Vol. 9 No. 43 *Journal of the Radio Research Laboratories* May 1962
Printed in Tokyo, Japan

UDC 621.391.822; 029.56

MEASUREMENT OF ATMOSPHERIC RADIO NOISE ON 2.5 MC/S ON BOARD THE ANTARCTIC RESEARCH EXPEDITION SHIP "SOYA"

By

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ABSTRACT

Field intensities of atmospheric radio noise on 2.5 Mc/s were measured on board the "Soya" in the course from Tokyo to Antarctica.

Results obtained in the analysis of the measurement are summarized as follows:

(1) Atmospheric radio noise in the daytime which is predominant in the tropical region and near South Africa corresponds well to the meteorological situation.

(2) Intensities of atmospheric radio noise measured agree well with the values measured at the fixed stations (Singapore and Pretoria) and with what was predicted in Report No. 65 of C.C.I.R. except a few points.

(3) Characteristics of the atmospheric radio noise were examined in connection with the solar zenith angle and the latitude. It is found that both the feature of diurnal variation and the relation between absorption and solar zenith angle change clearly with the latitude.

(4) Decrease of the intensity at midnight towards the south from about 32°S is greater than that of the intensity calculated only by the distance (the so-called unabosorbed field intensity) and smaller than what was predicted by Report No. 65.

(5) Atmospheric radio noise recorded is classified into two kinds by taking account of the meteorological situation, its diurnal variation, the absorption with distnace, etc. The first is the "local noise" generated by meteorological turbulence in rather shart distances and the second is the "distant noise" which originates in long distances and arrives at the receiver through the ionosphere.

(6) Abnormal enhancement of the atmosheric noise was seen when the ship entered the rain shower, while the noise fell down to zero level with a flash of lightning and then it rose up exponentially with the time constant of the order of 1 minute. These facts seem to suggest the mechanism of the atmospheric radio noise originating in the rain shower. In other words, the precipitation noise by rain shower emerges in the presence of both the rain drop and the static field between the earth and the cell of charged clouds.

1. Introduction

The C.C.I.R. recommends[1] that new and sufficient data of atmospheric radio noise throughout the world to justify any further revision of Report No.

65[2] should be accumulated and made available. For this purpose, the measurement of atmospheric radio noise was made in the oceanic areas on the fifth Japanese Antarctic Research Expedition.

Another purpose of the measurement is to get the mechanism generating the atmospheric radio noise associated with the meteorological situation.

It was suggested by Dowden[3] (1957) and Brice[4] (1958) that the diurnal variation of short range echoes[5] on the ionospheric recorder would be dute to the instrumental cause resulting from the diurnal variation in intensity of the atmospheric noise. In this sense, it is the third purpose of our measurement to confirm the diurnal variation of atmospheric noise with respect to the short range echoes. This will be described, however, on another occasion, in any appropriate paper on the short range echoes.

This paper describes the experimental results and some analyses of the atmospheric radio noise on 2.5 Mc/s over the route from Tokyo to Syowa Base in Antarctica.

2. Measurements

Continuous recordings of the atmospheric radio noise were carried out on board the "Soya" from the 16th of November, 1960, through the 15th of January, 1961, in the outward course to Antarctica as indicated in Fig. 1.

The receiver and the antenna used and some details of the apparatus are given in Table 1.

Table 1. Details of the Receiving Apparatus.

Receiving Antenna	8 m high vertical grounded
Receiver	HF field intensity meter
Receiving Frequency	2497.5 kc/s locked by crystal
I.F. Bandwidth	550 c/s at 6 db down
Time Constant of Detector	approximately 0.1 msec.
Recorder	approximately 500 msec.
Running Speed of Recording Paper	12 cm/hr

The frequency of the receiver was set within the guard band of the standard frequency wave on 2.5 Mc/s in order to reduce interference by undesired signals.

Miscellaneous characteristics of the receiving apparatus including the gain of antenna were measured in advance of the departure, and the calibration of overall gain of the apparatus was made on the voyage every day.

Records obtained were divided into 5-minute intervals in which as an intensity of atmospheric noise was taken the upper level of the part smeared densely with ink on the continuous recording paper. Intensities of the atmospheric noise

