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ON THE STATISTICAL MEASUREMENT OF VERTICAL ELECTRIC FIELD-INTENSITY-CHANGE ON 3 AND 90 KHz AT THE SOURCE OF ATMOSPHERICS

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Abstract

The electric field-intensity-changes at the source of atmospherics have been measured statistically at the two different frequencies 3 and 90 kHz at Imaichi Observatory in summer, 1970. The four statistical parameters, i. e., CRD, APD, OTID and PWD, have been analyzed from the observational data of the field-intensity-changes. By the comparison between the same kind of statistical parameters which have been obtained at the two frequencies for the different years, we have found the evidence that (1) the characteristic features of CRD and APD curves do not change from a year to another remakably, provided the comparison being made on the same frequency, while in the comparison on different frequencies the features change appreciably, (2) some feature of OTID curves at 3 kHz appreciably differs from at 90 kHz.

1. Introduction

A research programme has been continued at our institute for these few years. The aim of this programme is to study statistically the vertical electric field-intensity-changes caused by lightning discharges at the source of atmospherics. It was in the summer of 1969 that the technique of statistical measurement established through many years experiences in the research field of atmospheric radio noise from distant sources, has been introduced, for the first time, to the study of field-intensity-changes at 3 kHz at the atmospheric source. The well known four statistical parameters have been measured on the data of field-intensity-changes recorded at the source. They are (1) amplitude probability distribution (APD), (2) crossing rate distribution (CRD),

(3) occurrence time interval distribution (OTID) and (4) pulse width distribution (PWD). The measuring method of the field-intensity-changes has been described in details in the preceding issue of this proceedings (Nakai et al., 1970).

Using the same method as it was applied in 1969, the vertical electric field-intensity-changes were measured at 3 and 90 kHz in summer, 1970, when the thunderstorms approached to Imaichi Observatory. The four statistical parameters have been obtained from the analysis of the field-intensity data recorded at the two frequencies.

In this parer we will describe the results of analysis on the field-intensity-data of 1970 and discuss the results of comparison between the same kind of parameters obtained at the two different frequencies and see the change in a parameter value for the two different years 1969 and 1970.

2. C R D

Figs. 1 and 2 show the time changes of the field-intensity at the source in terms of the parameter CRD, indicating the effect of an approaching thunderstorm in summer, 1970. The receiver's bandwidths are 470 and 850 Hz for the two frequencies 3 and 90 kHz respectively. Full line CRD curves, in Figs. 1 and 2, have been obtained from the analysis of 150- and 200- seconds durations field-intensity-data at frequencies 3 and 90 kHz respectively. The times of hours indicated upperside a series of full line CRD curves represent that corresponding to the starting points of sampling data and also the observation times of the data from which these curves have been analyzed.

Shown by broken lines are the CRD curves at each of the two frequencies. They are obtained as an average of all the full line curves to be found to the left side of each broken line. Accordingly, the behaviour of broken line curves also indicate the way how the shapes of CRD curves change as the time length of sampling data increases.

Coordinates scales shown in Figs. 1 and 2 correspond to the full line CRD curve of $16^h 52^m 00^s$ and $16^h 47^m 40^s$ respectively, where the dB values indicate the threshold values in units of dB above 1 millivolt of the input voltage of the AD converter. These threshold scales can be used for each of full line curves of different times by using the respective origin indicated by an arrow. Regarding broken curves, though not indicated, their origins are determined to be found 6 dB rightward from the origin for the full line curve of the same time.

Some interesting features of the CRD curves have been described by Nakai et al (1970). The CRD curve is taken from the previous paper in Fig. 3. As a result of this, the CRD curve at 3 kHz given in the previous paper now can be compared with new CRD curves at the frequencies 3 and 90 kHz. The symbols, PROB, CR

