ATMOSPHERIC NOISE STUDY BY MEASUREMENT OF THE AMPLITUDE PROBABILITY DISTRIBUTION

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The cumulative probability of amplitude in the envelope of atmospheric noise has been measured at the output of a narrow-hand receiver at 50 kc/s. The level of integrated atmospherics has been recorded at the output of the receiver at the same frequency. The band width of the receiver was about 1,000 c/s. The departure from a single logarithmic-normal distribution has been investigated. The description is given of the type of the amplitude distribution. The description is given of a calculation which has been done to determine the effect that the departure from a single logarithmic-normal distribution have on the total noise power. The curves derived from this calculation may provide a useful means in estimating the R. M. S. value of the noise amplitude. The description is given of a calculation which has been done to investigate the behaviour of short-time fluctuations of the probability measured. The results may provide a means in estimating a pulse spacing of the larger amplitude. Various parameters have been derived from the amplitude distributions. The deseription is given of these parameters and the diurnal change of each parameter is shown, and the level of ietegrated atmospherics is compared with the R. M. S. value derived from the amplitude distribution.

I. Introduction.

The interference of wireless systems caused by atmospheric noise has been investigated in relation with measurement of atmospheric noise. Several measures of atmospheric noise have been chosen and investigated, that is, the cumulative probability of amplitude in the envelope of atmospheric noise, the moment of the distribution and the average number of the noise impulse[1)2)3)]. The observation of atmospheric noise at 50 kc/s was done for about ten days commencing at 19th June in 1957 at Toyokawa. The measurements have been confined to the measure of atmospheric noise, that is, the cumulative probability of amplitude in the envelope of atmospheric noise, and the level of integrated atmospherics. It has been shown that a representation of the distribution by a single logarithmic-normal distribution does not necessarily hold in the whole range of the probability. The distributions, therefore, have been classified into three types. The results are shown in this paper, and a calculation is described which has been done to determine the effect the departures from the logarithmic normal-distribution have on the total noise power. And a calculation is described which has been done on a supposition of a model of the noise pulse to explain the behaviour of fluctuations of the cumulative probability recorded, and the results are compared with data obtained from observations of atmospheric noise at 100 kc/s. The diurnal change are shown of various parameters derived from the distributions. The level of integrated atmospherics is compared with the R. M. S. value of the noise amplitude.

II. Method of Observation.

The records of the amplitude probability distributions in the envelope or integrated strength of atmospheric noise were obtained with the equipment, the block diagram of which is shown in Fig. 1. The antenna employed was a 10-meter vertical rod, with its lower end connected to a cathode follower to provide an impedance matching the low impedance of the concentric shielded cable of 100 meter length. And the other end of the cable was connected to the main amplifier of the reciver.

The receiver shown in the block diagram, Fig. 1, was designed to be tuned to a series of different frequencies between 50 and 535 kc/s, with its overall bandwidth between half-power points of about 1,000 c/s, and the output of the intermediate frequency, 30 kc/s, at the output of the receiver was fed to the common input of four probability computers and an integrated level meter.

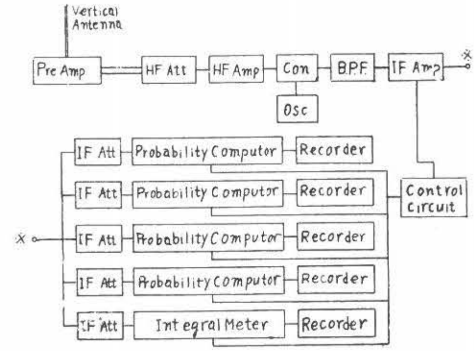


Fig. 1 Block diagram of equipment for measuring atmospheric noise.

Cumulative probabilities of the amplitude in the envelope of atmospheric noise were obtained with four probability computers as illustrated in Fig. 2. This circuit was designed, as reported by Sullivan, Hersperger, and others to measure the fractional time spent by the envelope above various thresholds.

The rectangular pulse of a current of constant height, 5 ma, with the same duration as that exceeded by the noise envelope against the given threshold feed the RC networks with a time constant of about 12 seconds. The voltage between the plates of the condenser 4,000 μF shows the cumulative probability of the noise envelope for the given threshold. The voltage was recorded on a paper with a linear scale moving at 1.2 cm per minute.

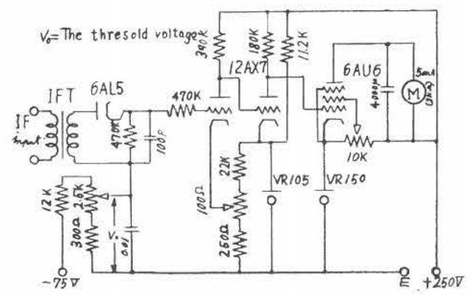


Fig. 2 Circuit for measuring the amplitude probability distribution.

The ietegrated level meter as shown in Fig. 3 was employed to measure the strength of integrated atmospherics received, that is, the IF output of the receiver fed to the input was rectified and averaged with a time constant of about 8 sec. The resulting voltage was recorded on a paper moving at 0.2 cm per minute.

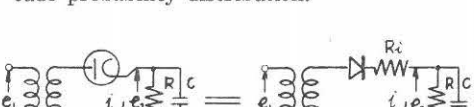


Fig. 3 Principal circuit for measuring the level of integrated atmospheric noise.

All the records except one quoted later in this paper were made at 50 kc for about ten days commencing on 19th June 1957, at the Research Institute of Atmospherics of Nagoya University. The measurement was done each hour with the probability computers and the integrated level meter for 15 minutes beginning at 00 minute. Then 15 minutes were divided into 3 groups, 1st 5 minutes being taken for recording fraction of time spent over assigned threshold voltages and 2nd or 3rd group was taken for recording over higher threshold given by changing the attenuator successively at the IF stage by 5 or 10 db respectively.

The probability computers were adjusted to set assigned threshold voltages two times a day, that is, once in the morning and once in the evening. The integrated level meter was calibrated by means of a c. w. signal generator at the beginning and the end of the period of the observations.

III. Record and Data.

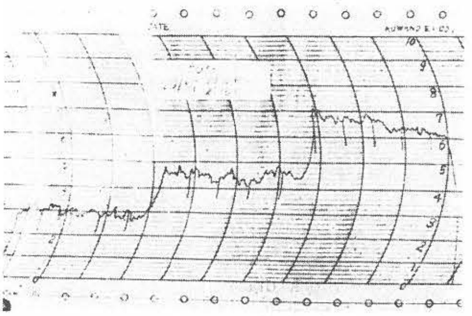


Fig. 4 Typical record of cumulative probability.

The record of the probability or fraction of time spent over the threshold voltage was such as shown in Fig. 4 with 3 different levels, each level representing in linear scale the probability measured for each 5-min. measurement. The traces as shown in Fig. 4 have generally shown fluctuations, which seem to affect the form of the amplitude probability distribution to be deduced, depending upon the position read on the fluctuating trace. To approach statistically stationary distribution, data were taken by estimating the average of the level of trace over each 4-min. period (later over the specified one min. period) except the 1st min. The average of the level of trace was obtained by reading a level at the instance spaced by 15 sec. over 4 min. period (later over 1 min. period). However, the period of 1 min. seems to be just long enough to provide statistically constant data, because the test has not shown any difference between two averages of level obtained over two periods of time, each with 1 or 4 min, that is, the fit has been found to be held in the range of probability of about 95 to 1 percent for 24 distributions obtained throughout one day during the observation.

IV. The Model of Pulse.

The responce of RC network, as shown in Fig. 5, to a series of rectangular voltage (or current) pulses occurring periodically which is spaced by a certain period of quiescient time may suggest the behavior of fluctuations of probability as described in Section III, and the following analysis of the response of RC network may provide a means of estimating the pulse spacing or the pulse width as descrived in section VII in the latter part of this paper.

