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THE CHARACTERISTICS OF POSITIVE GROUND DISCHARGES OF TROPICAL THUNDERSTORMS AT IBADAN, NIGERIA

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ABSTRACT:- *Positive ground lightning discharges were continuously recorded over a period of three years at Ibadan to supplement earlier composite records from 1987 by adapting the earlier design of Oladiran, et al (1988a) using the shape of the radiation field signatures and the frequency components of positive discharges (Oladiran and Israelsson, 1990). We recorded 92% discrimination between negative and positive ground flashes. The positive ground flashes were recorded at VLF and 17.3kHz, 3dB attenuation and yielded an average 13 and 11.6% ratios for (+CG)/(-CG) respectively. Compared to our results of 1988, the flash-rate characteristics for positive ground flashes is not significantly different from those of negative ground flashes and it does not show any seasonal preference. This leads to the conclusion that the occurrence of positive and negative ground flashes depends only on the cloud charge structure, its dynamics and the ground conditions.*

INTRODUCTION

The ground discharges, (CG), have been classified into two groups- (a) those that bring negative charges to ground (-CG), and (b) those bringing positive charges to the ground (+CG). The physical and electrical manifestations of these two types of flashes are very distinct vide: (i) The radiation fields contain maximum energies at different peak frequencies (9.7kHz and 17.3kHz for (-CG) and (+CG) respectively at 3dB attenuation (Cooray, 1984; Oladiran *et al*, 1988a)); (ii) When the leader is followed by return strokes, the number of return strokes accompanying (-CG) is usually more than those accompanying (+CG). (Aina, 1971a,b; Bruce and Golde, 1942); (iii) The shape of the radiation fields for the two types of discharges are of different forms in shape, rise time, duration and frequency component (Kitagawa and Brook, 1960); (iv) The (+CG) carry a larger magnitude of charge to earth than the (-CG) (Rust *et al*, 1981).

Consistent studies of the two types of CG started at Ibadan in 1986 and consist of:

(a) (-CG) flashes as earlier reported in 1988 (Oladiran *et al*, 1988b) using a new lightning flash counter and calibration circuit with improved discrimination of cloud and ground discharges to within 92% (Oladiran, *et al*, 1988a), and which showed that there were no contradicting evidences to the characteristics of (-CG) as earlier reported, and that finer determinations of empirical constants were therefore possible. Weibull distribution was further confirmed as a strong mathematical tool for characterizing thunderstorm parameters.

(b) The spectral characterization as reported by Oladiran and Israelsson (1990), the highlights of the results being:

(1) The weather characterization of the tropical thunderstorms as shown in Table 1.
(2) The ratio of negative ground discharges to cloud discharges was 1:14.2
(3) For all signals monitored, only 2.3% of the flashes from thunderstorms were (+CG).

Table 1: Weather Characterization of Lightning Signals

Storm duration (hr)	Max. & Mean rain rate (mm/hr)	Peak freq. Range and Mean (kHz)	Av. Discharge/ storm(ground)	No. of signals studied	% distribution of duration	Peak field (kV/m)
0 - 0.5	maximum = 186 Average = 92	8.4 - 14.2 Average = 12.4	36	46	8	16
0.5 - 1.0	maximum = 138 Average = 67	6.8 - 20.6 Average = 8.9	148	183	26	108
1.0 - 1.5	maximum = 105 Average = 52	10 - 15.3 Average = 13.6	302	198	31	63
1.5 - 2.0	maximum = 156 Average = 43	9.3 - 21. 8 Average = 10.3	185	104	22	38
> 2.0	maximum = 122 Average = 22	6.5 - 22.7 Average 7.8	87	83	13	13

In this report, further characterization of the (+CG) by direct measurement of ground flash density and the waveform characteristics of the accompanying spherics is made. A simple electrical circuit implementation for (+CG) counts is presented. The results are based on three years of continuous comparative recordings of counts and signal form of (+CG), (-CG) and the spheric signals.

