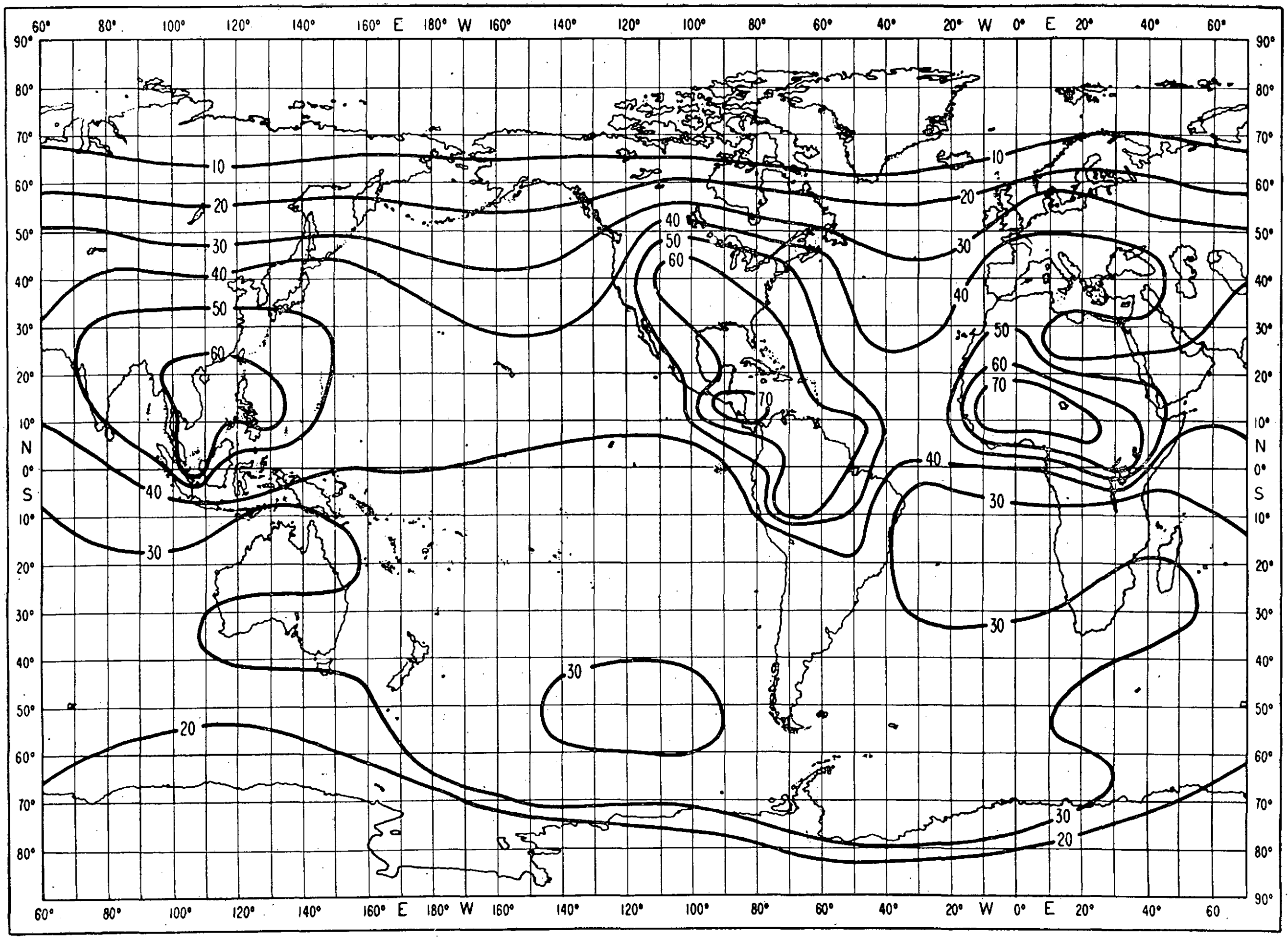


FIGURE 14

Expected values of radio noise F_a (in db above kTB) at 1 Mc/s, from 1200—1600 hrs, for June, July and August