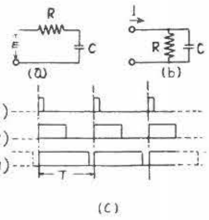


Fig. 5 (a) Series RC network, (b) Parallel RC network, (c) Periodically occurring waveforms consisting of rectadgular voltage (or current) pulse of the same height. Period $=T=(1+a)\tau$, (1) $a=9$, (2) $a=1$, (3) $a=1/9$

An illustration of such a series of rectangular voltage (or current) pulses is given in Fig. 5, in which the period is $T=(1+a)\tau$, and τ is the pulse width and $a\tau$ is the duration of quiescent time; then the ratio of $\frac{\tau}{(1+a)\tau}$ being a constant, any series of rectangular voltage pulse, each with a different period, has the same probability or the same potential difference between the plates of the condenser, when the loss is neglected in the resistance R.

Therefore, when the probability p is measured, the charging current at the output of the probability computer with time constant RC may be considered to be composed of many series of such rectangular current pulses, each with equal ratio of $\frac{\tau}{T}=p$ and different period T.

Fig. 5 represents 3 examples of a series of voltage or current pulses, each with the same period and different probability 10, 50 or 90 percent.

However, a time constant of RC network affects the probability which should be obtained in an ideal case. Then, let us calculate the response of the series RC network, as shown in Fig. 5b, to a series of rectangular voltage pulses of height E with period $T=(1+a)\tau$, where τ is the pulse width and $a\tau$ is the duration of quiescient time, because the response is well known to be equivalent to that of the parallel RC network, as shown in Fig. 5b, to a series of rectangular current pulse of the height $I=\frac{E}{R}$, with the same period T and the same duration of quiescient time $a\tau$.

The output voltage or the potential difference between the plates of the condenser at the beginning or end of series of rectangular voltage pulses with period T and the ratio $\frac{\tau}{(1+a_p)\tau}=p$ is derived as follows:

$$
\begin{array}{ll}
t_0 \leqq 0 & V_0=0\,, \\
t_1=\tau & V_1=\frac{E}{R}\cdot(1-\varepsilon^{-\alpha\tau}), \\
t_2=(1+a_p)\tau & V_2=\frac{E}{R}\cdot(1-\varepsilon^{-\alpha\tau})\varepsilon^{-\alpha a\tau}, \\
\cdots\cdots\cdots\cdots & \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\
\cdots\cdots\cdots\cdots & \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\
t_{2n}=n(1+a_p)\tau & V_{2n}=\frac{E}{R}(1-\varepsilon^{-\alpha\tau}+\varepsilon^{-\alpha(1+a_p)\tau}-\varepsilon^{-\alpha(2+a_p)\tau}+\cdots)\varepsilon^{-\alpha a\tau}, \\
t_{2n+1}=n(1+a_p)\tau+\tau & V_{2n+1}=\frac{E}{R}(1-\varepsilon^{-\alpha\tau}+\varepsilon^{-\alpha(1+a_p)\tau}+\varepsilon^{-\alpha(2+a_p)\tau}+\cdots),
\end{array}
$$

and the final value of the output voltage $\underline{V_{2n}}$ or $\underline{V_{2n+1}}$ is represented respectively as follows:

$$\underline{V_{2n}}=\frac{E}{R}\cdot\frac{1-\varepsilon^{-\alpha\tau}}{1-\varepsilon^{-\alpha(1+a_p)\tau}}\cdot\varepsilon^{-\alpha a_p\tau} \tag{1}$$

$$\underline{V_{2n+1}}=\frac{E}{R}\cdot\frac{1-\varepsilon^{-\alpha\tau}}{1-\varepsilon^{-\alpha(1+a_p)\tau}} \tag{2}$$

and the final value of $(V_{2n+1}-V_{2n})$ is derived as follows

$$V=\underline{V_{2n+1}-V_{2n}}=\frac{E}{R}\,\frac{(1-\varepsilon^{-\alpha\tau})(1-\varepsilon^{-\alpha a_p\tau})}{(1-\varepsilon^{-\alpha(1+a_p)\tau})} \tag{3}$$

where $\alpha=\mathrm{RC}$.

Now it is shown that the fluctuations with time of output voltage or the

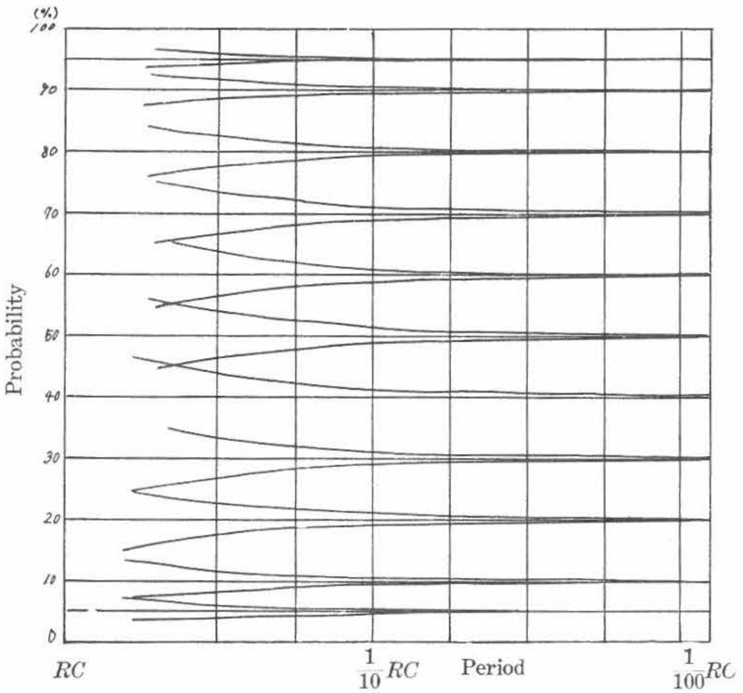


Fig. 6

probability depend on the ratio of the period T to the time constant RC. The final value of V_{2n} or V_{2n+1} was shown in Fig. 6 on a graph paper with the final value V_{2n} or V_{2n+1} on a linear scale of a unit $\frac{E}{R}$ and the period on a logarithmic scale. It is easily found here that the difference of $(V_{2n+1}-V_{2n})$ or V decreases as the ratio $\frac{T}{RC}$ decreases. The behavior of fluctuations of the output voltage may confirm the ways of deriving data from the records as shown in Fig. 4.

The application of the results will be again discussed in estimating the pulse spacing or pulse width from the records of the cumulative probability in Section VII in the latter part of this paper.

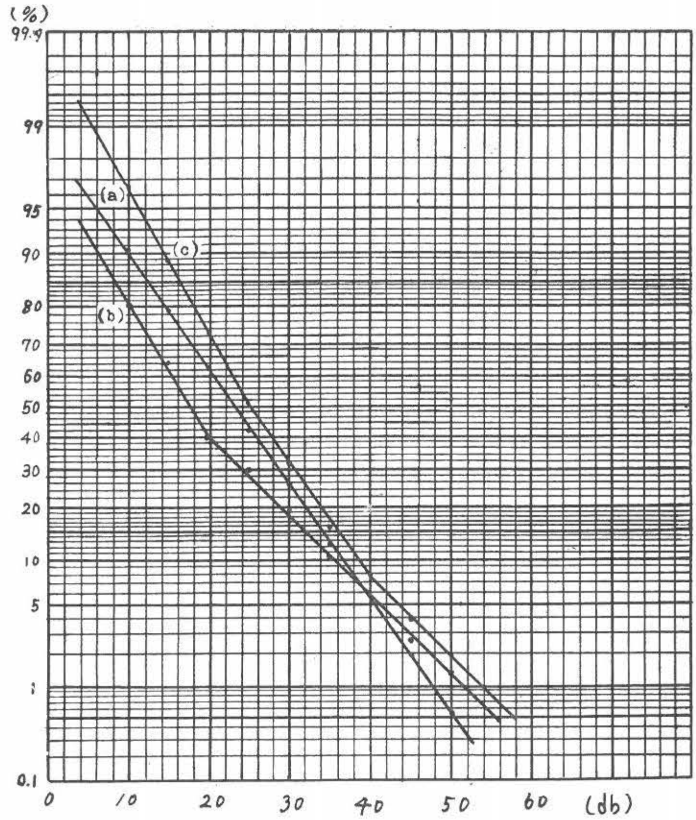
V. Representation of the Amplitude Probability Distribution.