EXPERIMENTAL ARRANGEMENT

The instrument designed and constructed by Pisler and Oladiran (1985) for time registration of flashes, and which stores 2000 flash events by date and time to the nearest 10ms interval was used. The flash count was also simultaneously made mechanically via a modified flash counter (Oladiran *et al*, 1988a). Spheric signals from a horizontal wire antenna elevated at 10m above the ground and 26m in length were simultaneously monitored and recorded on a transient storage oscilloscope. A coupling network as described by Oladiran and Israelsson (1990) was used to divide the signal from a plate antenna into two components to simultaneously activate the flash counter for mechanical counting and electronic occurrence time storage and be recorded on the other channel of the transient storage oscilloscope, so that visual signal comparison of the various signals could be made. Frequency decomposition of the electronic and radiation signals from lightning discharges have shown that the peak energies of (-CG) and (+CG) are centered at 9.0 kHz and 17.3 kHz respectively (Oladiran and Israelsson, 1990; Oladiran *et al*, 1988b). The lightning flash counters used in this investigation were calibrated with these properties. The digitized data is being prepared for rigorous computer-aided data decomposition.

RESULTS AND DISCUSSIONS

Table 2 shows the percentage distributions of (-CG) and (+CG) obtained from spheric signals at various frequencies (Nymphas, 1995). This Table is a low frequency characterization of discharges to ground and the results can be summarized as follows:

(i) The percentage distribution are strongly dependent on the frequency at which one is monitoring the signal:

(ii) There is no significant weather dependence observed when flashes are monitored at low frequencies. An attempt to find a dependence of recorded flash count on local temperature, maximum wind speed, total precipitation and maximum and minimum rate of rainfall; duration of rainfall, and the relative humidity yielded a maximum regression coefficient of 0.24 ± 0.06.

(iii) The average (+CG) to (-CG) ratio was found to be 0.13.

Table 2: Ground flash Characterization from spheric signals

Frequency (Hz)	Number of Flashes	Type of Flashes	
		(-CG)	(+CG)
1000	160	146	14
500	190	179	11
200	185	145	40
100	107	90	17

For measurements with lightning flash counters using the plate antenna and with a circuit peak frequency at 17.3 kHz and 3dB attenuation, the following results were obtained:

a. The rise time of the monitored radiation field lies within the range 0.4-20μs with a modal frequency response of 110-10.3kHz and mean values of 2.4ns rise time and 17.3 kHz peak frequency response at 3dB attenuation respectively.

b. No multiple recording was observed from the counter as verified by the transient signal recording at a circuit response time of 0.26s.

c. The diurnal variation of (+CG) showed a maximum at between 2100LT and 2200LT, while the minimum was situated between the local time range of 1400LT and 1500LT and a fractional distribution of 36% during the day and 64% during the night. The highest count rate of (+CG) was 105/hour between the hours of 2000 and 2200LT.

d. The number of thunderstorm days on which (+CG) occurred is 36 days on an annual average over a period of three years (1996-1998) with an annual count rate of 458/year as compared to an annual average of 24,850/year for (-CG) resulting in (+CG)/(-CG) ratio of 0.018 ($\approx$ 2%). The annual average number of (-CG) flashes is an updated average from 24,226/year reported in 1988 by Oladiran, *et al* (1988). The annual (+CG) monthly distribution by percentage is shown in Table 3.

Table 3: Monthly Distribution of Annual Positive Ground Flashes

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
No. of Thunderstorm days	1	1	2	3	2	5	8	0	6	7	1	0
No. of (+CG)	1	2	14	10	21	58	79	0	108	165	3	0
% distribution	0.2	0.4	3.1	2.2	4.6	12.7	17.3	0	23.6	35.4	0.7	0

The distribution shows a seasonal variation, hitherto unknown for the tropics. For each storm in which (+CG) occurred, the ratio, (+CG)/(-CG) averages 11.6%. We note that the annual average of the updated (-CG) is not significantly different from our earlier report (Oladiran *et al*, 1988b) and that the effect of the August break as earlier observed by many workers (Oshodi, 1971; Osaghaede, 1987) is a consistent phenomenon of this region. It is probable that the short rise times monitored for (+CG) (0.4ns to 6ns) would be directly related to the rise time of the accompanying currents. If this were so, then the degree of protection of properties offered by lightning protector may not be adequate for (+CG) (Geophysics Study Committee, 1986).

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