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STATISTICAL PARAMETERS ON THE ELECTRIC-FIELD-INTENSITY CHANGES AT THE SOURCE OF ATMOSPHERICS

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Summary

Statistical parameters, CRD OTID, have been analyzed using the data of the electric-field-intensity-changes measured near the source of atmospherics, and both the amplitude- and time- statistics of the field-intensity-changes have been investigated in the frequency of VLF, LF and HF bands.

1 Introduction

The electric-field-intensity-changes near the source of atmospherics have been measured statistically at three different frequencies, 3 KHz, 50 KHz and 5 MHz at Imaichi Observatory in summer, 1971. The four statistical parameters, i. e., CRD, APD, OTID, and PWD have been analyzed using the observational data of field-intensity-changes. This kind of measurement and analysis have already been made on 3 KHz in 1969 and on the two frequencies, 3 and 90 KHz in 1970.

New experimental results have been obtained from the data of 1971: (1) The CRD curves on 50 KHz can generally be expressed by a composite of two power functions, (2) the CRD curve on 5 MHz can be expressed by an exponential function, and (3) the shape of OTID curve changes with the frequency in a characteristic way, i. e., the frequency dependence of the shape of OTID curves is closely effected both by the amplitude structure of the return stroke type pulse and by the other type one contributing to the electric-field-intensity-changes.

2 Crossing rate distribution (CRD)

Fig. 1 and 2 show the time changes of the electric-field observed near the source, when the thunderstorm was generated in the afternoon of a summer day, 1971, and about for an hour it grew steadily and continued to produce discharges within a few to 10 km from the measuring site at Imaichi. Each CRD curve has been obtained from the analysis of field-changes datum of a 200 seconds duration on 50 KHz or 5 MHz. The data were obtained by using the two different receivers tuned to the two frequencies, 50 KHz and 5 MHz, with the 3 dB drop-points-bandwidth 480 Hz and 1 KHz respectively.

The CRD curves, as shown in Fig. 1, can fairly be approximated by a composite curve of two straight line sections covering the dynamic voltage range 45 to 65 dB. By estimating the slope value of these straight line sections, it has been found to change from 1.0 to 1.2 on the side of low threshold voltage and to change from 0.83

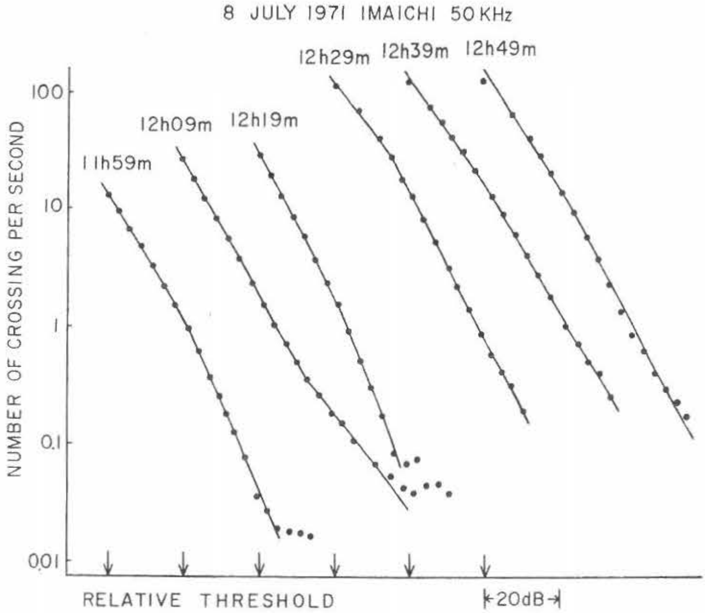

Fig. 1 Time variations of crossing rate distribution (CRD) at 50 KHz of the electric field-Intensity-change near the atmospheric source —log-log graph.
Arrows represent the origin of the abscissa concerning each hour time indicated upside the CRD curve.

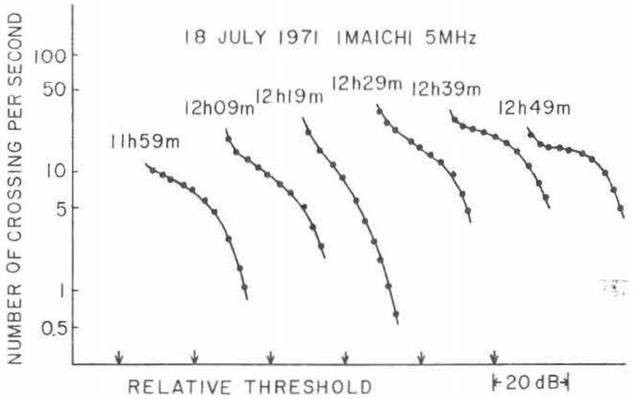

Fig. 2 Time variations of crossing rate distribution (CRD) at 5 MHz of the electric field-intensity-change near the atmospheric source —log-log graph.

to 1.66 on the side of high threshold voltage. For mathematical expression of CRD curve, a power function can be so adapted as to represent each straight line section of a composite curve on the graph with logarithmic scale on both coordinates, and the power function is characterized by the value of it's slope.