About 170 cases of the amplitude probability distributions in the envelope of atmospheric noise were obtained by means of deriving the statistically constant data from the records measured at 50 kc/s for about ten days, at Toyokawa. All the data were plotted, for examples as shown in Fig. 7, on a graph paper with the field strength on a logarithmic-scale and the probability on a normal-scale.

These distributions have been classified into three types that is

(1) 1st type of distribution seems to be reasonably represented by a single logarithmic normal distribution,

(2) 2nd type of distribution seems to be reasonably represented by two logarithmic normal distributions, each with different standard deviation,



Field intensity (0 db=1.48 μV/m)

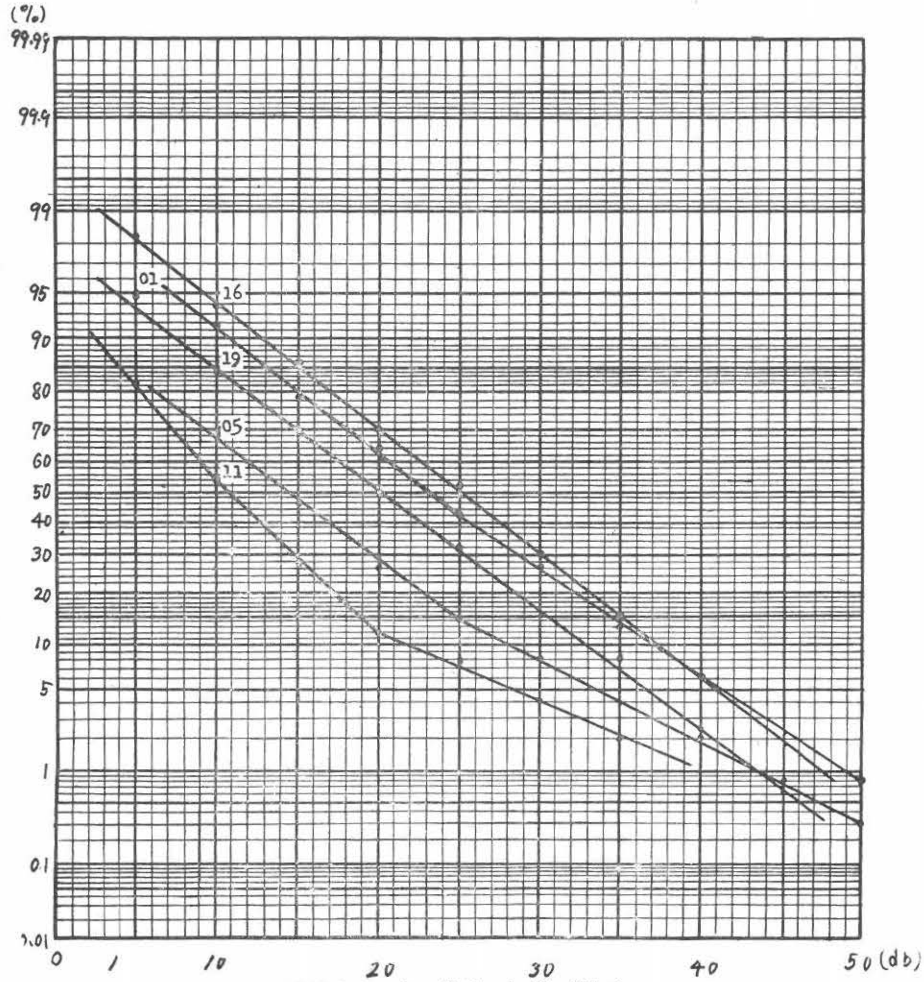
Fig. 7 Typical examples of type of approximation for the amplitude proba-bility distribution.
(a) 1957, 6/24 /00^h (b) 1957, 6/29 /03^h (c) 1957, 6/20 /18^h

(3) 3rd type of distribution seems to be reasonably represented by three logarithmic normal distributions, each with different standard deviation

Typical example of each type is shown in Fig. 7. This classification may be dependent upon the range of probability measured. The probability computers used to obtain data described in this paper is not sensitive enough for use at probability less than 0.5 percent. Therefore the classification described in this paper may be supposed to be held at most to the probability of 0.5~1 percent.

The type of the amplitude probability distribution classified seems to be dependent on time throughout one day whose typical examples are shown in Fig. 8. Then the percent of distribution of each type to a total number of distributions obtained each hour is shown against time of day as in Fig. 9. It is found there that the two logarithmic-normal-distributions approximation is the most ordinary approximation type of distribution found almost all the time throughout one day, the one logarithmic-normal-distribution-approximation is observed in most cases in the afternoon and during the night, and the three logarithmic-normal-distribution-approximation is observed frequently from about morning to mid-noon and at times near sun-rise and sun-set.

The next problem is to locate the probability at which the departure occurs from a single logarithmic normal distribution. Then these probabilities were



Field intensity (0 db=1.48 μV/m)

Fig. 8 Typical examples of amplitude probability distribution.

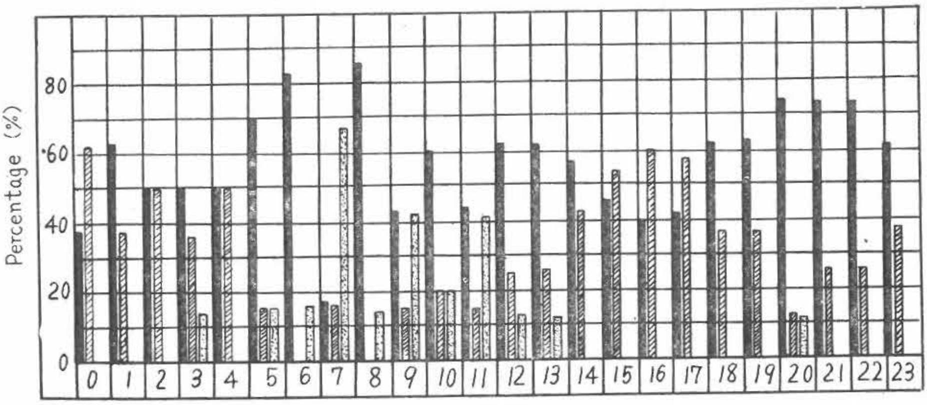
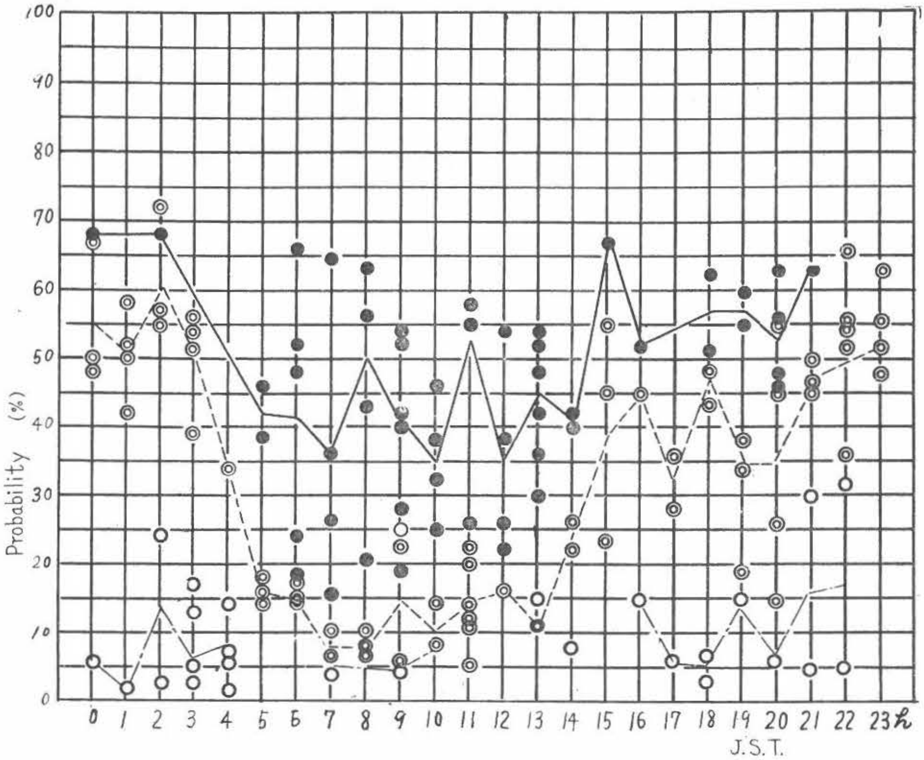


