A Preliminary Study of Intra-Cloud Lightning Electrical Characteristics during Tropical Summer Thunderstorm in North-East India

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Abstract

The preliminary results of observation of the intra-cloud lightning electrical characteristics during tropical summer thunderstorm, locally known as "Nor-Wester", at a hilly place in North-East India are reported here. The field experiments were conducted at the month of April 2007 using "SpectrumLab V2.7b14" software VLF receiver. Different spectra of intra-cloud lightning discharge at VLF range are observed with peaks ranging between 1.5 and 6 kHz. Average intra-cloud lightning channel conductivity is found to be 8.12E-10 Sm^{-1} from electrostatic discharge relaxation time. Specific characteristics of Integrated Field Intensity of Sferics (IFIS) at 14 kHz and 17 kHz are also studied.

1. Introduction

The electromagnetic radiation from lightning at microwave frequencies and below is generally referred to as the "radio frequency" portion of the spectrum. Radiation from lightning in this portion of the spectrum is important both for scientific investigations of lightning and for engineering assessments of the interference environment during thunderstorms. Measurements have been reported from frequencies below a few kilo-Hertz to frequencies above a Giga-Hertz [1].

In this paper we are reporting the preliminary results of measurement of intra-cloud lightning electrical characteristics during typical tropical summer thunderstorms in the state of Tripura (latitude ~ 23^0 N) in North-East India. Every year, during the months of April-May, short duration severe thunderstorms locally known as "Nor-Wester" happen mainly at the Eastern and North-Eastern part of India as well as Bangladesh causing lots of damage. The storms happen due to formation of low pressure regions in summer seasons. In the month of April 2007, seven such thunderstorms occurred. These are characterized by average wind speeds ranging between 50 and 90 $km.hr.^{-1}$ and heavy precipitation from cumulonimbus clouds for duration of fifteen to twenty minutes [2].

Lightning discharge characteristics from cumulonimbus clouds have been investigated by many scientists [3]. The physics of intra-cloud, cloud to ground discharge and their features are discussed in detail by several workers [4-7]. The effect of propagation of lightning generated radio frequency has also been investigated [8, 9].

Presently, we confined our measurements to investigate the VLF electromagnetic waves due to intra-cloud lightning by cumulonimbus clouds and to measure its lightning channel conductivity from the relaxation time of its electrostatic discharge. We also found some specific characteristics in the diurnal variation of Integrated Field Intensity of Sferics (IFIS) for seven thunderstorms. The heights of the lightning generating clouds were within four to five kilometers in range from our experimental site. So the effect of VLF propagation within the earth-ionosphere waveguide is automatically absent and we directly get the characteristics of the lightning producing source.

2. Experimental Setup

Our experimental setup consists of an inverted vertical L type antenna, a preamplifier with surge protection and SpectrumLab V2.7b14" software VLF receiver. The signal coming from the antenna is amplified ten times and passed through a VLF band pass filter having a bandwidth of 30 kHz at the preamplifier. It is then fed to a 24 bit sound card of a P-IV 2.66 GHz computer. At the input of the sound card, proper protection is taken to ensure the elimination of surge voltages coming from the lightning discharges. The software VLF receiver collects data at a

sampling of 48 kHz and records the raw data as ".wav" file for post processing in a programmed mode. For the study of Integrated Field Intensity of Sferics (IFIS), FFT of the preamplified signal is done online at 65,536 points per second using "Hann FFT window function" to get the Fourier spectrum. The maximum frequency that can be recorded is 24 kHz owing to original sampling rate of 48 kHz, maintaining the Nyquist criteria. Different digital band-pass filters at the desired frequencies with Q-factor of 300 are fabricated within the software receiver. The rms value of the signal within the band at the selected frequency is recorded at a sampling rate of one second. The record of IFIS is taken round the clock whereas the record of raw data as ".wav" file is taken mainly during thunderstorms because of large file size.

2. Observational Results

We conducted experiments inside Tripura University Campus in April 2007 during seven thunderstorms. The preamplifier was designed to become saturated at a predetermined voltage during CG flash period to protect the sound card. During intra-cloud lightning, the preamplifier showed linear response.