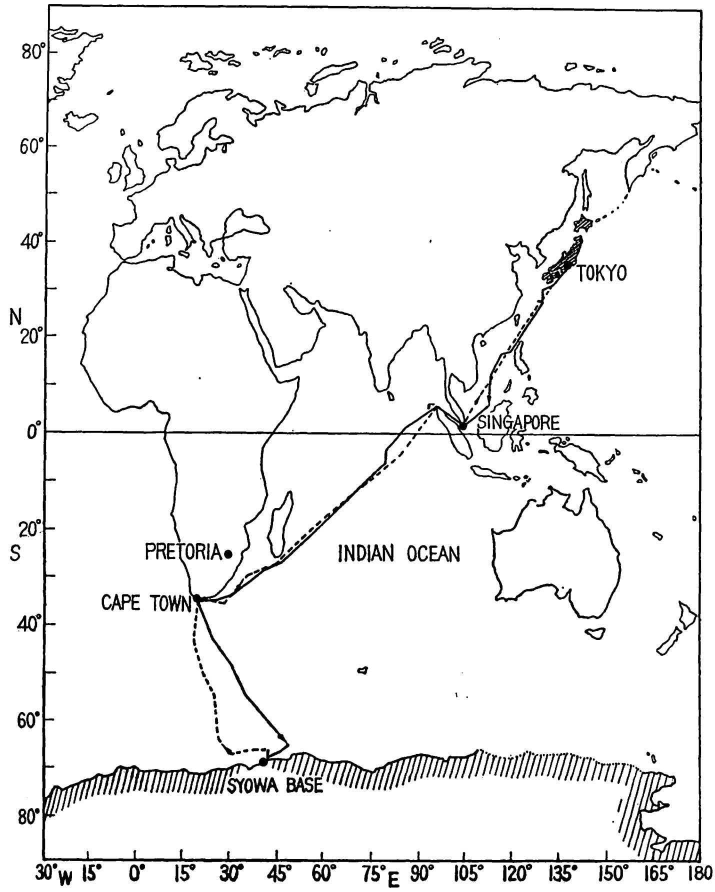


Fig. 1. Track chart of the Soya.
(—— outward, ... homeward)

used in the analysis below are the representative values of every 30 minutes and they correspond to the median value of six 5-minute intensities. For the sake of comparison with Report No. 65, these intensities for a bandwidth of 550 c/s were converted into the values for a bandwidth of 1 kc/s.

When there are seen on the record several impulses of the atmospheric noise exceeding approximately 20 db over the intensities smeared densely on the recording paper at 5-minute intervals, the descriptive symbol P is attached to the intensity of atmospheric noise.

The time used in the analysis is the local time (the ship time corrected once a day).

It will easily be recognized in the following paragraph 3.1 that, as a whole, the intensities of atmospheric noise reduced from the recording paper and calculated for a bandwidth of 1 kc/s are in good agreement with the values obtained from the available noise power, F_a, as in Report No. 65.

3. Results of Measurement and Their Analyses

3.1. Comparison of intensities of atmospheric noise measured with those predicted in Report No. 65 and measured at two fixed stations

In order to know the difference between the intensities of atmospheric noise reduced from our records and the available noise power which is used in reports or papers on the atmospheric radio noise, the available noise power on 2.5 Mc/s predicted in Report No. 65 and the intensities measured at Singapore and Pretoria stations were converted into the noise intensities in 1 kc/s bandwidth, and were compared with the values measured on board the "Soya". The predictions of atmospheric noise in Report No. 65 are divided into four seasons, that is, spring (Mar., Apr., May), summer (June, July, Aug.), autumn (Sept., Oct., Nov.) and winter (Dec., Jan., Feb.), and are subdivided into six parts of four hours each, that is, (00 h–04 h), (04 h–08h), (08 h–12 h), (12 h–16 h), (16 h–20 h) and (20 h–24 h) in local time.

Therefore, the noise intensities measured in a month from the 15 th of November through the 15 th of December were compared with the mean values of autumn and winter in Report No. 65. The noise intensities measured were averaged every 4 hours in time and every 5° in latitude. Fig. 2 shows variations in the intensity of atmospheric noise with latitudes in comparison with the measured and predicted intensities. In the figure, the solid and dashed lines indicate the measured and predicted intensities, respectively, and the hatched portion means the averaged level on which the values below the minimum receiving intensity are included.

As seen easily from the figure, the intensities measured agree rather well with the values predicted in Report No. 65 except two regions described below. The measured value is 15–25 db higher in the region of about 21°N in the figures of (08 h–12 h) and (12 h–16 h), and 6–10 db higher in high latitudes over 35°S in the figures of (20 h–24 h) and (00 h–04 h) than the predicted values. The cause of these discrepancies with the predicted values will be interpreted in paragraphs 3.2 and 3.4.

The intensities of atmospheric noise measured were also compared with those at Singapore Station (1.3°N, 103.8°E) and Pretoria Station (25.8°S, 28.3°E) which are situated near the course of our voyage. The noise intensities[6] at each station are given in monthly median values. Intercomparison of the diurnal variations in noise intensity is shown in Fig. 3 in which Fig. 3–a and Fig. 3–b show the comparison of intensities measured from 10°N to the equator with those at Singapore and of intensities measured from 20°S to 30°S with those at Pretoria, respectively. It will be recognized from the figures that these intensities agree well with each other, if it is possibly assumed that the discrepancy by night in Fig. 3–b may be due to the distance between Pretoria and the course of the ship.

Consequently, it is concluded that the intensities of atmospheric noise reduced from our measurement are reliable for purposes of comparison with the available nosie power in other literature.