Fig. 9 Graph showing the diurnal change of type of approximation

(a) a single log-normal-distribution-approximation

(b) two 〃 〃 〃

(c) three 〃 〃 〃



Field intensity (0 db=1.48 μV/m) ● 0~5 db ◎ 10~15 db ○ 20~30 db

Fig. 10 Graph showing the diurnal change of the probability at which the departure begins from a log-normal distribution.

estimated from the distributions approximated by two or three logarithmic normal distibutions, which were plotted against time of day as shown in Fig. 10 with the probability on a linear scale.

The distribution of these plots seems to be random, but a systematic variation seems to be found in relation with the amplitude of atmospheric noise corresponding to the probability at which the departure from a single logarithmic normal distribution occurs. Then these probabilities were divided into 3 groups, each consisting of probabilities corresponding to the noise amplitudes that are less than 5 or 10 db for the ratio of the amplitude. The average of the plots each hour for each group was estimated and plotted as shown in Fig. 10. The variation of the average with time for each group seems to be in proportion with that of the field strength of integrated atmospherics as shown in Fig. 21 in the latter part of this paper.

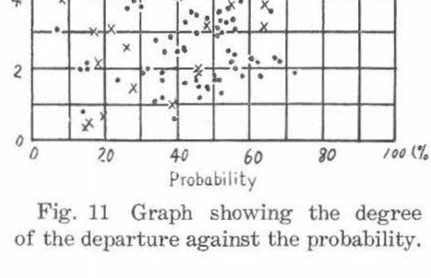


Fig. 11 Graph showing the degree of the departure against the probability.

The next problem is to investigate the degree of deprature from a single logarithmic normal distribution. The degree of departure may be expressed by a difference of two standard deviations, which can be estimated from the distribution made up of two or three logarithmic normal distributions. These differences of two standard deviations estimated from the distributions were plotted as shown in Fig. 11 as a function of the probability at which the departure occurs in the distribution.

These plots were represented by '×' or '●', the former mark representing that obtained from the distributions observed for 8 times from 05 h to 12 h. The latter one represents the one obtained from the distributions observed at each time except the specified time above. Fig. 11 shows that there are two groups, the one being made up of a part of the plots which show a larger departure at a low probability, and the other of a part of the plots with mark '×', and almost all the plots with mark '●', show the proportionality between the degree of departure and the probability.

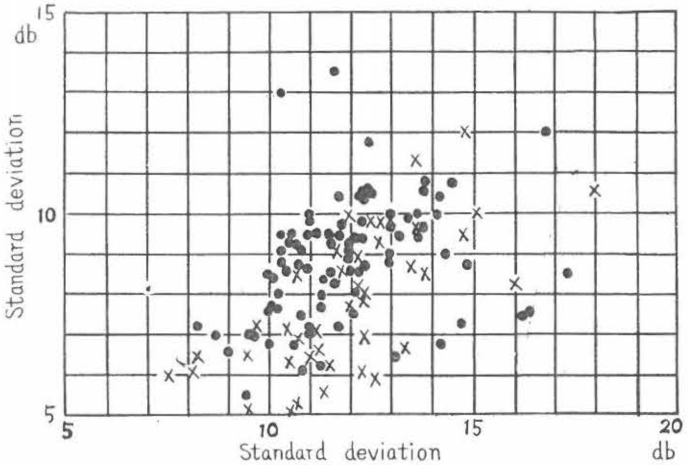


Fig. 12 Graph showing the degree of the departure against the magnitude of standard deviation,
(a) × data obtained for 05 h~12 h
(b) ● data obtained at times except that specified above

Next, the degree of departure has been investigated as a function of the density of the noise pulse, that is, the standard deviation for a logarithmic normal distribution approximated in higher range of probability was plotted against that for a logarithmic normal distribution approximated in lower range of probability as shown in Fig. 12. It is seen, in general, that the standard deviation of a logarithmic normal distribution in higher probability increases in proportion with that in the lower. Investigating the trend of the plots in detail, it seems that there are two groups, one group showing a larger departure than the other. The former in greater part consists of a part of the plots observed in the period 05 h–12 h, the other parts of the plots obtained in the same period goes into the other group made up of the plots observed at the other times. This emersion may shows that this part of plots for the 1st group has a similar character to that of the 2nd group.

These two trends of the plots may be explained by an interaction between two different noise characters, for example, an interaction between the set noise or weak man-made noise and atmospheric noise, or an interaction beween two groups of atmospherics, each with different characters, where one is the trend of the plots as shown in Fig. 11 showing the change of the degree of departure against the probability at which the departure begins and the other is the trend of the plots as shown in Fig. 12 showing the relation between two standard deviations, each being obtained from a logarithmic-normal distribution approximated in the higher or the lower range of the probability respectively.

It has been observed in the morning that the atmospheric noise of a larger amplitude arrives interruptedly at the aerial under a condition of generally quiet level of noise disturbances. Large departure therefore may result from the interraction between the atmospheric noise of high amplitude received interruptedly and the set-noise or week atmospheric noise which is received densely.

Then as the field intensity increased, it has been observed that the rate of arrival of atmospheric noise has generally become more dense and the amplitude of pulse has become larger. It may be considered that a medium or smaller deviation results in such conditions of atmospheric noise by way of similar interaction between two groups of noise as described above.

VI. The R. M. S. Value.

It is well known that the medium amplitude X or the R. M. S. value $\sqrt{\overline{X^2}}$ of the noise amplitude for a logarithmic-normal distribution may be estimated by the following equations respectively, that is

the medium amplitude: $\overline{X}=Me^{2.65\sigma^2}$ ··············(4)

the R. M. S. value : $\sqrt{\overline{X^2}}=Me^{5.3\sigma^2}$ ··············(5)

where

M=that amplitude exceeded by 50 percent of time

σ=standard deviation

But many distributions have been obtained which seem to be made up of two or three different logarithmic-normal distributions, each with different standard deviation. Then it is necessary in estimating the moment of these distributions to determine the effect that the departure from a single logarithmic-normal has on the total noise power. This necessity does occur once more in estimating the effect the extrapolation of logarithmic-normal distribution to the range of low probability which was not measured, has on the total noise power.

For this reason the contribution to the total noise power has been estimated as a function of the amplitude in envelope of an atmospheric noise for a logarithmic-normal distribution.

