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Horizontally and vertically polarized components of lightning electric fields

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1. Introduction

Divya and Rai (1986) were the first to take into account the finite ground conductivity in the computation of electric fields due to lightning. They found that the ratio of horizontal to the vertical component of atmospherics is independent of source parameters and is a function of soil conductivity. Later Divya (1986) measured these polarized components of electric fields at 5.00 kHz and from this obtained the value of soil conductivity. Her measurements were in conformity with the measurements using normal geophysical techniques. Kumar et al., (1995) considered the multi-layered earth in the calculation of horizontally and vertically polarized component of atmospherics. Sharma et al., (2000) used Lineard-Wiecherts potential for the calculations of electric fields above a finitely conducting ground.

Singh et al., (2002) extended the work of Divya and Rai (1986) and performed detailed calculations of horizontally and vertically polarized components of lightning electric fields. They took various current models and concluded that for exact calculations of electric fields in the VLF range one must take into account the return stroke current and lateral corona current together.

The purpose of the present paper is to measure the horizontally and vertically polarized components of electric fields in the VLF range due to lightning and to compare the results with theoretical studies.

2. Experimental Techniques

The lightning electric field is measured in the VLF range by using a broad band receiver. The vertical electric field component is measured by a vertical wire of height 10 m and radius 0.125 cm. The antenna is not loaded on the top to present the coupling of the horizontal component with the vertical. The signal is amplified and fed to the recording unit.

For the measurement of horizontal component of lightning the technique proposed by Thiel (1978) and with consequent improvements by Divya et al., (1987a, 1987b) and Divya and Rai (1990) have been used. A multistranded wire of 1 mm diameter, 15 m long and coated with PVC is used as horizontal antenna. This lays just on the ground in the geomagnetic east-west direction. The signal received are amplified and fed to the recorder.

The lightning analyzer which consists of the measurement of electrostatic field change, thunder and visible light is used to identify the kind of lightning (cloud to ground or intra-cloud), distance from the point of observation and the duration of the discharge for close lightning discharges. The recorded waveforms are Fourier analyzed and the frequency spectrum is obtained.

3. Results and Discussion

Fig. 1 is a typical example of the frequency spectrum of the individual pulse of atmospherics in the horizontally polarized component. The spectrum peaks at 8 kHz after which it falls off abruptly, remaining almost constant above about 55 kHz. Fig. 2 is a typical example of the frequency spectrum of the individual pulse of atmospherics in the vertically polarized component. In this case the peak occurs at 5 kHz. After the peak it falls almost exponentially which negligible small field strength above about 40 kHz.

Simultaneously records the fields in horizontal and vertical components are shown in Fig. 3 and 4. In all cases of horizontal component of atmospherics there is a peak below 1 kHz. Thus the horizontal component is expected to have comparatively large field in ELF range. Besides, the spectrum has been found to consist of more than one peak in the frequency range from 5 to 8 kHz and 9 to 15 kHz. In some cases first peak is larger (Fig. 3) while in others the second peak (Fig. 4). The third peak has always laser amplitude than the first and second peaks. In all the cases of vertical component only one large peak has been found lying in the frequency range from 4 to 7 kHz. The subsequent peaks fall in the frequency range from 9 to 13 kHz. The simultaneous records of atmospherics show that the horizontal component peaks at a higher frequency than the vertical component. The spectrum in horizontally and vertically polarized components has been observed oscillatory in nature. Average of the ratio R (horizontal to the vertical electric field components) at different frequencies for all the analyzed waveforms are shown in Fig. 5. The ratio is maximum at a frequency of 15 kHz and decreases with increasing frequency.