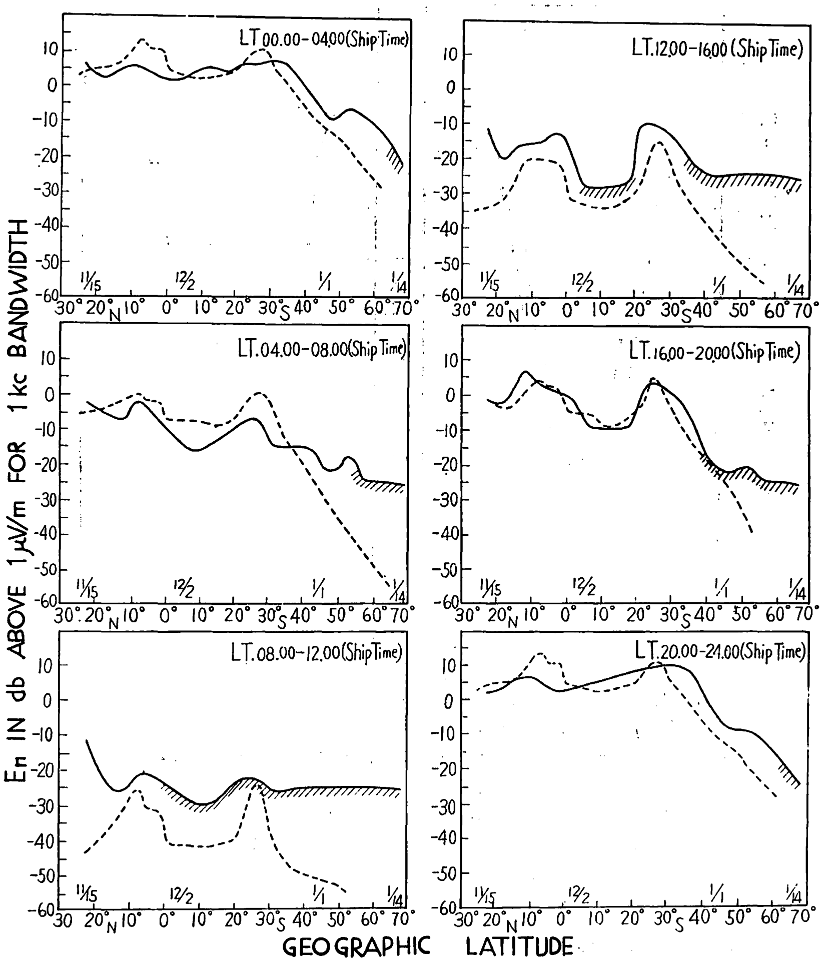


Fig. 2. Comparison between the average intensity by measurement and the value by Report No. 65 every 5° of latitude.

(—— Measured value, ---- Report No. 65)

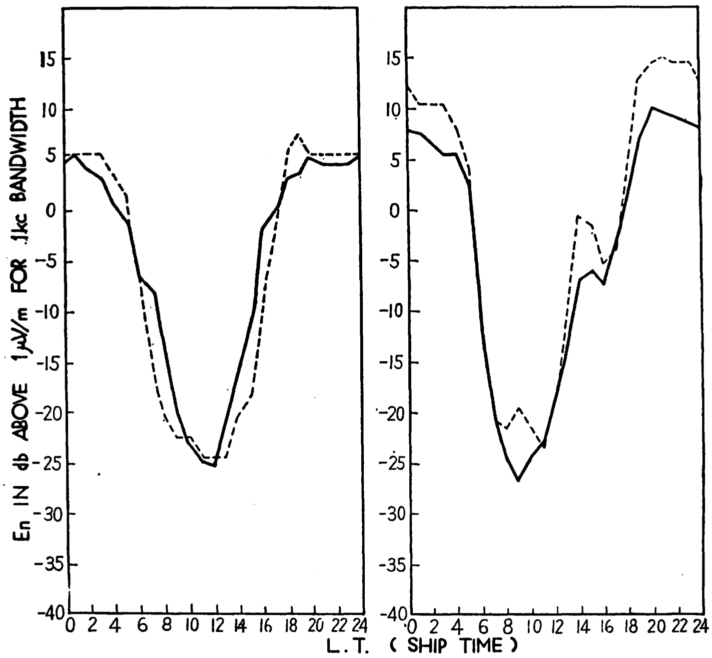
3.2. Variation of atmospheric radio noise with the meteorological situation

The average intensities of atmospheric noise measured were compared with the meteorological data along the course concerning pressure, temperature, vapour pressure, amount of clouds and rain, rain and snow shower, and thunder in the same interval.

These are shown in Fig. 4. Its explanation is as follows:

Atmospheric noise intensity......Field intensity, E_n, plotted for each 4-hourly time block along the course. Two curves of a thick solid line (08 h–12 h) and a thick dashed line (12 h–16 h) in the daytime should be noted in the comparison.

Pressure, temperature and vapour pressure......Three-hourly values.



(3-a) (3-b)

Fig. 3. Diurnal variation of atmospheric noise intensity.
(3-a) Comparison between the atmospheric noise intensity measured (——) and that at Singapore (- - - Dec. 1960).
(3-b) Comparison between the atmospheric noise intensity measured (——) and that at Pretoria (- - - Dec. 1960).

Amount of clouds and rain......Average amount of clouds and the total amount of rain during 9 hours centering at noon. The amounts of cumulonimbus and nimbo-stratus closely associated with thunder and rain are shown individually.

Rain and snow shower......Presence or absence of rain and snow shower during 9 hours centering at noon.

Thunder......Its presence being distinguished by the flash of lightning every 3 hours all day through.