An important formula may be used for a logarithmic-normal distribution, that is

$$x=m+\sigma t \quad \cdots\cdots(6)$$

where the

x=logarithm of the amplitude in envelope of atmospheric noise

m=the logarithm of that amplitude exceeded by 50 percent of time

t=a variable that is in relation with the normalized normal function or its cumulative density function

These functions are

the normalized normal function $P=\varphi(t)=\frac{1}{\sqrt{2\pi}}\exp\left(-\frac{t^2}{2}\right)$ ··············(7)

the cumulative density function $\phi(t)=\int_{-\infty}^{t}\varphi(t)\,dt$ ························(8)

Then, an approximation may be done for the moment of the distribution, that is

$$X=\int_0^\infty EP(E)dE \doteqdot \sum_s E_s\{\phi(t_q)-\phi(t_r)\}=\sum_s E_s\Delta\tau \cdots\cdots(9)$$

$$\sqrt{X^2}=\sqrt{\int_0^\infty E^2P(E)dE} \doteqdot \sqrt{\sum_s E_s^2\{\phi(t_q)-\phi(t_r)\}}=\sqrt{\sum_s E_s^2\Delta\tau} \cdots\cdots(10)$$

$$E=\text{antilog}\, x$$

where the whole range of x is divided by a certain length Δx beginning at $x=m$, x_s being the specified point in the sth range, and t_q or t_r show the value at the lower end or the upper end of the sth range respectively.

A practical application of the approximation formula of the square of the R. M. S. value was done for 5 logarithmic-normal distributions, each with standard deviation 5, 7.5, 10, 15 and 20 db, that is, the square of (antilog x) or the amplitude E and the differential cumulative probability $\Delta\tau$ was calculated for the range of the amplitude larger than antilog m. In this calculation all the ranges larger than 50% were not considered, because the effect the amplitude in this range of the probability has on the total noise power could be neglected compared with that in a lower range of the probability as the standard deviation becomes larger.

It was supposed that m is 0 db, Δx being 0.2 db for three logarithmic-normal distributions, each with standard deviation 5, 10 and 20 db, Δx being 0.3 db for the other two logarithmic-normal distributions. The values of the cumulative density function $\phi(t)$ were used from "Tables of Numerical Values of Statistics" comprised by the Committee of Statistical Science, published in June 1947.

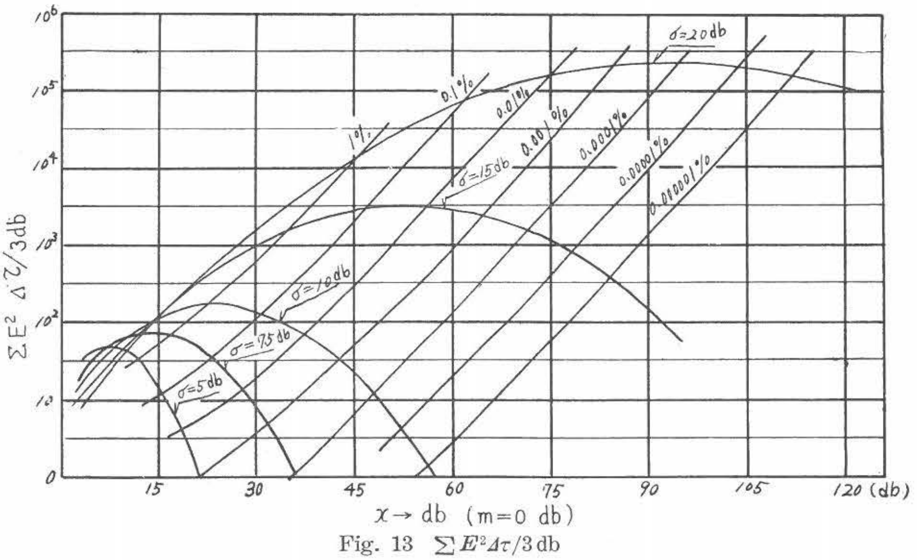


Fig. 13 $\sum E^2\Delta\tau/3$db

The required summation in relation with the numerical results derived from the calculation described above, was done for 3 db range length, then the results were plotted as shown in Fig. 13 with the amplitude on a logarithmic scale and the relative total noise power on a logarithmic scale. Then the relative total noise power contained in the range of the amplitude beginning at the amplitude exceeded by 50 percent of time was plotted as shown in Fig. 14 as the function of the upper limit of the amplitude in the range.

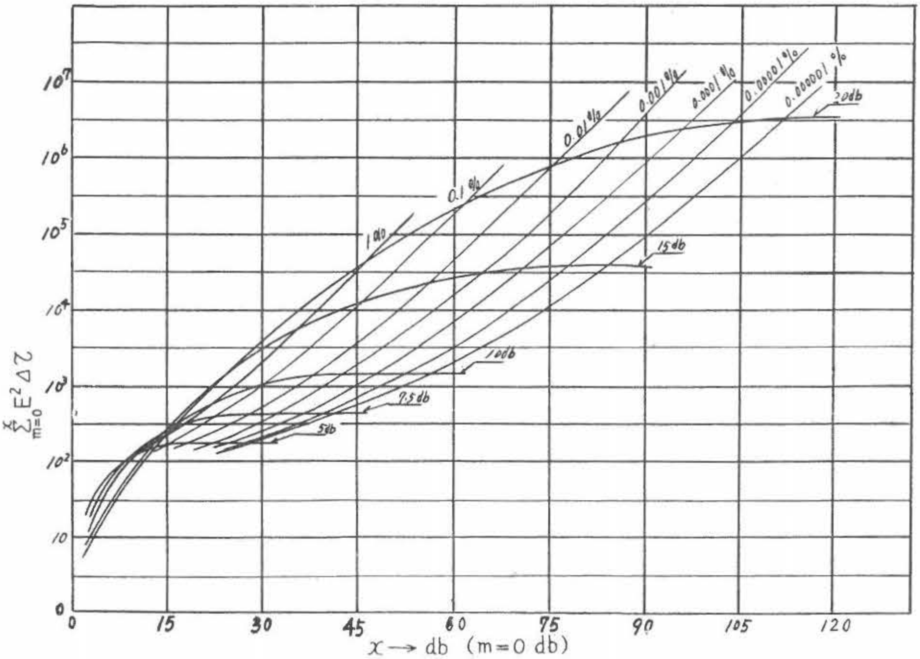


Fig. 14 $\sum_{m}^{x} E^2 \Delta\tau$

Equal probability curves were drawn, as shown in Fig. 13 and Fig. 14 on the curves with standard deviations 5, 7.5, 10, 15 and 20 db, for the probabilities 1, 0.1, 0.01, 0.001, 0.0001, 0.00001 and 0.000001 percent. It is easily understood that the most part of the noise power exists in the range of a much lower probability, as the standard deviation becomes larger. These curves may be used to estimate approximately the dynamic range of receiver required for measuring the greater part of power of atmospherics received, depending upon different standard deviations.

The numerical results derived above have been used here to determine the effect that the departure from a single logarithmic-normal distribution has on the total noise power.

Let us consider the distribution made up of two logarithmic-normal distributions, that is, the distribution is closely approximated by a logarithmic-normal distribution with standard deviations 5, 7.5 or 10 db and it change into another logarithmic-normal distribution with standard deviation 15 db at probabilities of 5, 1 or 0.1 percent. And the R. M. S. value of the noise amplitude has been estimated for three cases, that is,

(1) for three logarithmic-normal distributions with standard deviations 5, 7.5 or 10 db in the full range of probability,

(2) for the logarithmic-normal distribution with the standard deviation 15 db in the full range of probability,

(3) for the distribution made up of two logarithmic-normal distribution, each with different standard deviations (5, 15 db) (7.5, 15 db) (10, 15 db), for each case in which the probability at which the departure occurs, is 5, 1 or 0.1 percent.