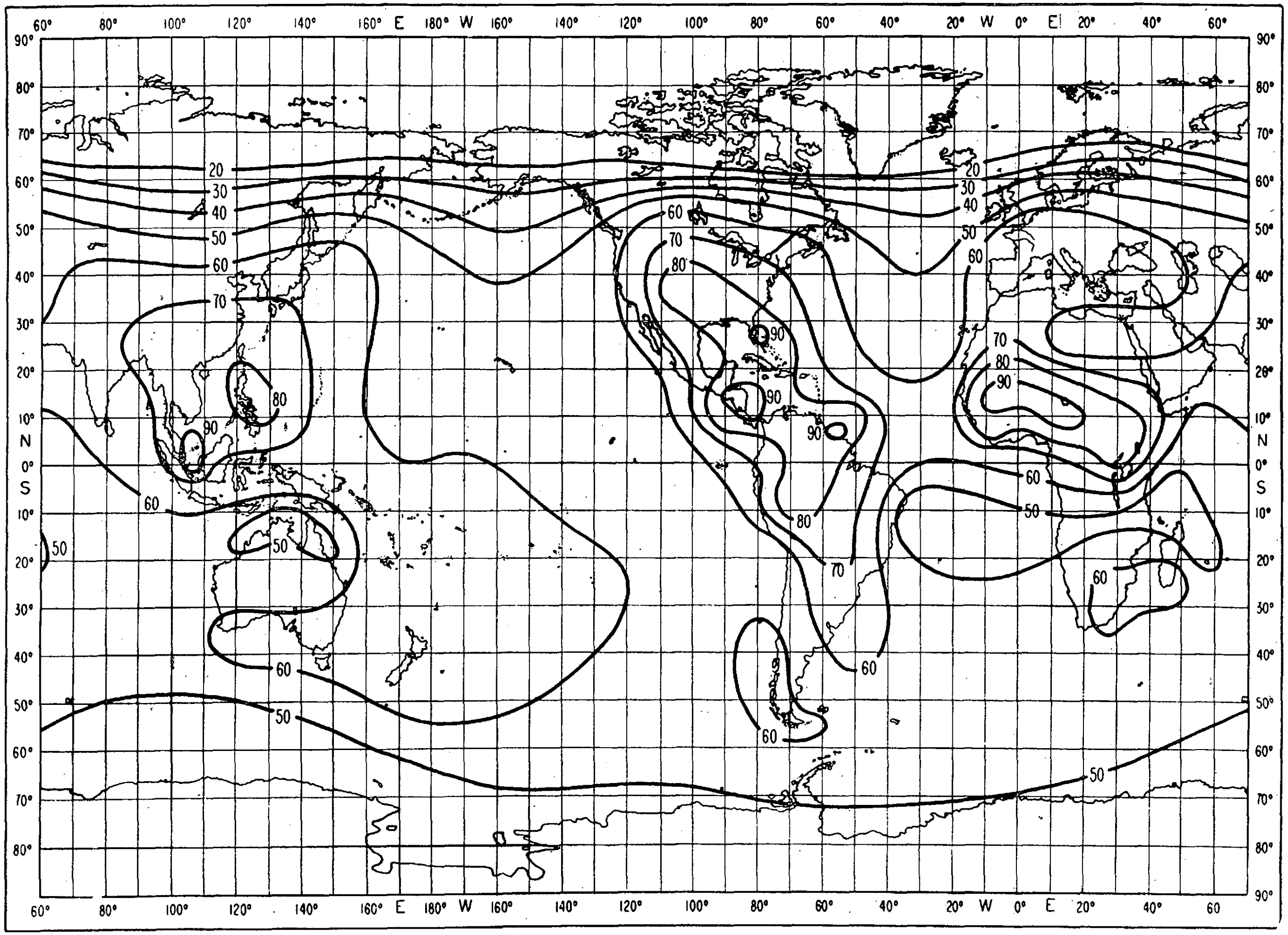


FIGURE 15

Expected values of radio noise F_a (in db above kTB) at 1 Mc/s, from 1600–2000 hrs, for June, July and August

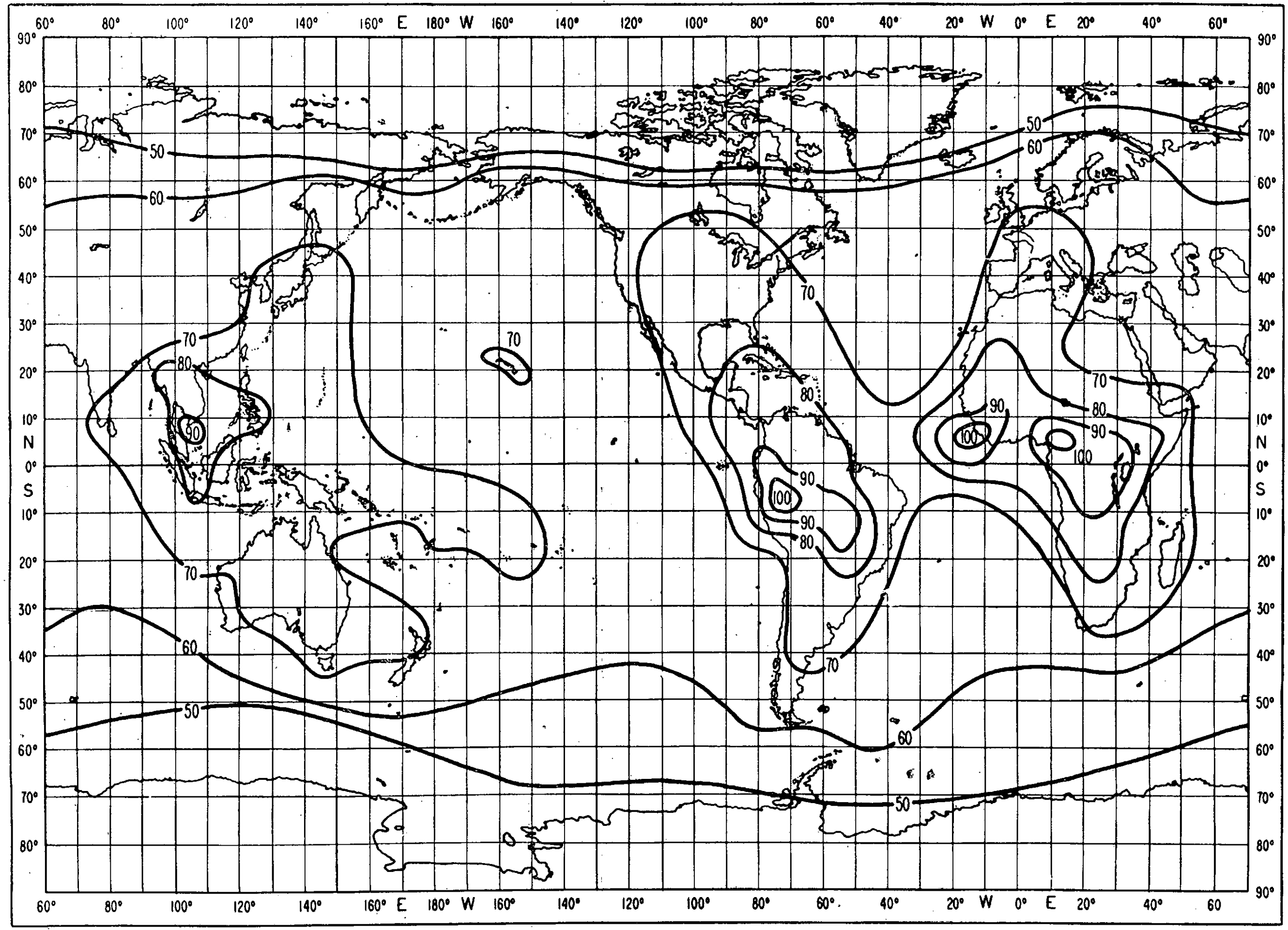


FIGURE 16

Expected values of radio noise F_a (in db above kTB) at 1 Mc/s, from 0000–0400 hrs, and from 2000–2400 hrs, for September, October and November