The shape of the CRD curves on 5 MHz, as is seen from Fig. 2, is very different from any shape of the CRD curves analyzed before on the three different frequencies, 3, 50 and 90 KHz, because the shape of CRD curves at the frequency of 5 MHz is wholly curvilinear on the graph with logarithmic scale on both coordinates. Apparently it is most unlikely to be representable by using any simple expression. While it has been found that the CRD curve can fairly be approximated by a straight line on the graph with logarithmic scale on the ordinate and linear scale on

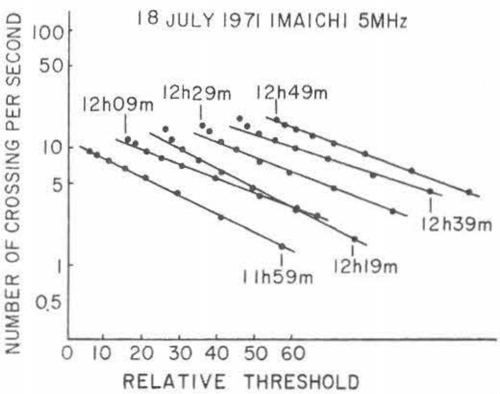

Fig. 3 Time variations of CRD at 5 MHz —log-linear graph.

the abscissa, so that an exponential function can be so adapted as to represent a straight line.

On the frequency dependence of the shape of the CRD curves, at this stage we can state as follows, by referring to the two previous papers (NAKAI et al., 1969 and 1970) on the statistical parameters of the electric-field-intensity-changes on the frequency of 3 KHz in 1969 and on the two frequencies, 3 and 90 KHz in 1970. (1) the CRD curves with the electric-field-intensity changes near the source of atmospherics can mathematically be expressed by a composite of two or three different power functions on the three frequencies, 3, 50 and 90 KHz in VLF and LF bands, and (2) the CRD curves can be expressed by an exponential function on the frequency of 5 MHz in HF band.

3 Occurrence time interval distribution (OTID)

If the time spacing between a particular pulse and its preceding pulse is larger than 10 milliseconds, the probability that the particular pulse belongs to the category of return stroke pulse should be larger than the category of the other type pulse including the k-change pulse. This can be used as a criterion in characterizing the OTID curves measured near the source of atmospherics. In Fig. 4 and 5 are shown the five different OTID curves on 3 KHz, and the three different OTID curves on 5 MHz, respectively. By comparing the OTID curves on 3 KHz with those on 5 MHz with respect to the probability that the time spacing is larger than 10 milliseconds, a considerable difference can be seen with the magnitude of the probability between two frequencies. Then, by applying the criterion about the relationship between the time spacing and the category of pulse, to the analysis of the OTID curves on the two frequencies, it can also be shown that such time statistics as OTID could closely be combined with the amplitude structure of the two category of pulses, i. e., the return stroke type and the other type. Then the followings are noticeable from these two figures: (1) for the frequency of 3 KHz, high probability $p1$ of all the pulses exceeding a given threshold voltage, ranging from 0.5 to 0.9 belongs to return stroke type pulse and the remaining low probability $(1-p1)$ belongs to the other type pulse, and (2) for the frequency of 5 MHz, only very low probability $p2$ ranging from 0.1 to 0.2 of pulses, as compared with the whole pulses exceeding a given threshold voltage, belongs to the return stroke type pulse and so the remaining high probability $(1-p2)$ belongs to the other type.

By following the line of thought described as above, the amplitude structure has been investigated using the electric-field-intensity changes measured on 3, 50 and 90

KHz and 5 MHz during the three years from 1969 to 1971. The result is shown in Fig. 6, where the values of probability with which the time spacing exceeds 10 milliseconds are plotted for a series of threshold voltage values. One plot represents the probability value estimated from a single OTID curve analyzed for a given threshold value. A group of plots involved within a column represent the range of the probability estimated from a few different OTID curves for a series of threshold voltage values and they concern with an electric-field-intensity-change datum of a 200 seconds duration measured with a given frequency. Upside the graph are shown the magnitudes of measured frequency. Each of plots involved in the respective column under the same frequency have been analyzed from the different electric-field-intensity-changes data i. e., they were measured on different day or at different times at the same frequency.