Then, the ratio of two R. M. S. values has been estimated as follows;

$$(A)=\frac{\text{the R. M. S. value (3)}}{\text{the R. M. S. value (1)}}$$

$$(B)=\frac{\text{the R. M. S. value (3)}}{\text{the R. M. S. value (2)}}$$

The ratio (A) or (B) of the R. M. S. value was plotted for each of 9 distributions made up of two logarithmic-normal distributions, as shown in Fig. 15, as the function of the standard deviation for a logarithmic-normal distribution occurring in a higher range of the probability. Real or dashed curves were drawn for the ratio of the R. M. S. value (A) or (B) respectively, with a parameter of the probability at which the departure begins in the distribution. Several conclusions may be derived by investigating the curves in Fig. 15 that is,

(1) The R. M. S. value of the distribution made up of two different logarithmic-normal distributions may be approximated within an admissible error by that of a logarithmic-normal distribution having a principal effect to the total noise power. But this statement depends on the probability at which the departure begins and the degree of departure.

(2) The range of measurement that is necessary in estimating the R. M. S. value depends on the magnitude of standard deviation of a logarithmic-normal distribution which is supposed to occur in the range of the probability beyond the mersurable range.

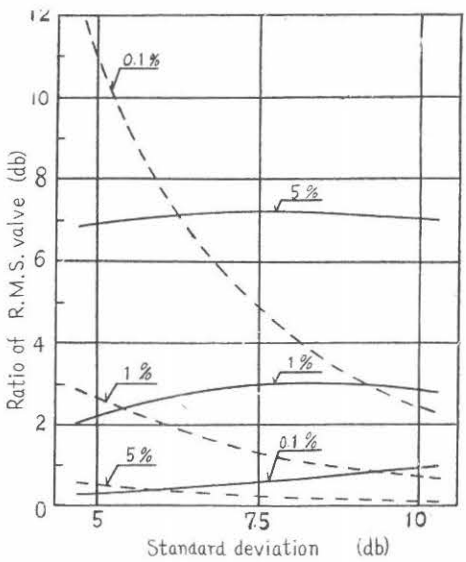


Fig. 15 The ratio of R. M. S. values.

Next, let us consider an alternative way of estimating approximately the total noise power, or the R. M. S. value of the distribution made up of two or three logarithmic-normal distributions. Then the curves in Fig. 14 may be used. For example, let us take the distribution made up of two logarithmic-normal distributions, each with standard deviation 10 or 15 db, in which the departure begins at 1 percent.

The cumulative noise power to the probability of 1 percent could be easily read on the 10-db curve at the probability of 1 percent, and the cumulative noise power in the range of the probability less than 1 percent could be obtained by the difference between the square of the R. M. S. value for the logarithmic-normal distribution with the standard deviation 15 db and the cumulative noise power read over the 15-db curve at the probability of 1 percent. The amplitude exceeded by 1 percent of time could be read by the abscissa corresponding to the probability of 1 percent on the 10 or 15 db curve respectively. One of the two cumulative noise powers, for example that are obtained with regard to the distribution considered is multiplied by the square of the ratio of two amplitudes less than 1, and now the summation of two cumulative noise powers obtained with regard to the same standard level is possible. Then the sum derived in this way would represent the total noise power for the distribution made up of two logarithmic-normal distributions from which the R. M. S. value could be derived easily. This graphical method of estimating a total noise power or the R. M. S. value may be used to determine the effect the departure has on the total noise power. Of course, this method may be applied in estimating the R. M. S. value of the distribution made up of three logarithmic-normal distributions. The calculation described here is limited to the method of estimating the R. M. S. value, but the curve could be derived in a similar way for the cumulative value of the product of the amplitude and the differential cumulative probability for a logarithmic-normal distribution. Then the curve may be used to determine the effect that the departure from a logarithmic-normal distribution has on the medium amplitude of the noise amplitude. But in this case, especially, the curve should be obtained for a full range of the probability.

VII. The Pulse Spacing.

The behavior of the trace in the record of fraction of time spent over the threshold has been explained by the response of RC network to a periodically occurring rectangular pulse series of current (or voltage) as described in Section IV. Now, the results obtained by the analysis as described in Section IV can be applied to data obtained from observations of atmospheric noise at 100 kc lasting about three days. This data had been obtained to investigate the degree of fluctuations of the trace of the record, before the observation of atmospheric noise at 50 kc described in this paper. Fraction of time spent over the threshold was measured with the apparatus as described in Secoion II. The method of observation was the same as described in Section II, except that the velocity of the recorder was about 0.5 cm per sec.

Data were taken from the records generally by estimating the average of maximum range of fluctuation of the trace over a 5-min. measurement. Then they were plotted as shown on the upper sheet in Fig. 16 or Fig. 17, as a function of the probability which was obtained by estimating visually the average of the probability over the 5-min. measurement. Data were divided into different groups, each representing data obtained for various period of a day.

For each group, the average of maximum range of fluctuation of the trace was averaged over each range of the probability of 5 percent length, new averages was each plotted and connected by a real or dashed line, as shown on the lower sheet in Fig. 16 or Fig. 17.

On the other hand, the final value V as shown in the equation (3) was estimated for various periods, each being 12/20, 12/15, 12/10, 12/5, 12/2.5 etc. Then the results were plotted and connected by dashed smooth curves as shown on the

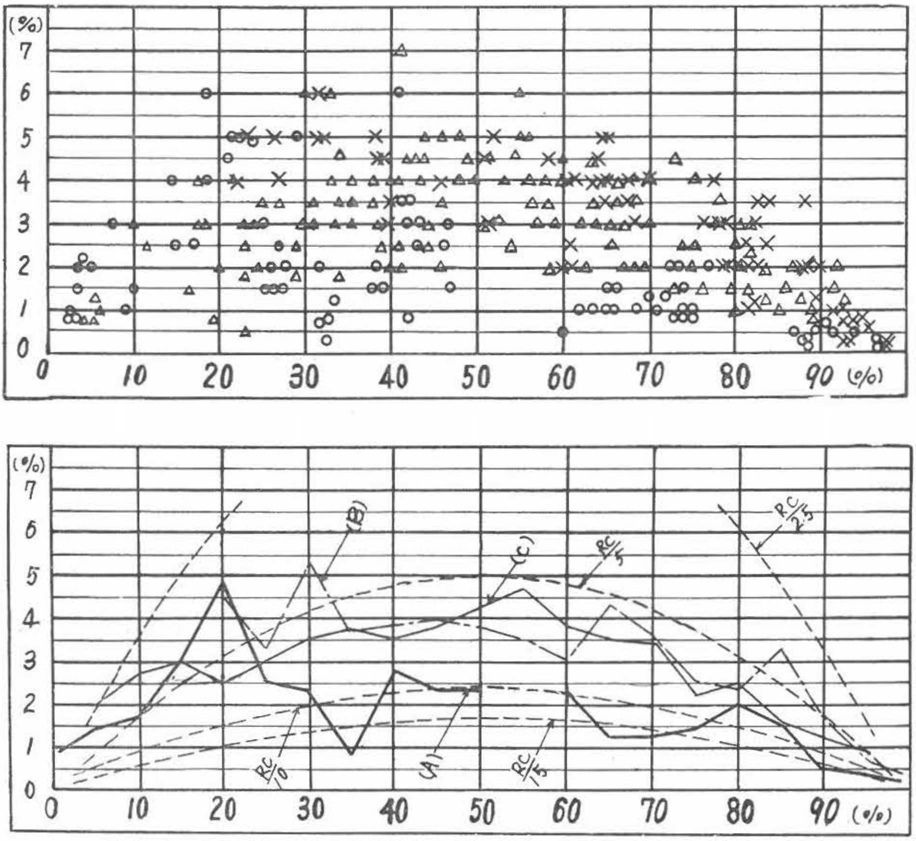


Fig. 16 Graph showing the variation in the average of maximum fluctuations of trace against probabililty.