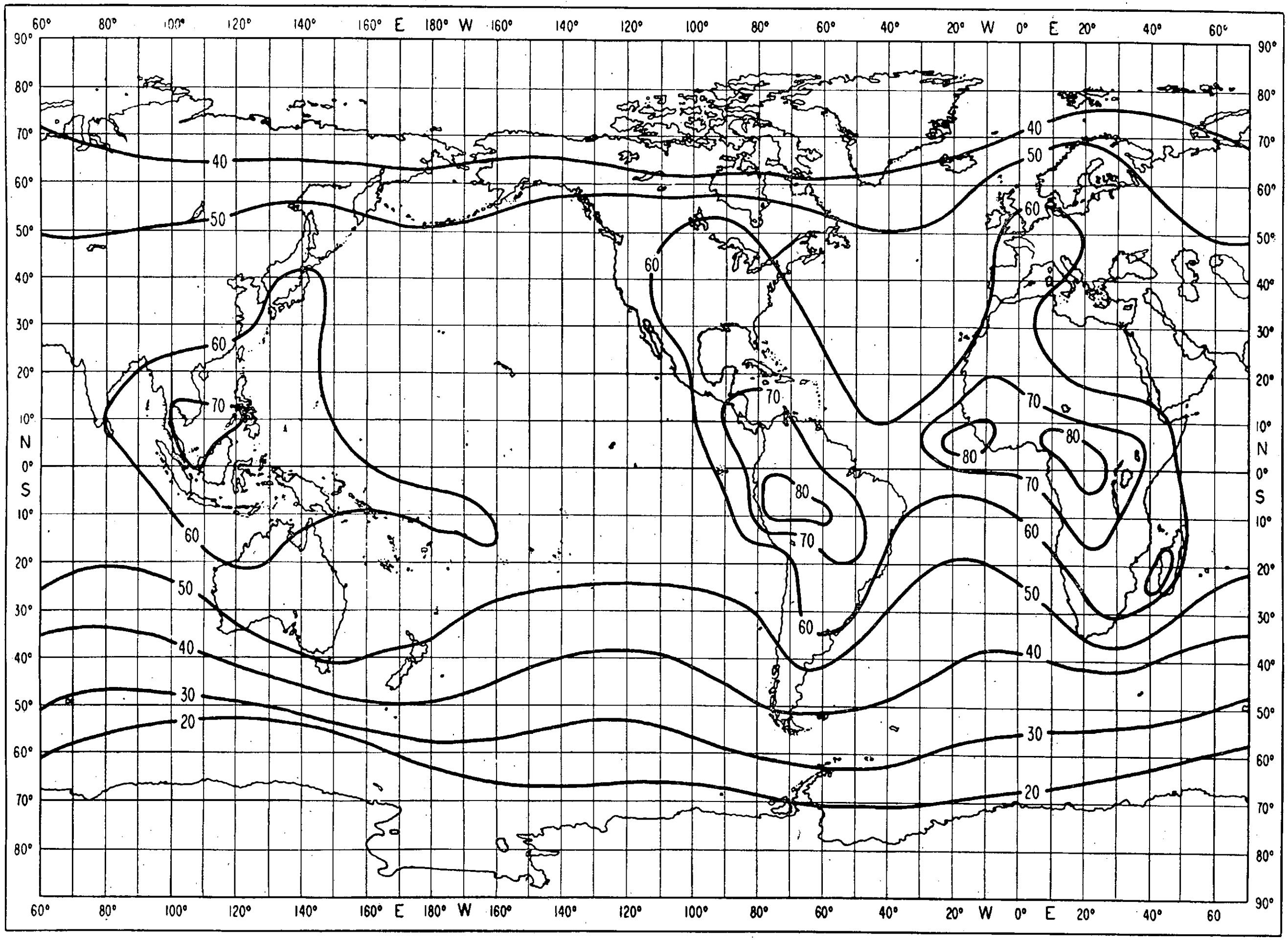


FIGURE 17

Expected values of radio noise F_a (in db above kTB) at 1 Mc/s, from 0400—0800 hrs, for September, October and November