It should be noted that the variations of atmospheric noise during the daytime are greater than those in the nightime. Correspondence of higher intensities of the noise during the daytime to the meteorological situation can obviously be seen in the regions of 21°N (the Bashi Channel), 5°N (the Malay Peninsula), 25°S (Southern Madagascar) and 32°S (Southern Coast of Africa). It is common in these regions without exception that pressure is low or on the decrease, vapour pressure exceeds at least 25 mb, and the average amount of clouds reaches a high level accompanied by rain or snow shower or thunder. In higher latitudes than 35°S, however, a large amount of clouds are often

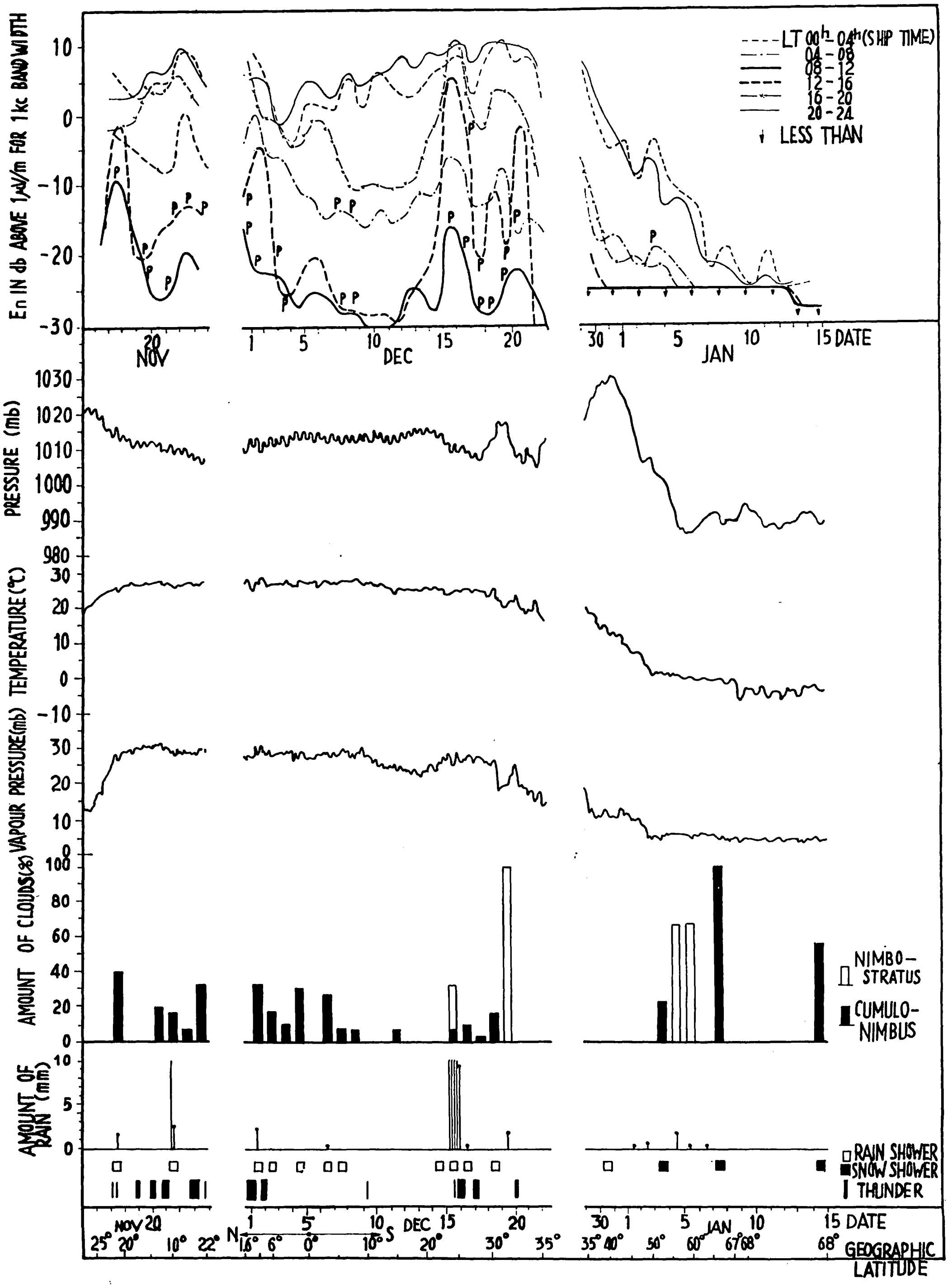


Fig. 4. Comparison between the meteorological data and the radio noise intensity measured on board the "Soya."

observed, nevertheless, no increase of atmospheric noise can be seen during the daytime. It seems to be certain that the development of cumulo-nimbus or nimbo-stratus can be prevented according to the decrease of temperature and vapour pressure.

The variation of atmospheric noise in lower latitudes at night is within 14 db and lower than that during the daytime, although the regions where the noise intensity is high during the daytime correspond also to those with a high level at night. However, the intensity at night in higher latitudes shows a tendency to gradual decrease.

From the facts mentioned above, the following conclusions may be derived: The high intensities of atmospheric noise in the daytime closely associated with the meteorological situation are considered to be caused by the "local noise" which arises from the source of noise near the receiver. The source of noise would be identified with the inter-cloud discharge, a thunderbolt, precipitation noise by raindrops, etc.(7)

3.3. Latitudinal characteristics of the noise intensity

Fig. 5 shows the mean diurnal variation of the intensity of atmospheric noise at various latitudes. In this figure, the noise intensity begins to decrease gradually at sunrise and reaches the minimum at noon and then increases to higher levels at night. These diurnal variations of the intensity dependent on the solar zenith angle are shown in Fig. 6 against $\cos \chi$ in logarithmic scale on the abscissa. It may be seen from the figure that the noise intensities in the afternoon at 15 h 30 m ($\cos \chi = 0.5$) and 14 h 00 m ($\cos \chi = 0.73$) at 5°N, and at 14 h 00 m ($\cos \chi = 0.85$) and 16 h 00 m ($\cos \chi = 0.85$) at the latitudes of 25°S and 35°S are higher than those in the morning. In other words, the "local noise" described in the preceding paragraph has higher frequency of occurrence in the afternoon at the latitudes of 5°N, 25°S and 35°S. This will also be approved by the fact that the occurrence frequency of a thunderstorm is high in the afternoon.