(A) 1957, 4/30/16 h 00 m～20 h 05 m (B) 1957, 4/30/20 h 06 m～23 h 15 m

(C) 1957, 5/1/00 h 00 m～05 h 15 m

lower sheet of Fig. 16 or Fig. 17.

In general, the maximum range of fluctuation of the trace is larger in the night time than in the day time up to the probability of 20-30 percent, and vice versa in the range of lower probability. And it is also larger in lower ranges of probability than in higher ranges both in daytime and at night.

By fit of these data for each group to the various curves as shown on the lower sheet of Fig. 16 or Fig. 17, the period of pulse may be estimated roughly; that is,

(1) for data (A)

T is about 1.2 ± 0.4 sec. to the probability of 30 percent, being larger in the lower probability. The maximum period is about 3.5 sec.

(2) for data (B) and (C)

T is about 1.7 ± 0.5 sec. to the probability of 35 percent, being larger in the lower probability. The maximum period is about 4.8 sec.

(3) for data (D)

T is somewhat less than 0.8 sec. to the probability of 35 percent, which is

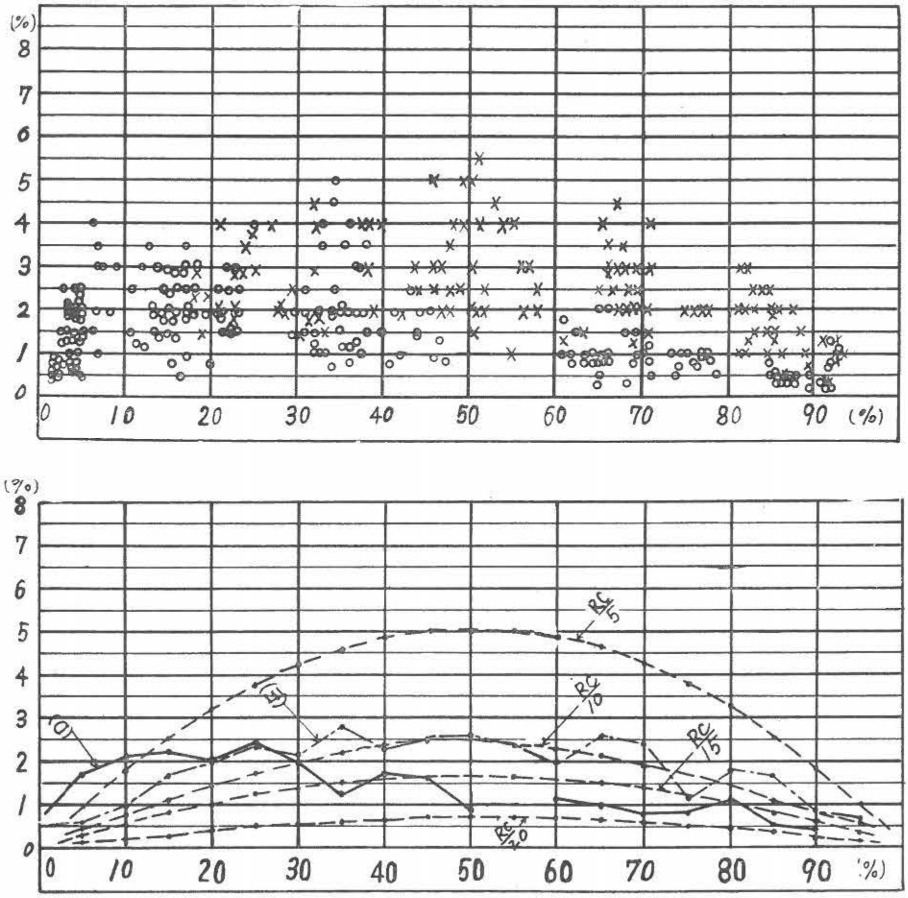


Fig. 17 Graph showing the variation in the average of maximum fluctuations of trace against probability.
(D) 1957, 5/1/06 h 00 m～15 m (E) 1957, 5/1/21 h 00 m～5/2 06 h 15 m

larger in the lower probability. The maximum period is about 4.8 sec.

(4) for date E.

T is about 1.2 ± 0.4 sec. to the probability of 30 percent, being larger in the lower probability.

The results obtained seem to provide roughly the order of the period of pulses, from which the pulse width may be obtained by estimating the probabilities at which the period specified occurs, but further discussions cannot be done here owing to the lack of data usable for comparison.

VIII. Diurnal Changes of Various Parameters.

The diurnal change will be described of various parameters derived from the amplitude probability distribution or the field intensity of integrated atmospherics. And a comparison between the field intensity of integrated atmospherics and the medium amplitude or the R. M. S. value of the noise amplitude. The R. M. S.

value, the medium amplitude, and standard deviation was each derived for a principal distribution having the most part of the noise power, for the distribution made up of two or three logarithmic-normal distributions.

(1) Standard Deviation.

Standard deviation was estimated from the distribution drawn on a graph paper with the field strength on a logarithmic scale and the probability on a normal-scale, being plotted against time, as shown in Fig. 18. The range of variation is found to be about 12±2 db in most case, except the period from 06 h to 11 h. This period showed a larger variation. It seems to be the correlation between the field intensity of atmospherics in regard to the magnitude of standard deviation and its dispersion.

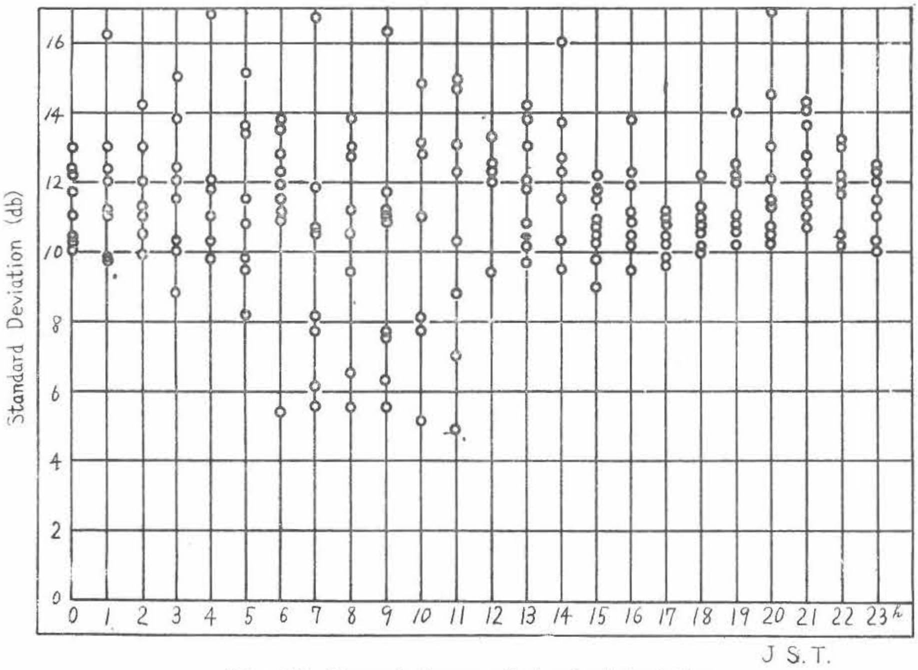


Fig. 18 Diurnal change of standard deviation.

(2) That Amplitude Exceeded by 50 or 5 Percent of Time.

That amplitude exceeded by 50 or 5 percent of time was read from the distribution drawn on such a graph as described above. The average of the amplitude each hour was estimated for each case, and was plotted against time as shown in Fig. 19. The diurnal change for each amplitude showed a nearly parallel variation.

(3) Cumulative Probability.