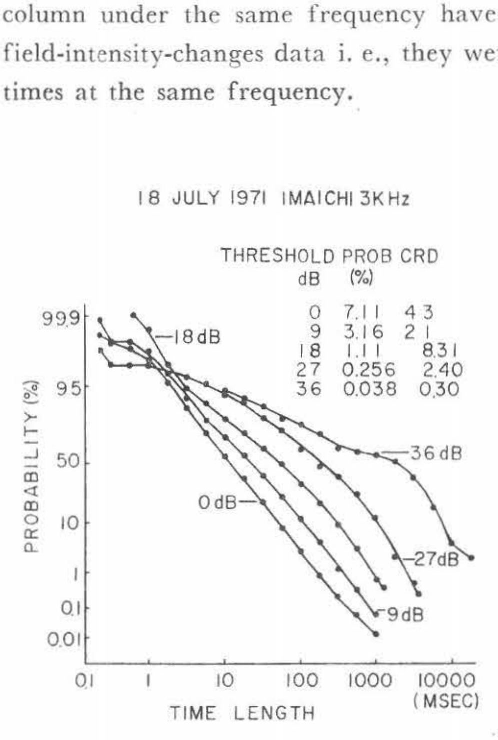

Fig. 4 Occurrence time interval distribution (OTID) of the electric-field-intensity change at 3 KHz near the atmospheric source —log-normal graph.

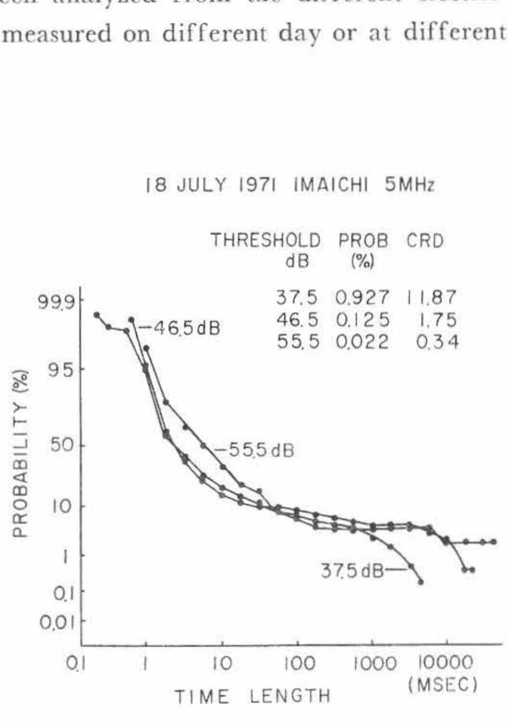

Fig. 5 Occurrence time interval distribution (OTID) of the electric-field-intensity change at 5 MHz near the atmospheric source —log-normal graph.

There is a clear trend among the scattering of plots in Fig. 6, where the locality of plot steadily goes down towards the right direction on the graph, although the situation with the plots is about the same between the two frequencies of 3 and 50 KHz. That is, the ratio of number of return stroke type pulse to the whole number of pulses is about the same at the two frequencies, but thereafter with the increasing

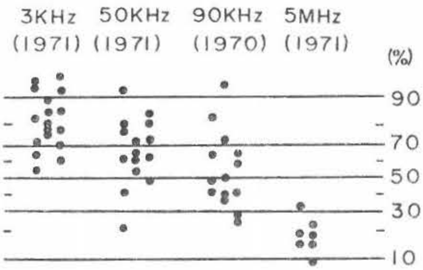

Fig. 6 Graph showing the relationship between the time statistics and amplitude structure with the frequency.

frequency the ratio decreases from a high value 0.9 estimated on the two frequencies of 3 and 50 KHz to a low value 0.1 on 5 MHz. The considerable change in the magnitude of the ratio clearly represents an alteration of the role played by the two different category of pulses with the electric-field-intensity changes.

4 Conclusion

It is very instructive for further study to refer to a close relationship which could exist between the amplitude-statistics of the electric-field-intensity changes measured near the source of atmospherics and that of the atmospheric noise field at the input of receiver, where the latter field is made up of the contributions given by the spatially long-distance-propagating electromagnetic waves in the space between the ionosphere and the earth, radiated from a lot of sources of atmospherics distributed geographically on the surface of the earth. By referring to the two different models of the atmospheric noise proposed by Nakai (1966) in the VLF and LF bands and by Furutsu and Ishida (1960) in HF band, the two empirical expressions, i. e., (1) a composite of two or three power functions on 3, 50 and 90 KHz and (2) an exponential function on 5 MHz are quite consistent with the two particular function types used in specifying the height distribution of the impulsive noise applied to the input of the receiver for measuring the atmospheric noise both in the frequency of VLF, LF bands and of HF band. The fine fit is very important, because the observational facts give one proof for the validity of the theoretical assumptions on the two models of the atmospheric noise in VLF, LF and HF bands, and also for their usefulness.

In addition to the usefulness of the amplitude-statistics of the electric-field-intensity-changes, the usefulness of its time-statistics may be considerable, because it is a very important and indispensable parameter in establishing a complete model of the atmospheric noise both with respect to amplitude- and time-statistics.

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