The studies on the waveform of the atmospherics in the horizontally and vertically polarized components show that the frequency spectrum of horizontally polarized component is quite different than that of vertically polarized component. The spectrum of the vertical component peaks in the frequency around 5 kHz (see in Volland, 1982). Rai (1974) employing both wide band (1 to 100 kHz) and narrow band (tuned at 5, 10, 15 and 20 kHz frequencies) receivers simultaneously the field of vertical electric field to lie in the range 4 to 7 kHz. Uman and Krider (1982) found the peak value of the frequency spectrum to be at 5 kHz. Rai and Varshneya (1982) found in their measurements of the radiation field of multiple return strokes the peak to lie between 5 to 7 kHz. The theoretical calculations by Kumar et al., (1992), Singh et al., (2002) and others are also in conformity to our experimental studies of vertically polarized components.

The experimental studies on the horizontally polarized components are rare. However, the theoretical studies by Divya and Rai (1986), Kumar et al., (1990), Singh et al., (2002) and others confirm our measurements.

The present study has a short coming in the sense that the horizontal component has been measured in the east-west direction only. Any horizontal component will also have an north-south component. This might have affected the amplitude of the horizontally polarized component and ratio of the horizontal to the vertical field components.

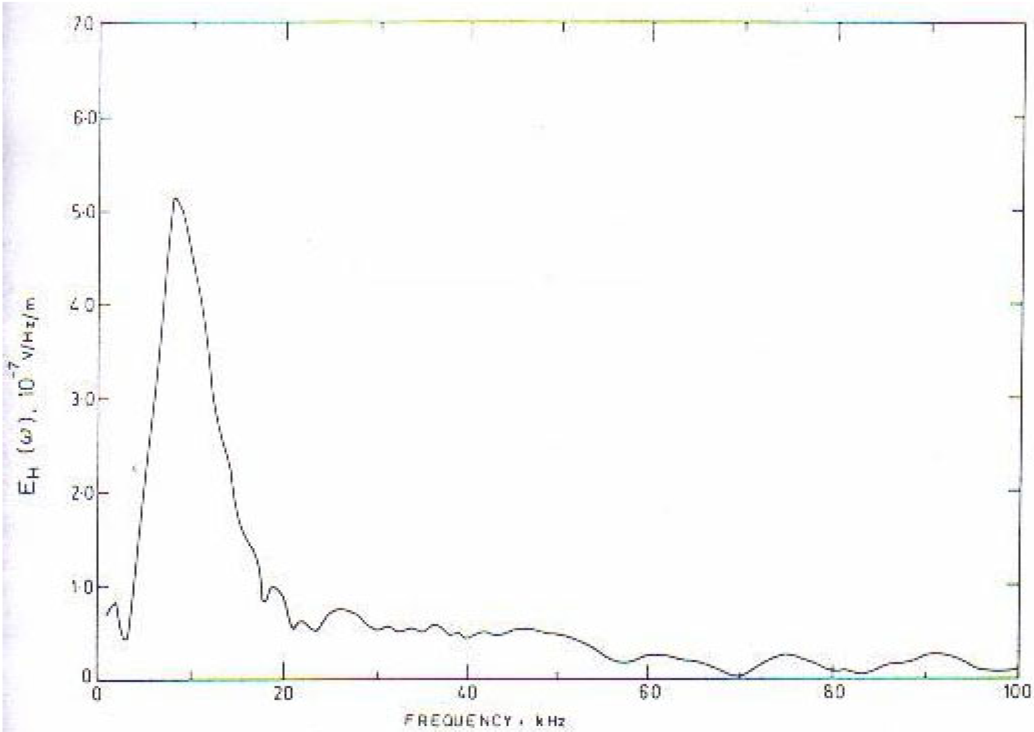