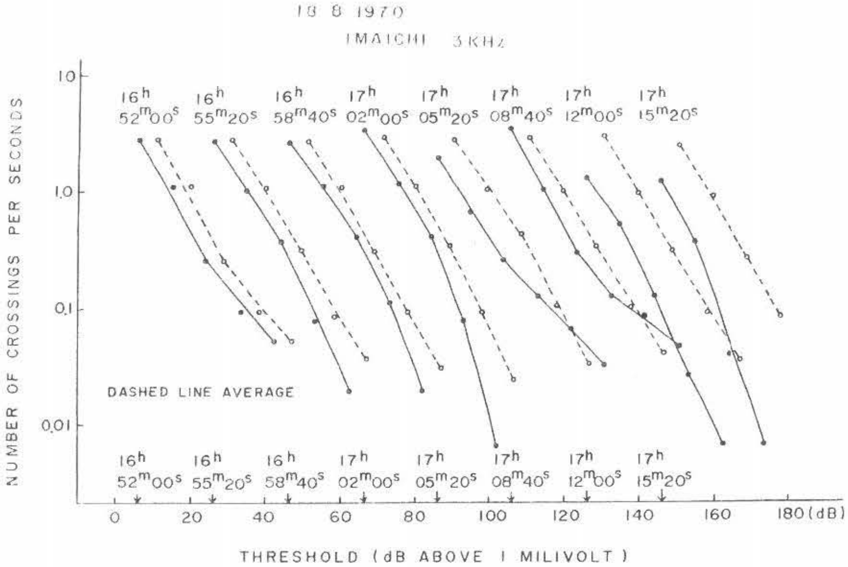

Fig. 1. Time variations of crossing rate distribution (CRD) at 3 kHz of the electric field intensity change at the atmospheric source —— log-log graph.

and THRESHOLD that appear in Figs. 3, 4 and 5 have the meanings as follows: PROB represents the percentage with which the noise envelope exceeds a threshold value indicated by the figures given below the caption of THRESHOLD, and CR the crossing rate, i. e., the number of crossings per second on the same threshold value.

As it is clearly understood from the graph in Fig. 3, a CRD curve at 3 kHz can generally approximated by a composite curve consisting of three straight line sections. Despite this, Figs. 1 and 2 show the result of the year of 1970 that the CRD curves at 3 and 90 kHz can seemingly be approximated by a composite curve consisting of one or two straight line sections. It has been concluded, in the previous paper regarding the result of the year of 1969 at 3 kHz, that the two straight line sections in the middle- and high-threshold ranges of the CRD curve consist of predominant contributions from the return stroke pulses. We see the difference in the number of component straight line sections even on the same frequenncy, if the comparison is made for the different years, that is, the lack, on new CRD curves, of the straight line section that corresponds to the low threshold range. This can be attributed to the way of setting the attenuator of the receivers. Accordingly, the interpretation that the formation of a CRD curve is strongly controled by the characteristics of the return stroke- and K change-pulses (Nakai et al., 1970) seems to be applicable to the

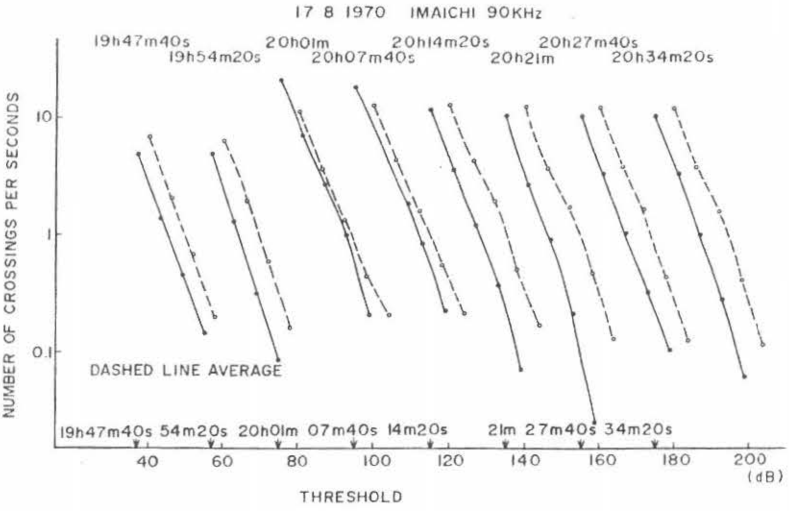

Fig. 2. Time variations of crosssing rate distributions (CRD) at 90 kHz of the electric field intensity change at the atmospheric source —— log-log graph.