The solar control of noise intensity was examined by the data in the morning, ignoring the "local noise" in the afternoon described above.

If the absorption of atmospheric noise is considered to follow the equation:

$$\Gamma = A(\cos \chi)^n \tag{1}$$

the absorption coefficient, A, and the exponent, n, are shwon in Fig. 7 against the geographical latitude, where Γ was deduced from the noise intensity at night. The variation of n and A with the latitude in the figure agrees roughly with the characteristics obtained from the data of absorption measurements at vertical incidence of pulse(9).

3.4. Distance characteristics of the noise intensity at night

The noise intensity at night shown in Fig. 4 decreases towards high latitudes. This tendency is also seen in Report No. 65. The distance characteristics towards the south were considered on the assumption that the noise source is near the region of South Africa, because the noise intensity in the region at night is very stable (within ± 1.5 db) and intense.

The noise intensities measured are plotted in Fig. 8 against the distance

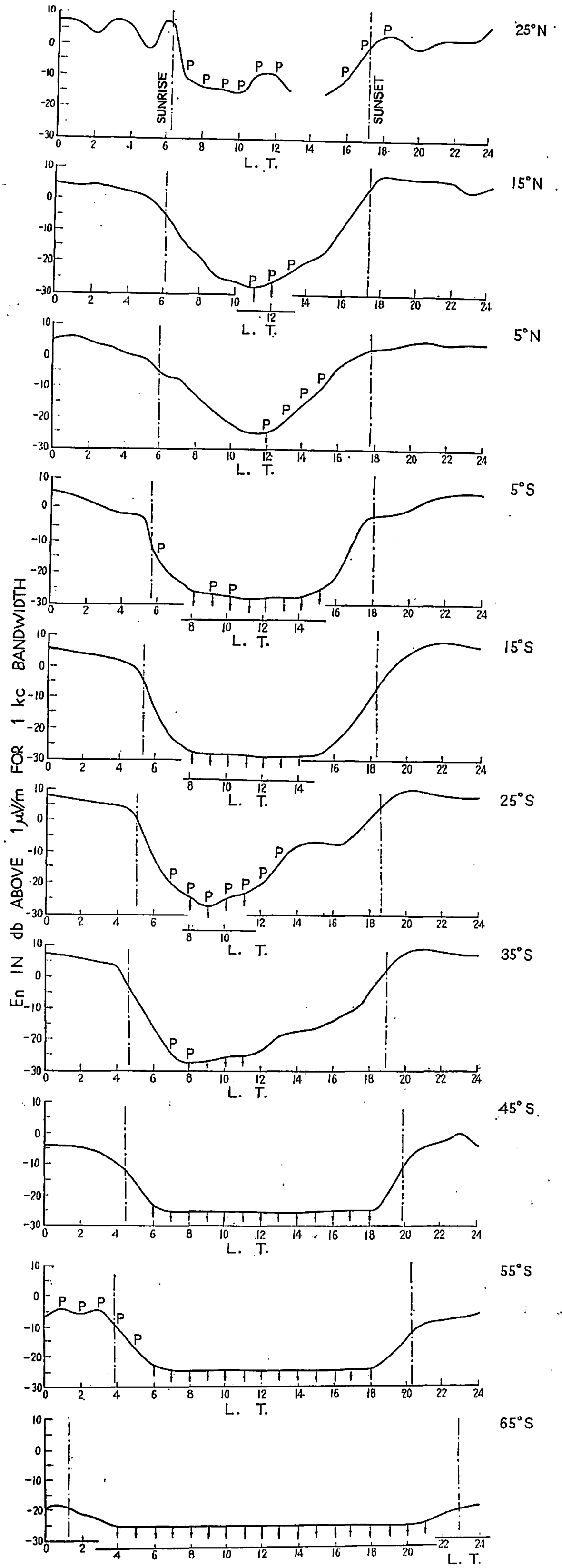


Fig. 5. Diurnal variation of atmospheric noise intensity in different latitudes.

