A NOTE ON THE POLARITY OF THE RECEIVED WAVEFORMS OF ATMOSPHREICS

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Recent observations of atmospherics have been carried out at three stations (Mizusawa-City, suburb of Kumamoto-City and our Institute), and measurements of direction-finding have been done by the sferics network consisted of the above three stations with crossed loop aerials tuned at 10 kc/s, whereas waveforms have been received by the wide band amplifier with 250 μsec delay circuit at two stations. Both records were photographed on slowly moving 16 mm films, and after that sferics fixes were determined by the usual method of triangulation.

Now it is quite interesting to know whether the atmospherics received at a great distance is originated from a cloud-to-ground lightning discharge or from an intracloud discharge. This leads us to examine the polarities of waveforms of atmospherics with respect to those traversed distances. The present study was designed to secure this information.

When we inspect only the first half cycles of the waveforms, the positive polarities as well as the negative ones can be found in the waveforms traversing nearly equal distances. From this result it may be suggested that the polarities of received waveforms are mainly due to the polarities of waveforms radiated from sources. The rate of polarities of smooth daytime type waveforms observed in a week in Aug. 1959 are studied with respect to those traversed distances. Waveforms with ambiguous polarities due to the small amplitudes of the first half cycles are excluded, and the waveforms propagated great distances along land paths as well as those originated near our country are employed in our study. The rate of received waveforms with respect to polarities is represented in Table 1, and these rates are in good agreement with Lutkin's[1] results showing that the rate of received negative polarity was 32.3% throughout 288 waveforms originating at distances 800km to 4,000km. Next, concerning the rate of negative polarities near sources, Ishikawa[2] summarized the 1293 waveforms observed at night within 70km for three summers, and he found the value of 60.3% as the rate of negative polarities except for the ambiguous waveforms. Hence this value of rate is adopted by the author as the value at origin. Other researches by Ishikawa yielded the fact that the waveforms with

Table 1. Rate of received smooth daytime type waveforms with respect to polarities

polarity	number of waveforms
positive	118 (71%)
negative	49 (29%)
ambiguous	36 (/)
total	203 (100%)

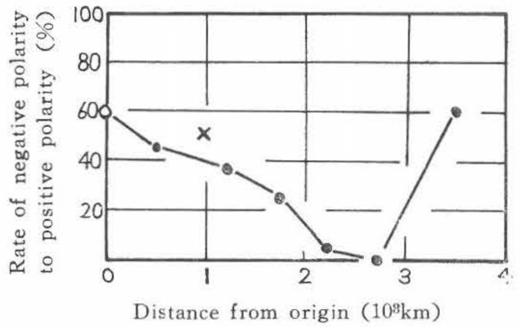

Fig. 1 Rate of reception with respect to polarities of daytime type waveforms

positive polarity consist mainly of cloud-to-ground lightning discharges (partly intracloud discharges), while those with negative polarity are originated completely from intracloud lightning discharges. Now the rates of negative polarities are examined with respect to respective intervals of distance. The total number of waveforms dealt here is 167, and these distances from origins distribute from 120km to 4,000km. The results obtained are summarized in Fig. 1, from which it can be seen that respective polarities are equally received within 1,000km, whereas the rate of negative polarity decreases almost linearly with increasing distance, and finally the polarity of received waveforms becomes perfectly positive.

Now the cloud-to-ground discharges can be considered as vertical electric dipoles, while the intracloud discharges have both vertical and horizontal electric components due to their oblique discharges. But even in the latter case only the vertical components are needed, because the horizontal components at great distances are ignored by mirror images owing io the infinitely conducting earth. Consequently, considering the vertical dipoles in both discharges, it is true that the cloud-to-ground discharges have the opposite sign to the intracloud discharges. Hence, from Fig. 1 it is evident that the rate of reception of cloud-to-ground discharges increases with distance. The significance of this result is that the value of the dipole moment of intracloud discharge will be smaller than that of cloud-to-ground discharge. In this respect we shall refer the investigations made by Malan.(3) The field intensities radiated from the respective lightning flashes within the distance of 50km were measured at different frequencies, and the ratios of the amplitudes of the cloud-to-ground stroke radiation to the amplitudes of the most intense radiation components of cloud discharges were given, and the approximate features are drawn by the author in Fig. 2. From Fig. 2 it becomes clear that the dipole moment of cloud-to-ground discharges is generally ten times as geat as that of in-