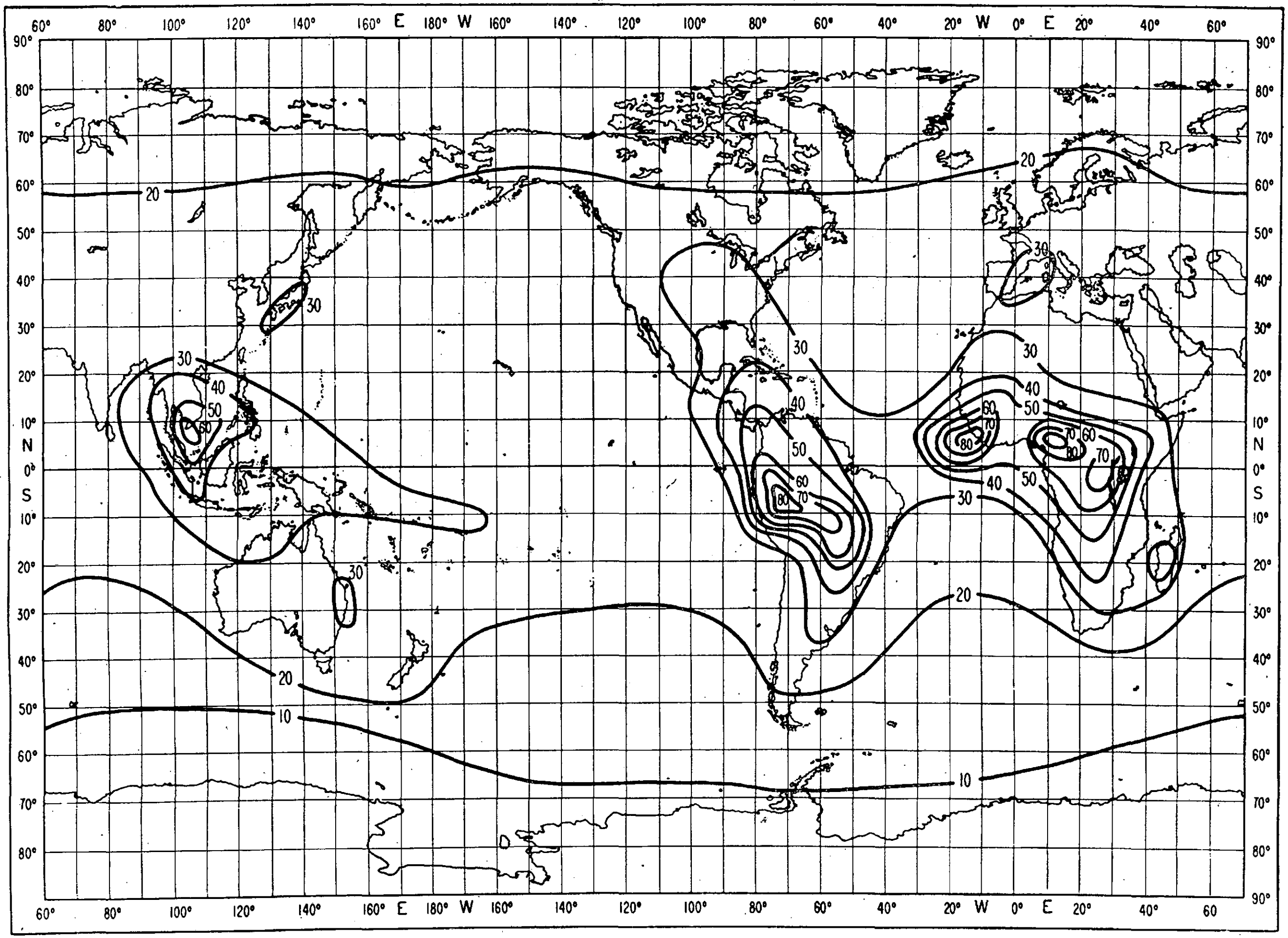


FIGURE 18

Expected values of radio noise F_a (in db above kTB) at 1 Mc/s, from 0800–1200 hrs, for September, October and November

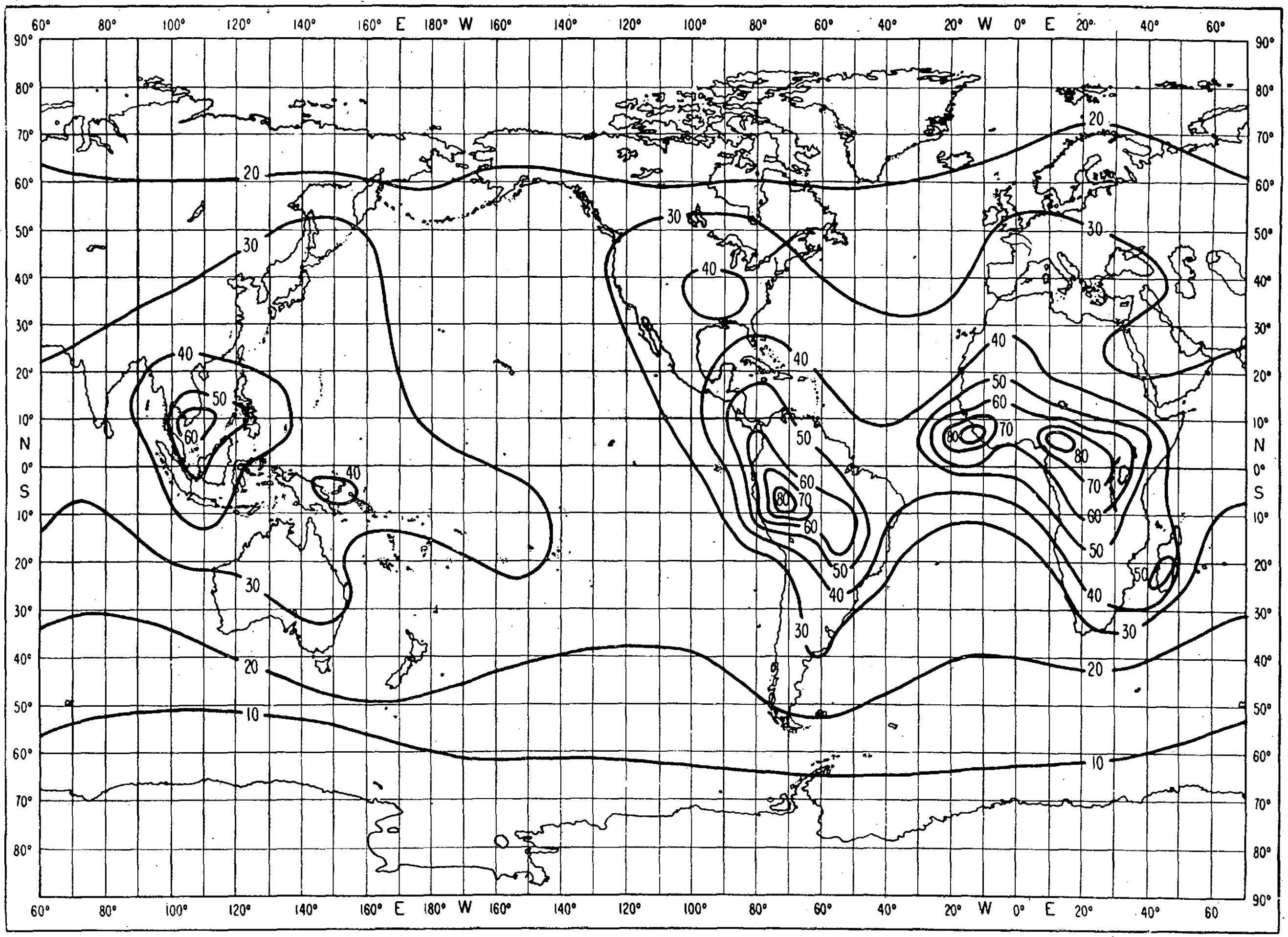


FIGURE 19

Expected values of radio noise F_a (in db above kTB) at 1 Mc/s, from 1200–1600 hrs, for September, October and November