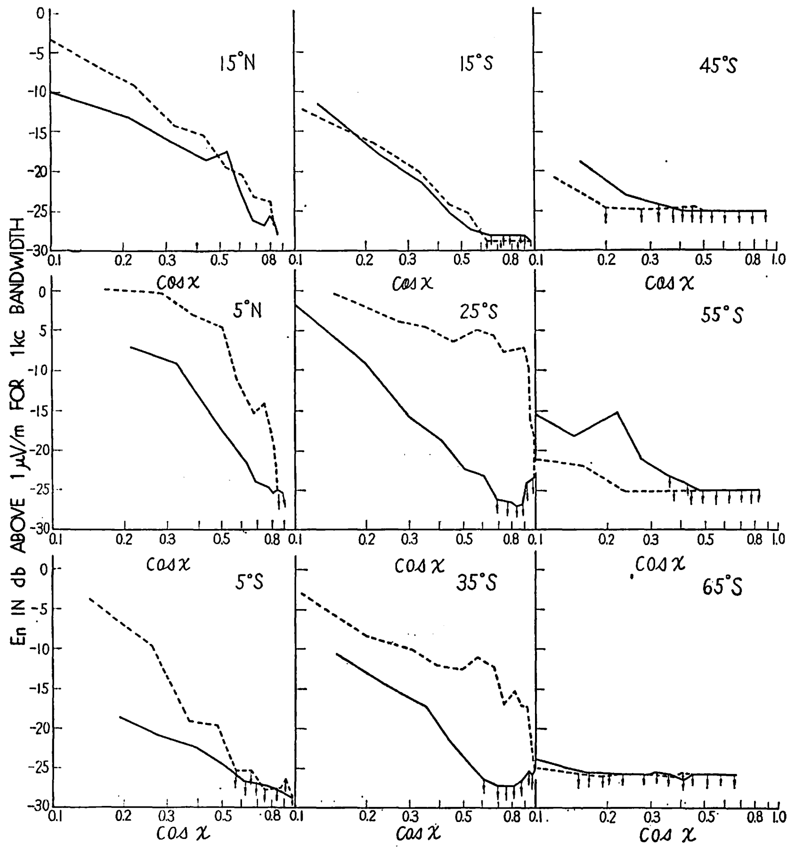


Fig. 6. Variation of the noise intensity in various latitudes versus solar zenith angle.
(—— A. M, - - - P. M, ↓ less than)

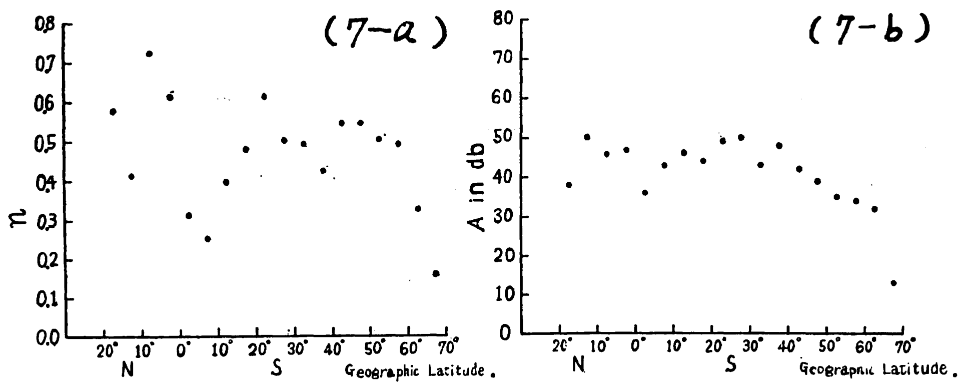


Fig. 7. Latitudinal variation of the absorption: $\Gamma = A(\cos \chi)^n$
(7-a) exponent (n)
(7-b) absorption coefficient (A)

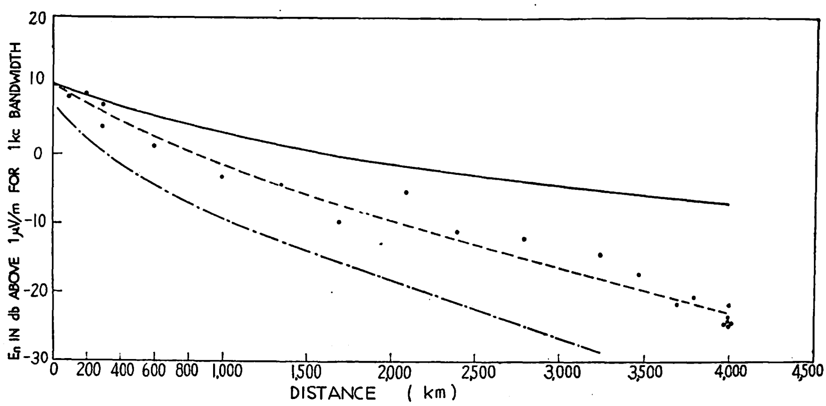


Fig. 8. Distance characteristics.

· Measured values,
--- Unabsorbed field intensity including the absorption at night,
—— Unabsorbed field intensity,
—·— Field intensity predicted in Report No. 65.

from 32°S towards the south along the course. For comparison in the figure are drawn the unabsorbed field intensity[10] by a solid line, the field intensity including the "night absorption"[11] by a dashed line, and the predicted intensity in Report No. 65 by a dash-dot line. It may easily be recognized that the measured intensities marked by dots agree closely with the dashed line, the field intensity including the "night absorption".

It is concluded that field intensity over the distance from 32°S to 70°S is explained on the assumption that the noise source is near South Africa and the atmospheric radio noise does not originate in a high latitude, but propagates from the region of lower latitudes. Furthermore, it is of importance that the noise intensity predicted in Report No. 65 is lower in high latitudes than what was measured.