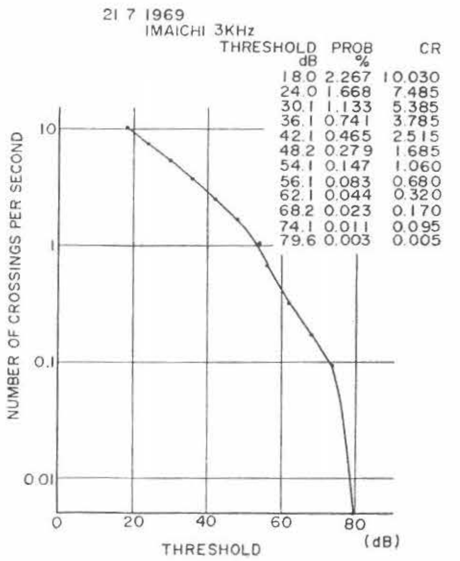

Fig. 3. Crossing rate distribution (CRD) of the electric field intensity change on 3 kHz at the atmospheric source —— log-log graph.

case of new CRD curves at the frequency 3 kHz too.

As for a mathematical expression of a CRD curve, a power function can be so adapted as to represent each straight line section of a composite curve on the graph with the logarithmic scales on both coordinates. Two or three power indices characterizing power functions have been determined by estimating the magnitudes of slopes of straight line sections of the curve, and tabulated in Table 1, where s_2 and s_3 represent the slopes of straight line sections of the curve in the middle- and high-threshold values as seen from the CRD curve in Fig. 3, where the figures outside the brackets represent the values of power indices estimated for full line CRD curves, and the figures inside the brackets stand for broken line curves. It is found, regarding full line curves, that (1) there is a good agreement, on an average, between the corresponding slopes s_2 for the two groups of CRD curves at 3 kHz obtained in the year of 1969 and 1970, and (2) there is a clear trend that the slopes s_2 and s_3 at 90 kHz are larger than at 3 kHz in the year of 1970.

Table 1

	3 kHz 1969	3 kHz 1970	90 kHz 1970
S_2	0.88* — 1.38*	0.9 — 1.17 (1.02 — 1.11)	1.37 — 1.73 (1.48 — 1.6)
S_3	21.8* — 2.82*	0.65 — 1.9 (1.02 — 1.25)	1.66 — 2.66 (1.66 — 2.22)

The figures with symbol * represent the variable range of 80%, while the other figures the variable range after excepting both the maximum and minimum value.

3. OTID

Figs. 4 and 5 show the two groups of OTID curves for various threshold values at the two frequencies 3 and 90 kHz respectively, which have been analyzed from the same sampling field-intensity data as that from which the CRD curves of the corresponding time of hours in Figs. 1 and 2 were obtained. As for a close relationship between a pair of a CRD curve and an OTID curve-group of the same time, each plot on the CRD curve represents the measured number of crossings per second with which the noise envelope traverses in one direction a threshold value indicated on the abscissa, while an OTID curve characterizing the occurrence time of the pulses which exceed the same threshold value has been analyzed and it is drawn as one member of the OTID curve-group of the same time in Figs. 4 and 5.

By making use of such a close relationship between a CRD curve and the corresponding OTID curve-group, we might expect the solution of the interesting question, "what kind of a pulse in the elementary discharge processes appearing at the source of atmospherics do contribute to the formation of the CRD curve at the two frequencies 3 and 90 kHz?" The following criterion may be introduced to distiguish the return stroke pulse from the K change pulse. If the time spacing between a particular pulse and its preceding pulse is longer than 10 milliseconds, the probability that the particular pulse belongs to the category of return stroke pulse should be larger than the other category (Ishikawa, 1960; Kitagawa and Brook, 1960; Schonland, 1956). If not, the possibility that the pulse belongs to the category of K change pulses should be larger than the other. Based on the above criterion, it might be possible to discuss the difference in behaviours of OTID, and the difference in the formation of CRD curve between 3 and 90 kHz.