FIG 1: FREQUENCY SPECTRUM IN HORIZONTALLY POLARIZED COMPONENT

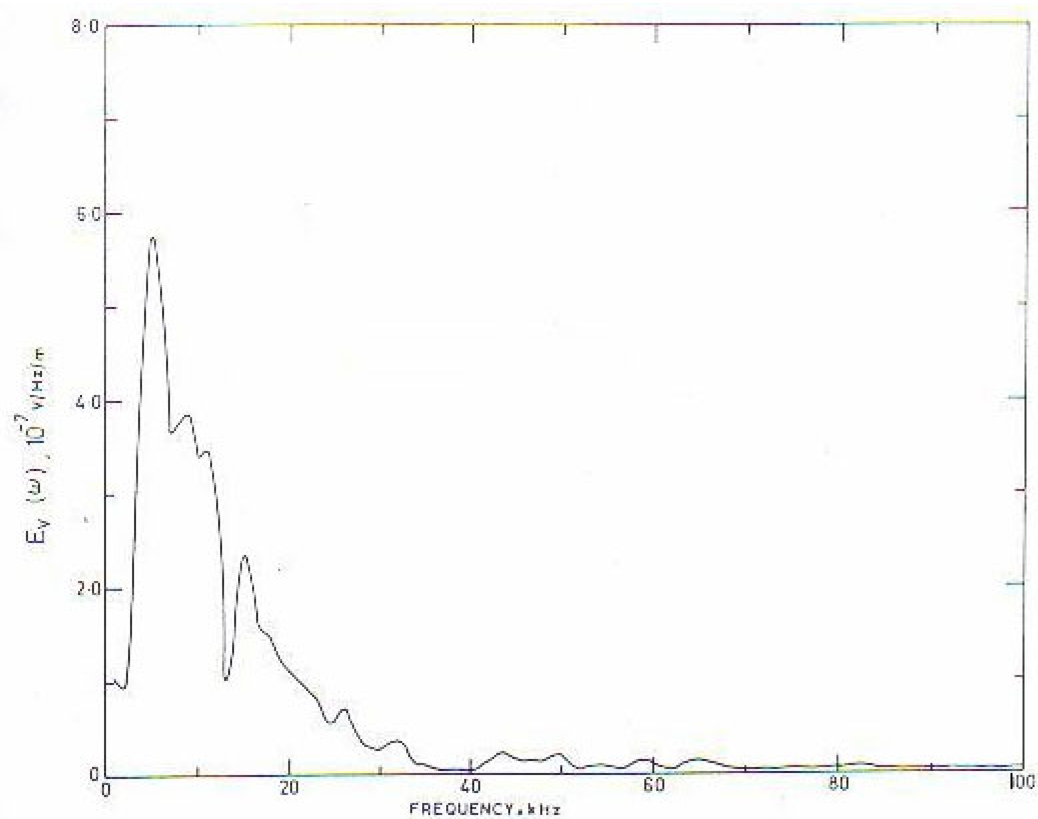

FIG 2: FREQUENCY SPECTRUM IN VERTICALLY POLARIZED COMPONENT

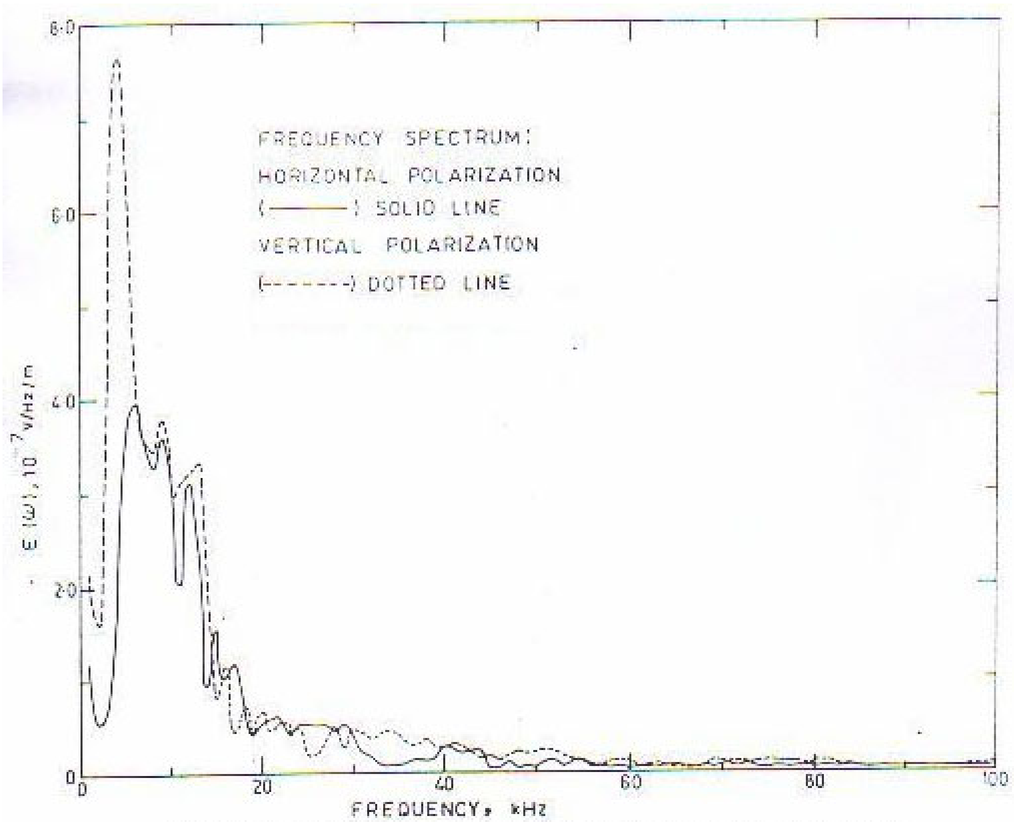

FIG 3: FREQUENCY SPECTRUM OF THE SIMULTANEOUS PULSES

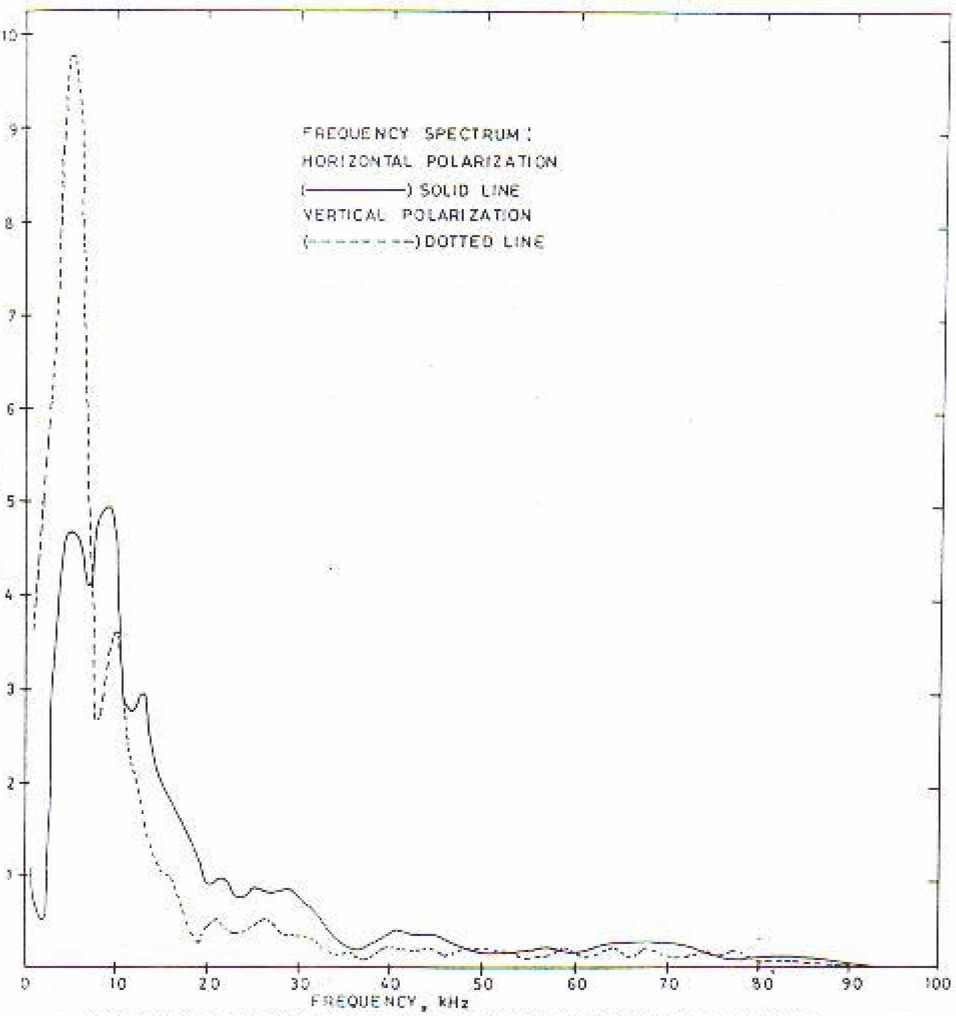

FIG 4: FREQUENCY SPECTRUM OF THE SIMULTANEOUS PULSES

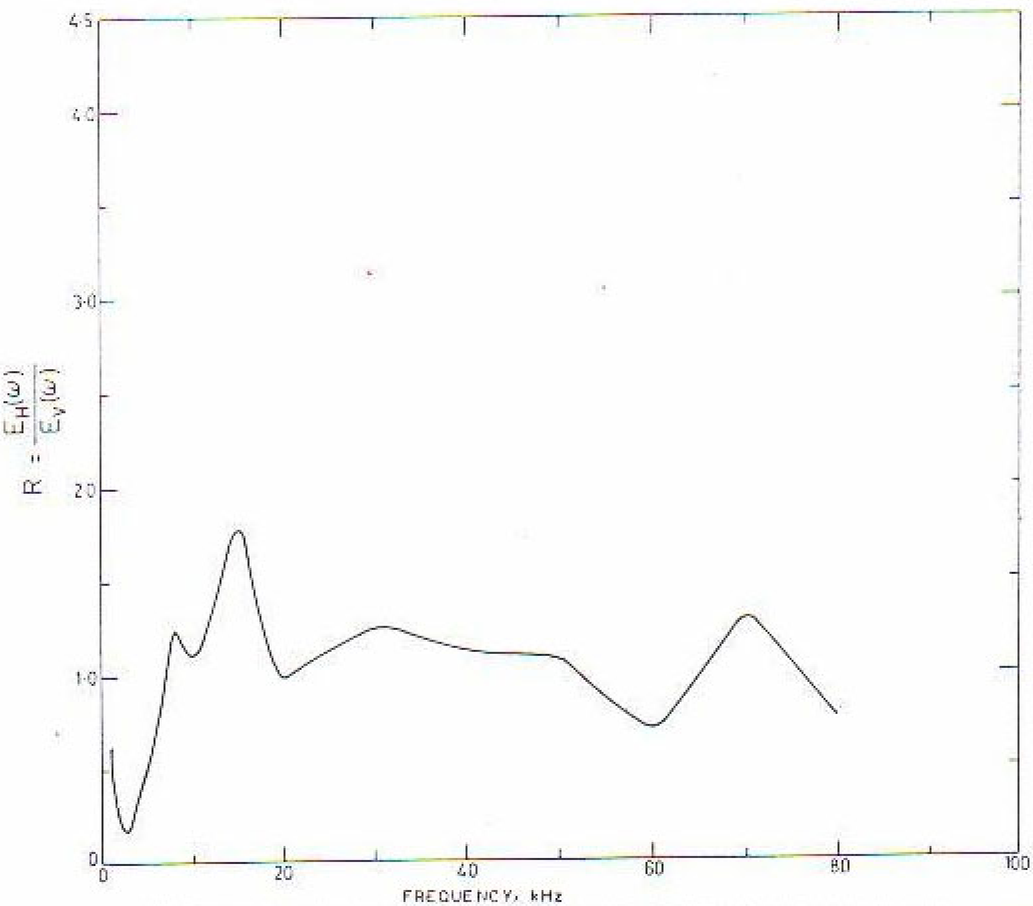

FIG 5: VARIATION OF RATIO 'R' WITH FREQUENCY OF ATMOSPHERICS

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