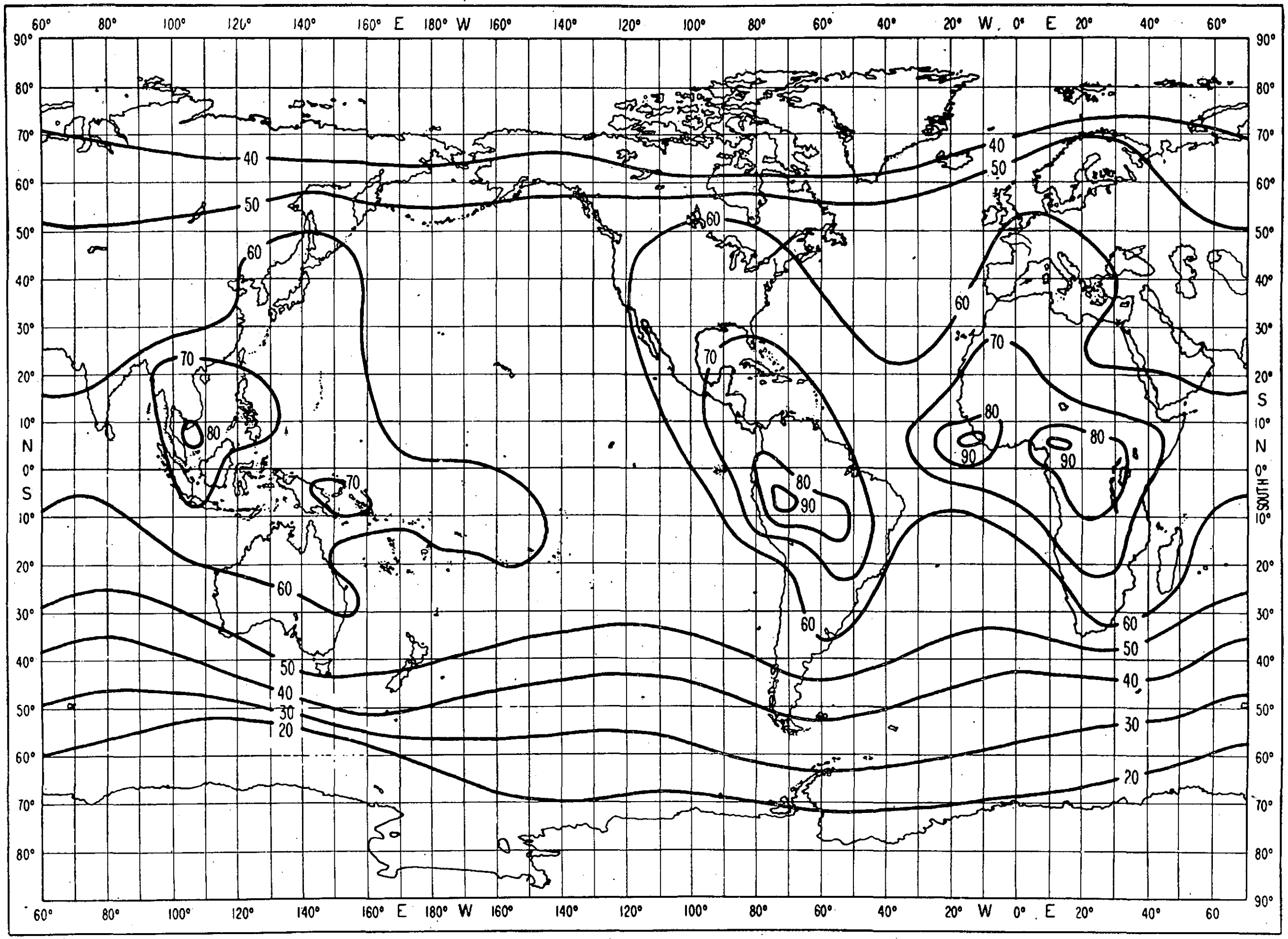
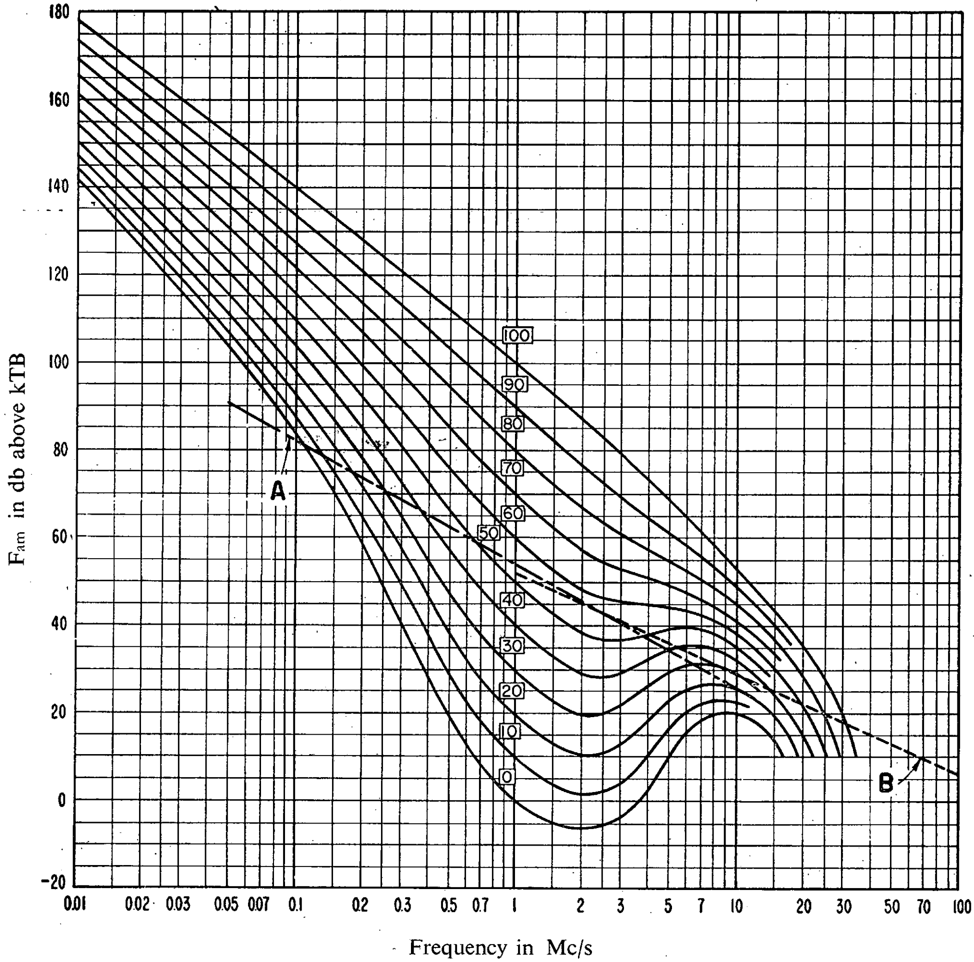