Each time, thunderstorm occurred at various times of the day for duration of around half an hour. For seven days, we recorded raw data for a total duration of ninety minutes. Only twenty minutes of data had the signature of intra-cloud lightning as other data were from CG flash which led the preamplifier to saturation. A sample raw data for intra cloud lightning in time domain is shown in Figure 1. Four different types of electromagnetic (EM) spectrums were found for intra-cloud lightnings which are shown in Figure 2, 3, 4 and 5 respectively. Type I, Type II, Type IV EM spectrums have a peak frequency around 3.5 kHz, 3.83 kHz and 1.55 kHz respectively while Type III EM spectrum has two peak frequencies around 2.78 kHz and 5.47 kHz. Another interesting feature of Type III and Type IV EM spectrum is that from 300 Hz to peak frequency, the EM spectrum is ascending in nature whereas for other types, the spectrum is first descending and then ascending in nature. The EM spectrum of Sferics in the absence of any local thunder-cloud activity is shown in Figure 6 which shows no distinctive peaks which are supposed to be the characteristics of cumulonimbus intra-cloud lightning activity during Nor-Wester.

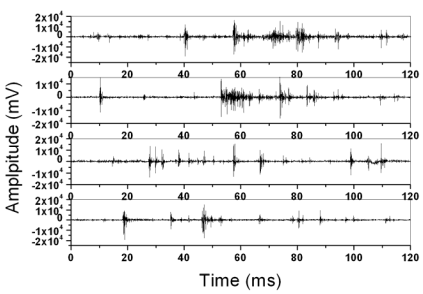

Figure 1: Intra-cloud lightning discharges

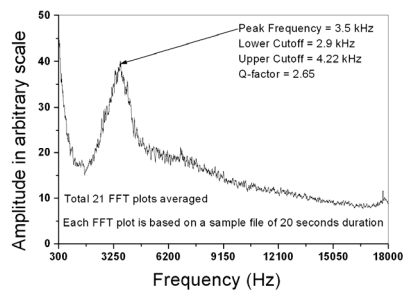

Figure 2: Type I spectrum

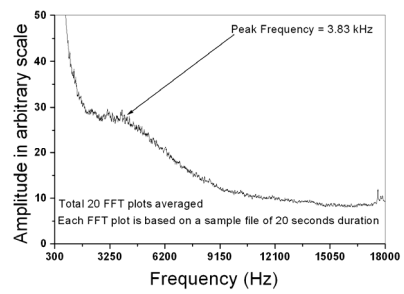

Figure 3: Type II spectrum

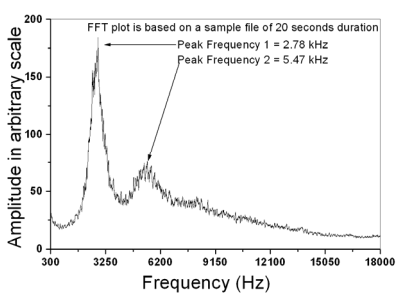

Figure 4: Type III spectrum

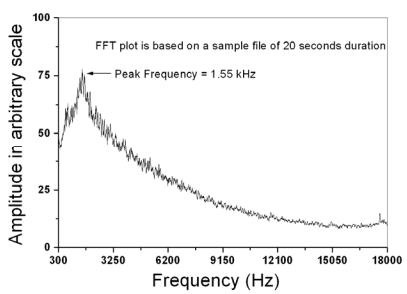

Figure 5: Type IV spectrum

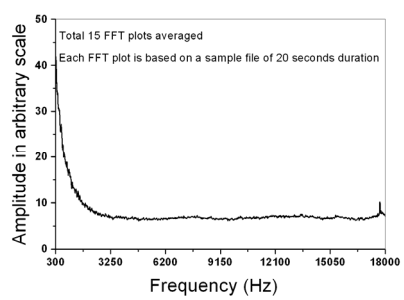

Figure 6: Spectrum during no thunderstorm

Figure 7 shows three different types of typical intra-cloud electrostatic discharges. The polarity of discharge in upper panel and middle panel is opposite in nature. The ratio of upper panel and middle panel type discharge is 5:2. Total 112 electrostatic discharges were analyzed in terms of their relaxation time of the conductive medium of the lightning producing channel which is defined as $\tau = \varepsilon_O \sigma^{-1}$, where ε_O is the permittivity of the free space and σ

the conductivity of the channel. The histogram of electrostatic discharge is shown in Figure 8. The average relaxation time is found as 10.9 ms. The average conductivity of the lightning producing channel found from average relaxation time is 8.12E-10 Sm^{-1} which is about 1000 times the fair weather conductivity at the average height of cumulonimbus clouds.

