Lightning radiation field spectra of cloud flashes

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Abstract – Electric radiation fields produced by lightning cloud flashes have been Fourier analysed to obtain amplitude spectra for frequencies in the range of 20 kHz to 20 MHz. The spectra were generated by analysing the first 10ms time window of cloud flashes and they show f^{-1} frequency dependence up to 2 MHz followed by f^{-2} dependence and higher for frequencies above 2 MHz. By utilizing digital filters it has been shown that measurements taken with narrow band filters do agree with the results produced under wide band measurements.

Keywords: Lightning; Radiation field spectra; Cloud flashes

1. Introduction

Electric fields generated by lightning events recorded through wide band measurements have been Fourier analyzed by many researches in the past. All these studies were conducted by selecting individual pulses in various lightning processes such as return strokes (Sherhan et. al., 1980, Weidman et. al., 1981, Weidman and Krider, 1986, Willett et. al., 1990), stepped leaders (Weidman et. al., 1981, Weidman and Krider, 1986), subsequent strokes (Sherhan et. al., 1980, Willett et. al., 1990), intra-cloud flashes (Weidman et. al., 1981, Weidman and Krider, 1986, Willett et. al., 1990), isolated cloud pulses (Willett et. al., 1989) etc and then by computing the average spectral amplitude for each process separately. Comparisons are also available for subsequent return strokes between the natural and triggered lightning (Le Vine et. al., 1989). In most of the earlier studies the point of observation and the point of strike has been the land (Sherhan et. al., 1980). Thus, propagation of lightning generated EM fields over finitely conducting ground may seriously affect their final results especially at high frequencies. However, more recent studies have been conducted where the path of propagation is entirely over seawater (Weidman et. al., 1981, Weidman and Krider, 1986, Le Vine et., al., 1989). These studies have indicated that the lightning amplitude spectra more or less produces similar dependenciesfor individual lightning processes and vary as f^{-1} up to a few MHz and f^{-2} or higher for frequencies above 2 MHz.

In contrast to wideband measurements, some studies have reported lightning amplitude spectra observed with measurements carried out using narrow band filter measurements (Horner and Bradley, 1964). It has been shown elsewhere that one can normalize the narrow band filter measurements to compare with the wideband measurements (Le Vine, 1987). Although the results obtained through both techniques tend to agree below 1 MHz after the normalization, a disparity has been observed at the higher frequencies. It has also been suggested that the adopted process of selecting individual pulses in separate lightning events may be the cause of this disparity since this process tends to neglect all embedded pulses with small amplitudes (Nanevicz et. al., 1987). A large number of such small pulses can effectively enhance the amplitude spectra especially at higher frequencies.

The purpose of this work was to analyze for the first time, rather than individual pulses in lightning events, a substantial portion of a full lightning event such as a cloud flash. Cloud flashes were selected since there is no ground attenuation and thus one can obtain 'unaltered' electric fields. In the present study, we have recorded and analyzed the first 10 ms of cloud flash events. We have shown that our results agree very well with the previous work carried out for individual pulses in lightning events. By analyzing the same data samples using digital filters, we have also shown that the narrow band filter measurements do agree with the wideband measurements subjected to normalization with filter bandwidths.

2. Experiment

The measurements of electric fields generated by cloud flashes were conducted in July 1994 in an open area close to the Institute of High Voltage Research, Uppsala University (latitude 59.8° N, and longitude 17.6° E), Sweden using a system similar to what has been previously described by Cooray and Lundquist (1982). A flat plate antenna was used to measure the vertical component of the electric field. The decay time constant of the antenna used in the present work was 13 ms which is well over the width of pulses of interest. The antenna was fixed on the rooftop of a metallic wagon located in a meadow and all recording instruments were placed inside the wagon in order to shield them from any interference due to background electric fields. A short shielded cable was used to connect the antenna to a buffer amplifier. The output of the buffer amplifier was connected to a LeCroy 9350L digital storage oscilloscope and triggered by the electric field signal. The measurements were carried out with a sampling rate of 10 ns. For each waveform 1 million samples were recorded within a time window of 10 ms. Simultaneous