3.5. Precipitation noise accompanied by a rain shower

Noise enhancement was often observed at the same time with a rain shower in the tropical region as shown in Fig. 9. The radio noise increased when the ship entered a rain shower, and this enhancement of noise in the shower was sometimes interrupted by an abrupt fall to the background level at the same time with the lightning discharge observed. This is apparently confirmed to be the precipitation noise accompanied by a rain shower. The relations of the number of times of occurrence with the duration (T) and with the maximum intensity (E_n(max)) are shown in Figs. 10-a and 10-b, respectively, from 30 examples obtained. Although the duration (T) corresponds to the time of passing through the rain cloud, the duration of the order of several minutes as obtained from Fig. 10-a does not mean the dimension of the cell of rain cloud, because the relative direction of the movement of the cloud to the ship can not be known. Fig. 10-b shows that the maximum amplitude of noise in the shower

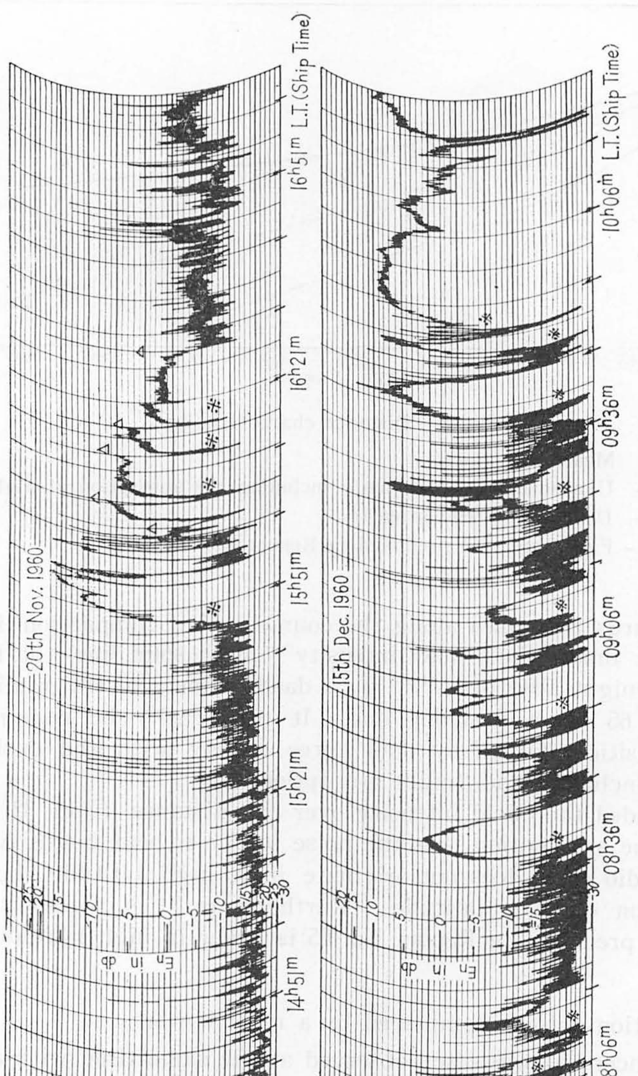


Fig. 9. Example of records of precipitation noise in rain shower.
(* Noise enhancement by rain shower,
△ Lightning discharge.)

is within about 10 db at its maximum.

The build-up form of the precipitation noise was examined as follows:

$$E=E_0\left(1-e^{-\frac{t}{\tau}}\right) \tag{2}$$

where E is the noise intensity at the time t and τ is the equivalent time constant of the noise source.

When the equation (2) is transformed with respect to τ,

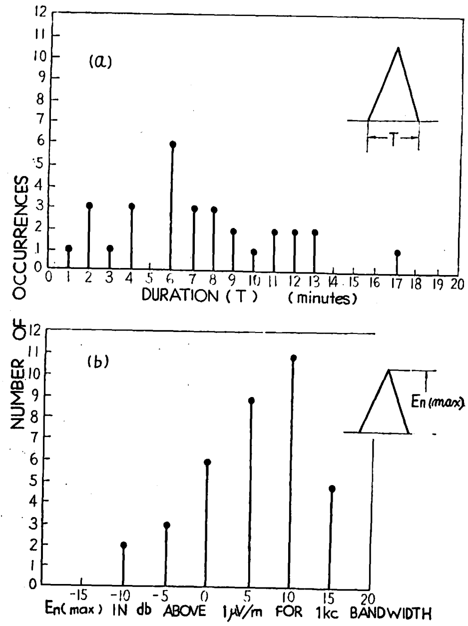


Fig. 10. Characteristics of noise by rain shower.
(10-a) Relation between the duration and the number of occurrences.
(10-b) Relation between E_n (max) and the number of occurrences.

$$\tau=\frac{t_1}{\log_e(E_2/E_1-1)^{-1}} \tag{3}$$

where E_1 and E_2 are the noise intensity at t_1 and t_2 respectively. Therefore, τ is represented by the gradient of the line in Fig. 11 with $(E_2/E_1-1)^{-1}$ on the ordinate by logarithmic scale and with t_1 on the abscissa.

It is obvious that the reduced intensities plotted by dots in Fig. 11 follow the straight lines; in other words, the precipitation noise increases exponentially. The number of times of occurrence of τ is shown in Fig. 12.

It is concluded that the precipitation noise by a rain shower originates in the presence of both raindrops and the static field between the earth and clouds, and, furthermore, the noise source has apparently the time constant of about 1 minute.