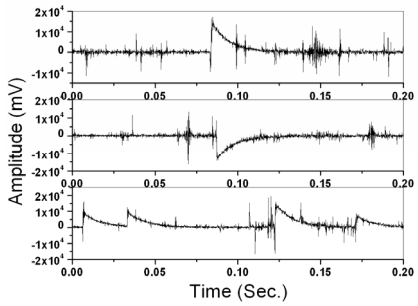

Figure 7: Intra-cloud electrostatic discharge

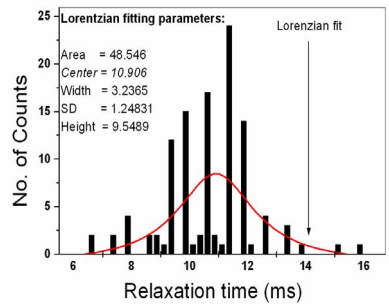

Figure 8: Histogram of electrostatic discharge relaxation time

The diurnal variation of IFIS at 14 and 17 kHz on 10th and 26th April, 2007 is shown in Figure 9 and 10. We concentrated only at those two frequencies because average diurnal variations of IFIS at all atmospheric conditions for previous two months were better than other frequencies in terms of noise figure. The plots show that the local onset time of thunderstorm is not coincident with the peak in electrical activity in the atmosphere which generally leads the commencement of the thunderstorms. Other specific features of the diurnal variation of Sferics for seven storm days are displayed in Table 1.

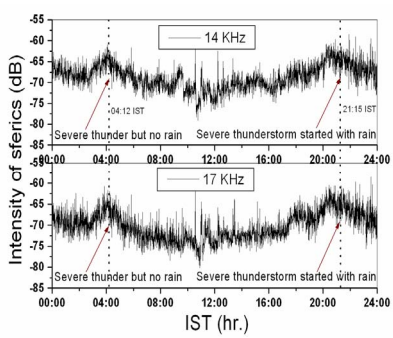

Figure 9: Diurnal variation of Sferics on 10.04.07

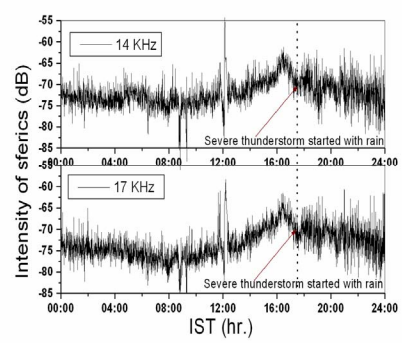

Figure 10: Diurnal variation of Sferics 26.04.07

Table 1: Specific characteristics of the diurnal variation Sferics at storm days

Starting date & time of the thunderstorm	Duration	Peak activity in sferics	Total sferics enhancement from normal level (dB)	Sferics enhancement rate from normal level (dB/hr.)	Sferics dis-enhancement rate up to normal level (dB/hr.)	Time to come to normal level (hr.)
10.04.07 09:15 P.M.	around 20 min.	08:40 P.M.	10	2.25	2	02:30 A.M. of 11.04.07
12.04.07 09:30 A.M.	around 10 min.	09: 30 A.M. in 17 kHz, not sharply clear in 14 kHz	5	2	10	10:00 A.M of the same day
21.04.07 04:30 P.M.	around 30 min.	around 04: 30 P.M	11	1.17	-	-
23.04.07 05:25 P.M.	around 30 min.	around 04:20 P.M.	8	1.6	1.33	10:30 P. M. of the same day
24.04.07 12:20 P.M.	around 15 min.	around 12:50 P.M.	10	5 for 14 kHz 9 for 17 kHz	1.43	03:15 P.M. of the same day
25.04.07 05:30 P.M.	around 10 min.	around 01:30 P.M.	7	1.5	1	08:00 P.M of the same day
26.04.07 05:30 P.M.	around 30 min.	04:30 P.M.	12	1	1	around midnight

3. Discussions

The characteristics of intra-cloud lightning discharge in a hilly place are presented here. The different types of EM spectra found in VLF range show peaks at different frequencies ranging between 1.5 to 6 kHz. The peak activity at those particular frequencies may be related to the complex mechanism of breakdown process of intra-cloud lightning channel. The local topographical features may also influence the lightning activity which is to be experimented in more detail in future.

Direct measurement of conductivity of the intra-cloud lightning producing channel is difficult using balloon or rocket method during severe thunderstorm. Using the information of relaxation time, the average channel conductivity has been measured indirectly. We believe, more in-situ data for different types of clouds would result in better conclusion.

The study of IFIS at two VLF frequencies revealed the temporal growth and decay of electrical activity in the atmosphere at the day of the thunderstorm. A comprehensive study at other VLF frequencies is required for the understanding of relationship between different spectral components.

4. Conclusions

Statistical analysis of the collected data using Principal Component Analysis (PCM) technique is being done with the software Mathematica V5.5. We hope, the analysis would give more insight to the process of intra-cloud lightning process inside cumulonimbus clouds.

5. References

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