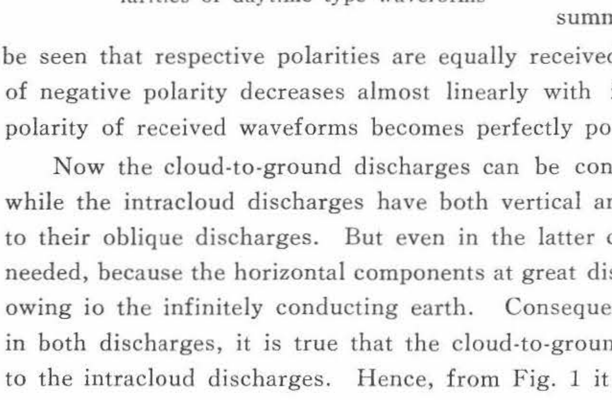

Fig. 2 Ratios of the amplitudes of the cloud-to-ground discharge radiation to the amplitudes of the most intense radiation components of cloud discharges (after Malan)

tracloud discharges at about 10 kc/s. Hence the rate of reception of cloud-to-ground discharge should increase with increasing distance as shown in Fig. 1.

Furthermore it is to be noted that the rate of reception of negative polarities increases abruptly over the distance of about 3,000km. The author considers this change of polarity as the phase-shift due to the long distance propagation. To account for this fact, we shall apply the wave guide mode theory by Wait[4] to the explanation of waveforms of atmospherics. The term depending on the phase in the expression of field strength due to the first order mode is written as $\exp\left[j\frac{w}{c} D\left\{ 1-\mathrm{Re}(S_1) \right\}\right]$, where c, w and D denote light velocity, angular frequecy and propagation distance respectively. S_1 is an eigenvalue (complex number) of the first order mode determined by the so-called boundary conditions. Now if the predominant frequency at the wave-front of a waveform of atmospherics assumed to be 12 kc/s, $\mathrm{Re}(S_1)=0.9962$ is obtained from the graphical representation by Howe and Wait[5] in the case of infinitely conducting earth, and $B=0.2$ (the value of B corresponds to $w_\gamma=1.3\times10^5\ \mathrm{sec}^{-1}$ and to the height of ionosphere$=72.5$ km) Solving the next equation,

$$\exp\left[j\frac{w}{c} D_0\left\{ 1-\mathrm{Re}(S_1) \right\}\right]=\exp(j\pi)$$

$D_0 \simeq 3.3\times10^3$km can be obtained. In other words it can be said that the change of polarity can not be found within the distance of D_0. Therefore the abrupt increase in the curve shown in Fig. 1 is not caused by the differences of lightning discharges but caused by the phase-shifts due to the long distance propagations. Because of the differences of the phase-frequency spectra at origins, the distances at which the reversal of polarities of respective waveforms occur do not always coincide each other.

On the other hand in the case of the echo type waveforms at night, the distances of respective waveforms dealt here are assumed to be the approximate value of 1,000km, because most of the echo type waveforms are originated within about 1,500km. Investigations of polarities of the respective first peaks of both rounded regular peaked type and the peaked regular peaked type waveforms are done. In this case the waveforms without sferics fixes as well as those with them are considered, and, again, the waveforms having the appropriate features to examine the details of waveforms are selected. The results summarized for respective types are shown in Table 2. From these figures given in Table 2, the following properties are observed. (a) The ratio of positive polar-

Table 2. Polarities with respect to two types of waveforms at night.

Sort of waveforms / Year	peaked reg. peaked type		rounded reg. peaked type	
	positive	negative	positive	negative
Aug. 1959	1	45	35	13
Sep. 1958	6	14	55	35
total	7	59	90	48
Sum total	204			

ities to negative polarities is 97/107, which agrees approximately to the corresponding value in the daytime, and is represented as a mark x in Fig. 1. (b) Because none of the negative polarities are originated from cloud-to-ground discharges, both rounded regular peaked type waveforms (48) and peaked regular peaked type waveforms (59) are considered as originated from intracloud discharges. (c) Positive polarities are concentrated on the rounded regular peaked type, therefore the rounded regular peaked type waveforms are almost all originated from the cloud-to-ground discharges. The data presented in this paper are based largely on observations which were carried out for one week each in Sept. 1958 and Aug. 1959. Because further observations of waveforms of atmospherics would not change the general situation of the above statistical results, the author gives the data, and suggests some deduced results concerning the lightning discharges and the polarities of waveforms of atmospherics.

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