The fraction of time exceeded by the amplitude in the envelope of atmospheric noise over a given field strength was estimated from the distribution drawn on a graph paper with the field strength on a logarithmic-normal scale and the fraction of time on a normal-scale. A typical example is shown in Fig. 20, in which the fraction of time was plotted against time. Various curves were drawn along the plots, each with a parameter of the field strength.

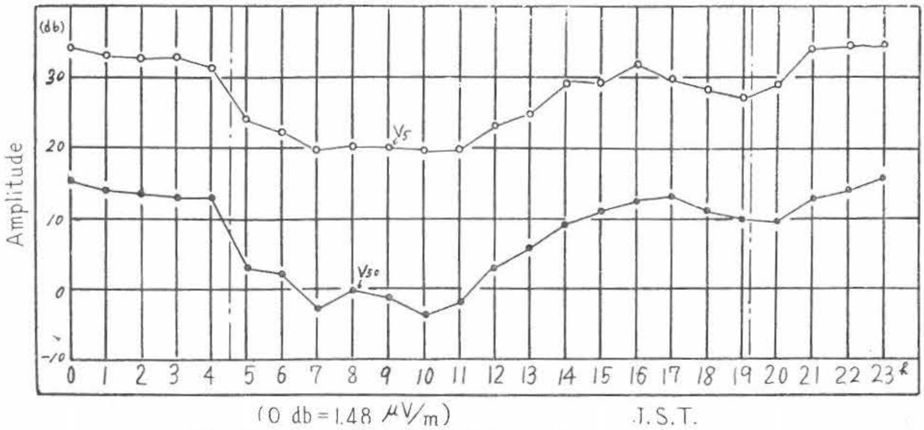


Fig. 19 Diurnal change of V_5 or V_{50}.
V_{50}: that amplitude exceeded by 50 percent of time
V_5 : that amplitude exceeded by 5 percent of time

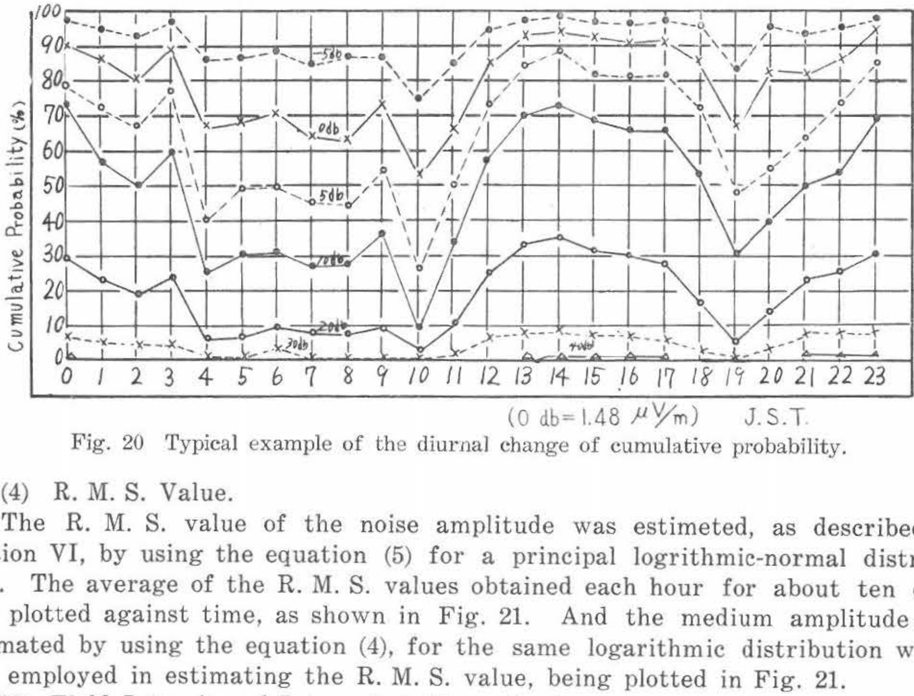


Fig. 20 Typical example of the diurnal change of cumulative probability.

(4) R. M. S. Value.

The R. M. S. value of the noise amplitude was estimeted, as described in Section VI, by using the equation (5) for a principal logrithmic-normal distribution. The average of the R. M. S. values obtained each hour for about ten days was plotted against time, as shown in Fig. 21. And the medium amplitude was estimated by using the equation (4), for the same logarithmic distribution which was employed in estimating the R. M. S. value, being plotted in Fig. 21.

(5) Field Intensity of Integrated Atmospherics.

The field intensity of integrated atmospherics was measured for 15 min. each hour as described in Section II. The average of the field intensity for 1st 5 min. was estimated each hour, being plotted against time as shown in Fig. 21.

It seems that there is a proportional relation between the R. M. S. value and the field intensity of integrated atmospherics, and the fit is good between the field intensity and the medium amplitude for a principal lagarithmic-normal distribution having a principal effect to the total noise power.

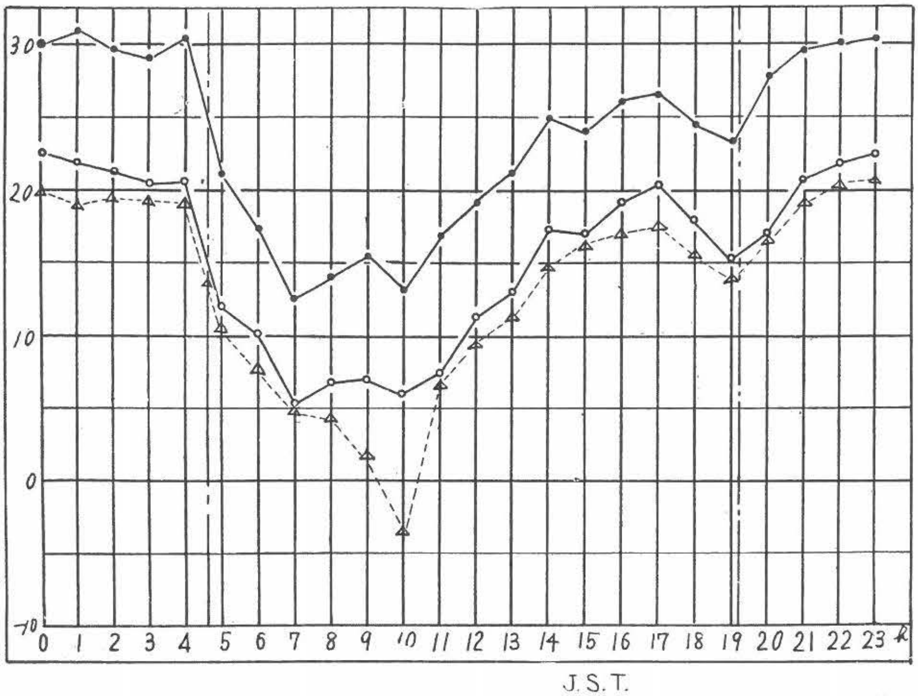


Fig. 21 Diurnal change of level of integrated atmospherics, the medium amplitude, or the R. M. S. value of the noise amplitude.

△: level of integrated atmospherics
• : R. M. S. value
○ : medium amplitude

IX. Conclusion.

Several conclusions may be derived from what has been described in this paper, as follows:

1. The cumulative probability of amplitude in the envelope of uncontaminated atmospheric noise seems to be reasonably represented by a single logarithmic-normal distribution to the probability of about 0.5 or 5 percent, but it seems that the departure from a single logarithmic-normal distribution more frequently begins in the low range of probability, which is considered to be caused by an interraction between two groups of atmosphric noise, each with different characters.
2. The field intensity of integrated atmospherics seems to be in proportion with the R. M. S. value of the noise amplitnde derived from the amplitude probability distribution and seems to be in correlation with some parameters derived from the distribution.
3. The average of maximum fluctuations of the trace appearing in the records of the cumulative probability may give a rough estimation of the pulse-spacing or the pulse width.

X. Acknowledgement.

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