FIGURE 20

Expected values of radio noise F_a (in db above kTB) at 1 Mc/s, from 1600—2000 hrs, for September, October and November

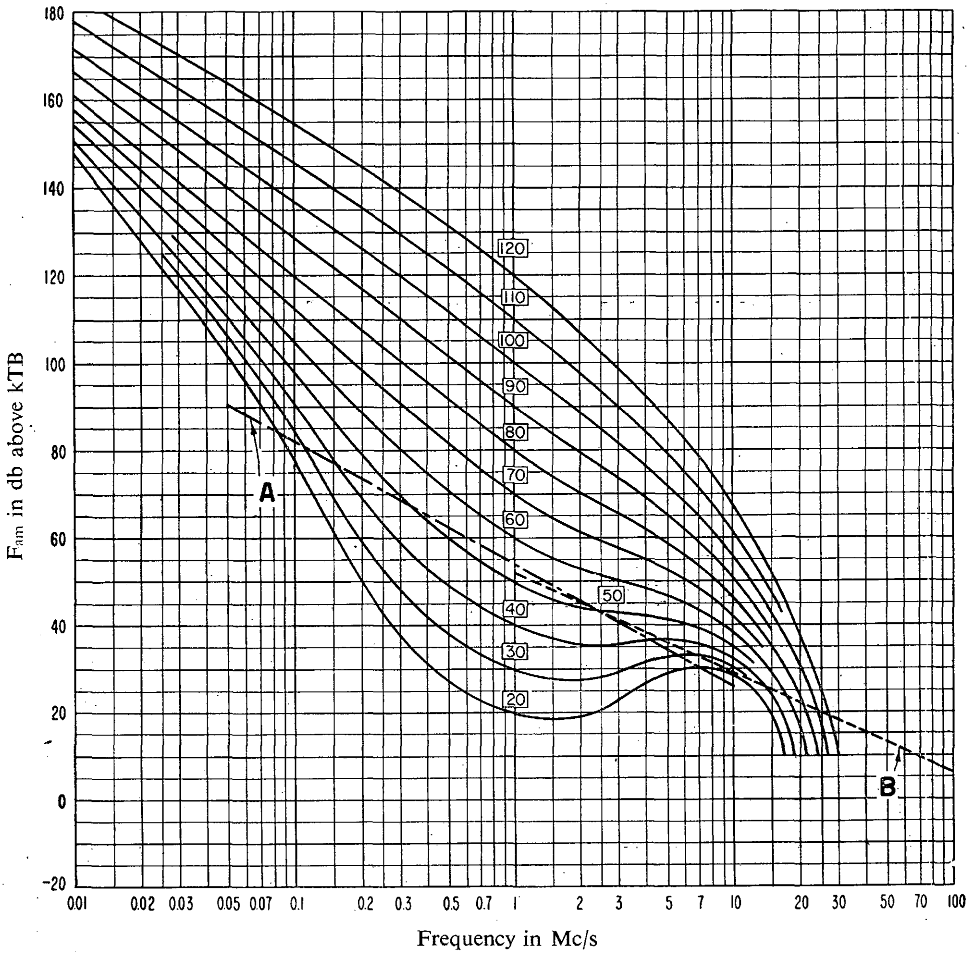


A — Expected values of man-made noise at a quiet receiving location.
B — Expected values of galactic radio noise.
The figures in rectangles indicate the noise grades at 1 Mc/s.

FIGURE 21

Median values of radio noise expected for a short vertical antenna for the time blocks :

0800—1200 hrs and 1200—1600 hrs for all seasons
0400—0800 hrs and 1600—2000 hrs for spring and summer



A — Expected values of man-made noise at a quiet receiving location

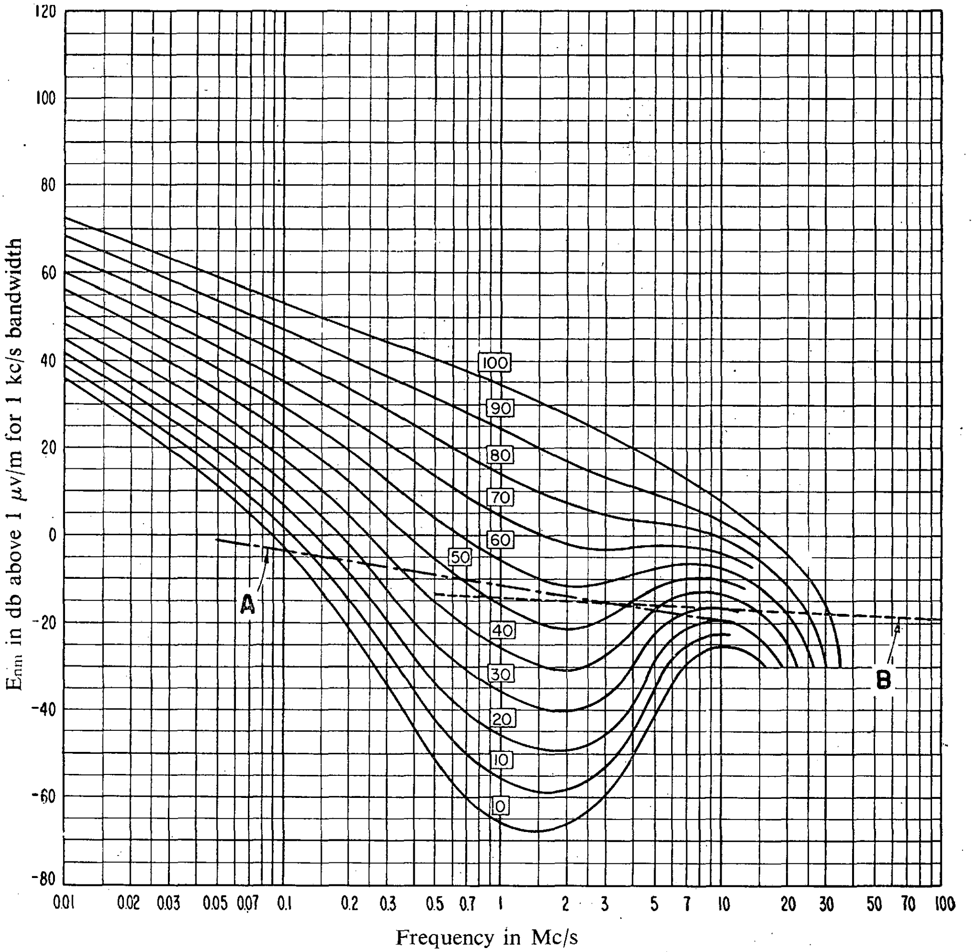
B — Expected values of galactic radio noise