The probability on each of the OTID curves, with which the occurrence time interval between pulses represented by the ordinate exceeds a time length, 10 milliseconds, indicated on the abscissa has been estimated on the two graphs at 3 and 90 kHz in Figs. 4 and 5. It has been found that these estimated magnitudes for 3 kHz are a value larger than 92, 91 and 86 and 70 % for a series of threshold valus, 6, 15, 24 and 35 dB. For 90 kHz they are 92, 69, 53, 41 and 35 % for another series of

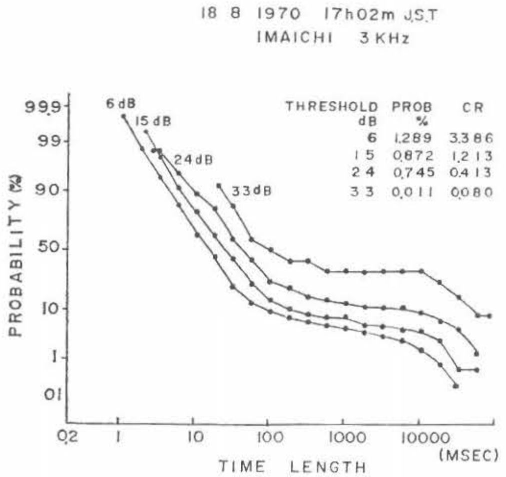

Fig. 4. Occurrrence time interval distribution (OTID) of the electric field intensity change at 3 kHz at the atmospheric source —— log-normal graph.

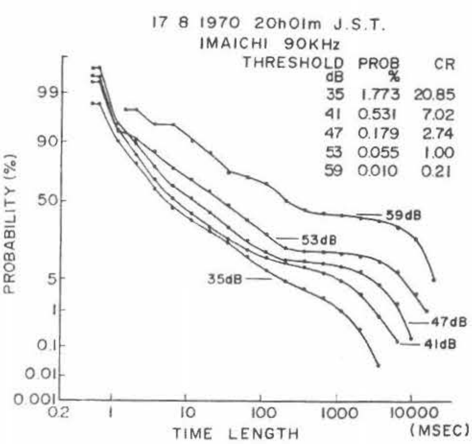

Fig. 5. Occurrence time interval distribution (OTID) of the electric field intensity change on 90 kHz at the atmospheric source —— log-normal graph.

threshold values, 35, 41, 47, 53 and 59 dB. By comparison between the two frequencies it is found that the estimated percentage values for 3 kHz are larger than those for 90 kHz.

To determine whether the above result holds in general, the estimation of probability following the above procedure has been made on the whole OTID curves. The number of estimated probability values are nearly equal to or a little smaller than the number of the plots on all the full line CRD curves in Figs. 1 and 2, for each of the two frequencies of 3 and 90 kHz. The estimated magnitudes are classified into the two categories, and we find that the number of cases in which the probability is larger than 60 % is 27 for 3 kHz and 15 for 90 kHz, while the number of cases in which it is smaller than 60 % is 6 for 3 kHz and 17 for 90 kHz. The ratio of numbers of different kind, therefore, 27/6 at 3 kHz and 15/17 at 90 kHz. From the difference in the magnitudes of the ratio, it is clear that there is an appreciable difference with respect to the contributions to the formation of CRD curve, of the two kinds of pulses, the return stroke- and K change-pulses. The formation of a CRD curve at 3 kHz has already been described by Nakai et al (1970).

4. APD and PWD

APD curves have been analyzed synchronizingly with the other three statistical parameters using the same field-intensity-data and are drawn on the log-normal graphs. It has been found that an APD curve at each of the two frequencies, in most cases, can be approximated by a straight line, and accordingly it follows the log-normal law. The magnitude of standard deviation of a log-normal distribution curve fitted to each of the APD curves has been determined by estimating the slope of straight line on the log-normal graph and its variable range tabulated in Table 2 together with that of the same parameter obtained on the APD curves at 3 kHz for the year of 1969.

It is found easily that there is a good agreement in the variable range of standard deviation between the two groups of APD curves at 3 kHz obtained for two different years of 1969 and 1970, and that the magnitude of standard deviation at 90 kHz is smaller than that at 3 kHz.

By comparisons of the PWD curves at the two frequencies, it has been found that the pulse width at 3 kHz is, on a rough estimation, several times larger than at 90 kHz, even if the difference in the receiver's bandwidths 470 and 850 Hz at the two frequencies is taken into account.

Table 2

	Region of 80 % change of standard deviation dB
3 kHz 1969	25.5 — 31.5
3 kHz 1970	25.0 — 29.0
90 kHz 1970	16.5 — 19.0

5. Acknowledgement

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