4. Concluding Remarks

The measurement was made for only two months from November through January. Hence, the conclusions on comparison with Report No. 65 may be applied to at least the winter months (December, January and February). Further observations are needed to know the world-wide distribution of atmospheric

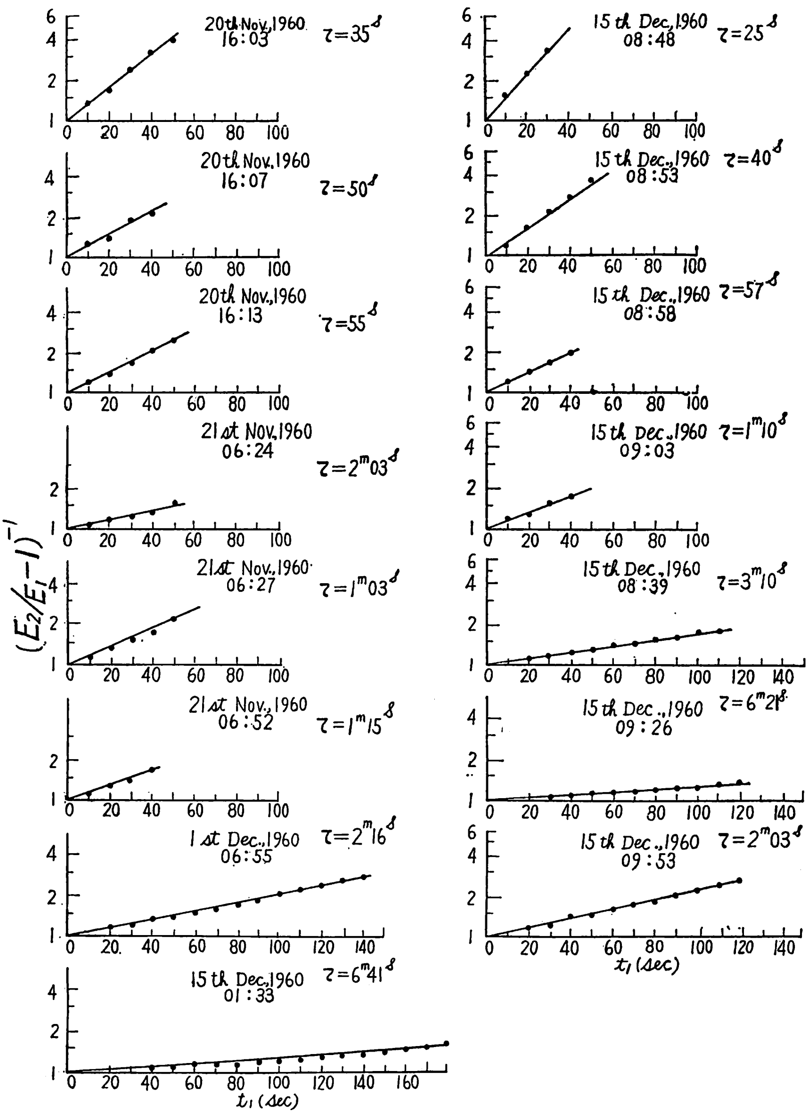


Fig. 11. Relation between $(E_2/E_1-1)^{-1}$ and t_1.

noise in the areas unexplored yet, including the Bashi Channel and high latitudinal regions.

It should be noticed that the precipitation noise by blizzard(12) (snow-storm) and the emission of radio noise from an aurora play an important role in high latitudes, especially in the local winter.

The diurnal variation of atmospheric noise in low latitudes shows that the change of noise intensity reaches about 30 db within a few hours after sunrise and before sunset. Nevertheless, Report No. 65 gives only an intensity in a

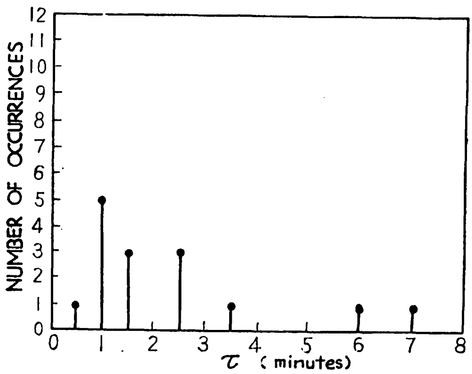


Fig. 12. Number of times of occurrence of τ.

4-hour time block. It seems clear that the precise feature of the diurnal variation of atmospheric noise can not be obtained from these six intensities a day. Therefore, it may be recommeded that the noise intensity should be given at least every two hours.

It has been suggested that the raindrops polarized by the electro-static field between the earth and the cell of charged clouds bombard the receiving antenna with atmospheric noises. This is supported by the fact that the precipitation noise was observed only when the ship entered a rain shower and that the noise intensity decreased instantaneously with the lightning discharge and then was followed by the exponential increase.

It is hoped that the generating mechanism of atmospheric noise would be clarified in detail by the observation of electro-static field in the air and the direct measurement of the charge of raindrops.

Acknowledgement

The authors wish to express thanks to Mr. Yasutaro Morita of the Japan Meteorological Agency for the meteorological data with the interpretation thereon placed at the authors' disposal, to the researchers in this field of the Radio Research Laboratories for the suggestive discussions given, and to Mr. Kazuyoshi Sawada and Mr. Shoji Watanabe who rendered much help in the reduction and interpretation of the data.

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