Early/fast VLF events: A comparison between theoretical models and spread-spectrum VLF scattering observations

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Early/fast very low frequency (VLF, 3-30 kHz) events are known to be directly associated with ionospheric conductivity changes produced by lightning. They have been observed coincidentally in time with a variety of transient luminous events (TLEs), such as sprites, sprite halos, and elves. It is as yet unresolved, however, which causative mechanisms (e.g., sprite, sprite halo, elves) accurately describe early/fast VLF event production. In this paper, we present new observations of VLF scattering during an early/fast VLF event. These observations clearly show the frequency dependence of VLF scattering during the event. We compare these observations as a function of frequency with theoretical VLF scattering calculations for electron density changes associated with sprite halos and for those associated with elves.

1. Introduction

Early/fast very low frequency (VLF, 3-30 kHz) events were first identified in 1983 [1]. Transient luminous events (TLEs) were first observed in 1989 [2], and since that time, a number of experimental observations have associated early/fast VLF events with optical observations of sprites [3,4,5], sprite halos [5,6], and elves [7]. Furthermore, a number of theoretical studies have associated early/fast VLF scattering events with both sprite halos [6] and elves [7]. Nevertheless, certain deficiencies remain in both experimental and theoretical analyses of the problem. The answer to the question as to whether any or all TLEs can produce early/fast VLF events thus remains unresolved.

In this paper, we present observations of an early/fast VLF event using a new spread-spectrum VLF remote sensing technique. We show that during the early/fast VLF event, the observed changes in amplitude and phase are essentially constant with frequency across the 200-Hz bandwidth of the VLF signal. These observations are juxtaposed with spread-spectrum observations of VLF scattering during a lightning-induced electron precipitation event, which clearly demonstrates the sensitivity of the measurement technique to changes in amplitude and phase that vary significantly with frequency.

These observations are interpreted using a three dimensional Earth-ionosphere waveguide VLF scattering model, implemented using the Long Wave Capability (LWPC) code [8,9,10,11,12]. Electron density changes associated with sprite halos and elves are estimated based on past published work [6,7], and LWPC is used to calculate the VLF scattered field as a function of frequency under a variety of ionospheric conditions.

We compare the VLF scattering predictions as a function of frequency to the new spread-spectrum observations of VLF scattering during an early/fast VLF event.

3. References

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