The figures in rectangles indicate the noise grades at 1 Mc/s

FIGURE 22

Median values of radio noise expected for a short vertical antenna for the time blocks :

0000—0400 hrs and 2000—2400 hrs for all seasons
0400—0800 hrs and 1600—2000 hrs for autumn and winter



A — Expected values of man-made noise at a quiet receiving location

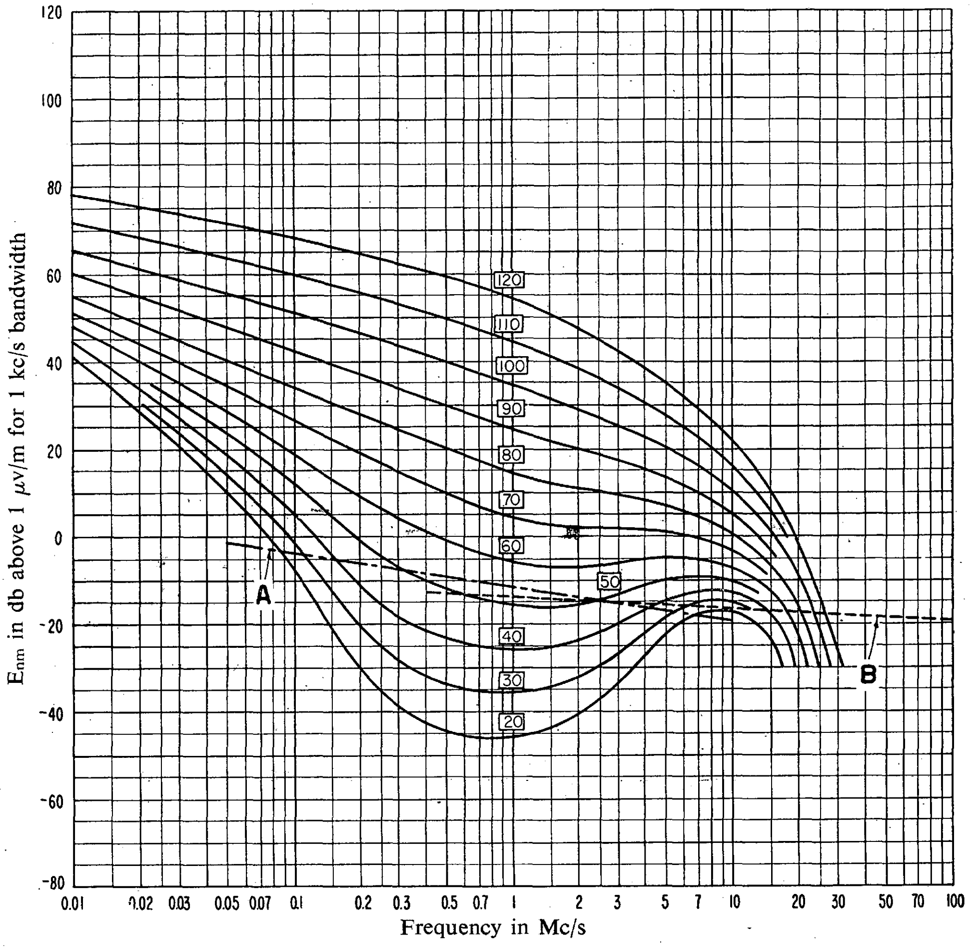
B — Expected values of galactic radio noise

The figures in rectangles indicate the noise grades at 1 Mc/s

FIGURE 23

Median values of radio noise expected for a short vertical antenna for the time blocks :

0800—1200 hrs and 1200—1600 hrs for all seasons
0400—0800 hrs and 1600—2000 hrs for spring and summer



A — Expected values of man-made noise at a quiet receiving location

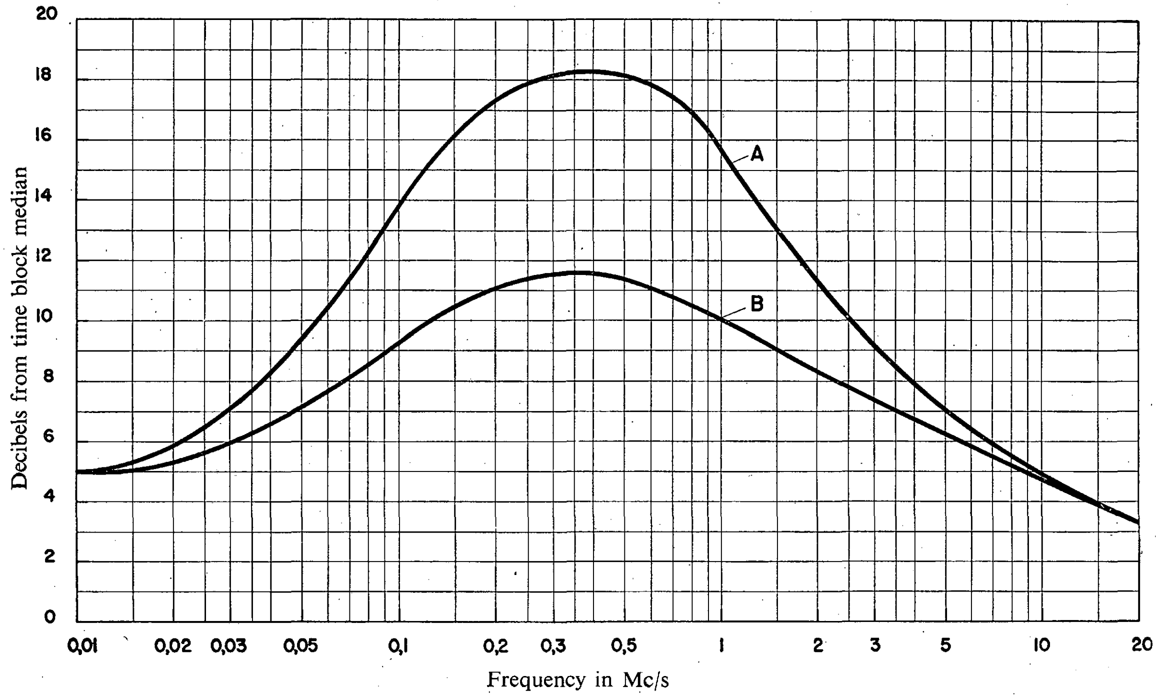
B — Expected values of galactic radio noise

The figures in rectangles indicate the noise grades at 1 Mc/s

FIGURE 24

Median values of radio noise expected for a short vertical antenna for the time blocks :

0000—0400 hrs and 2000—2400 hrs for all seasons
0400—0800 hrs and 1600—2000 hrs for autumn and winter



A — Ratio D_u (in db) of the upper decile to the median for the time blocks :
0400—0800 hrs 0800—1200 hrs
1200—1600 hrs 1600—2000 hrs

B — Ratio D_u (in db) of the upper decile to the median for the time blocks:
0000—0400 hrs
2000—2400 hrs

and ratio D_l (in db) of the median to the lower decile for all time blocks

FIGURE 25

Variations from the time block median radio noise levels

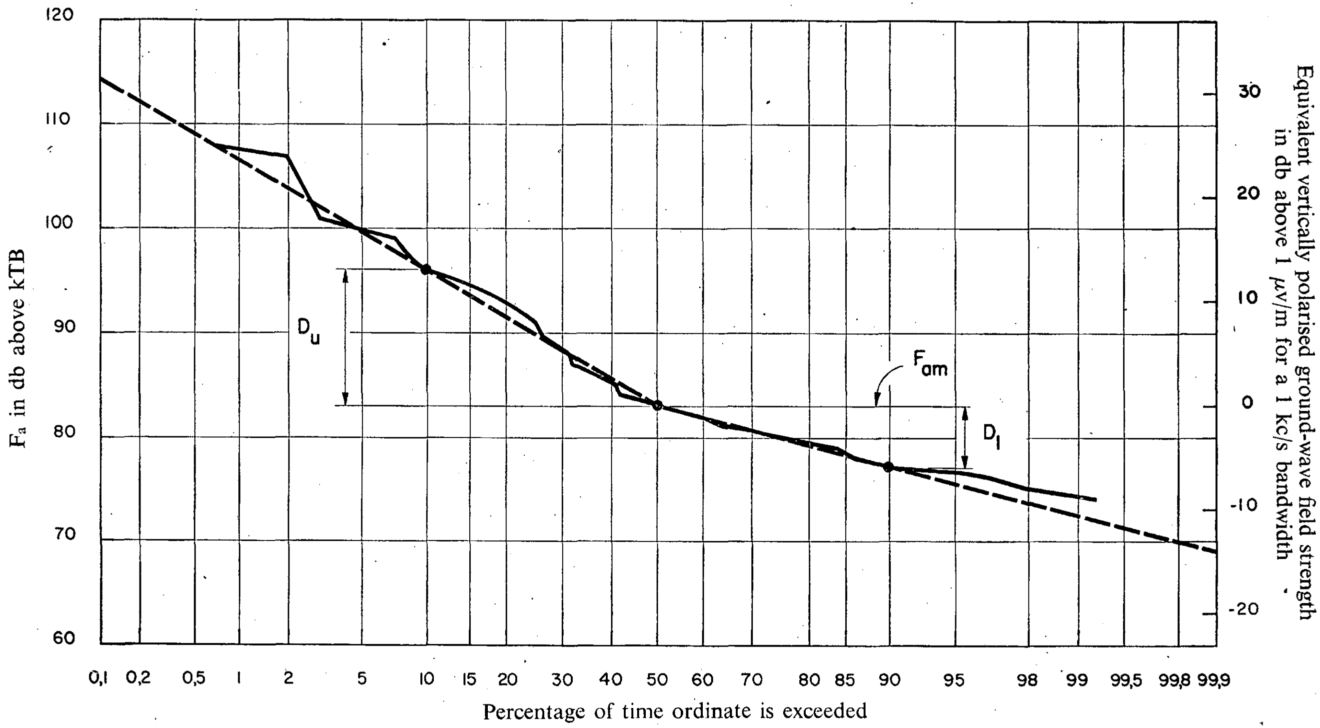
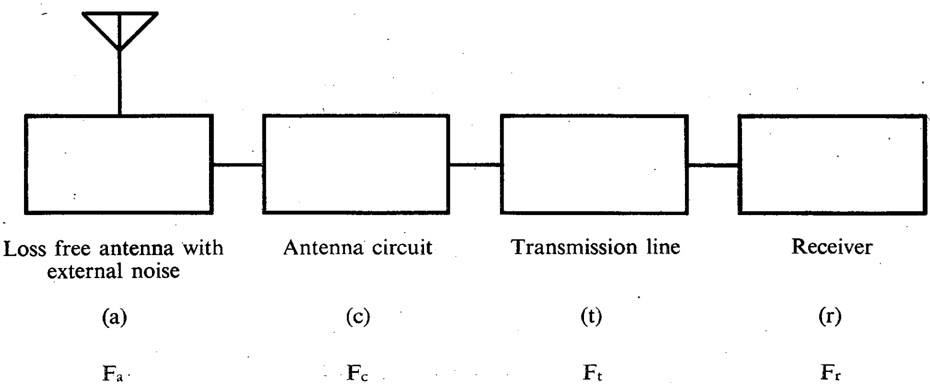


FIGURE 26

Typical distribution of hourly medians
Front Royal, Virginia, 135 kc/s, for the time block 1200—1600 hrs
September, October and November 1952



$$F = F_{actr.} = F_a - 1 + F_c\ F_t\ F_r$$

FIGURE 27

Network for the definition of F, the effective receiver noise figure

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