Spectral Observations of Early/Fast VLF Scattering Events

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Under certain conditions, the field changes and radiated power associated with lightning are capable of significantly modifying local conductivities of the *D*-region ionosphere. At very low frequencies (VLF, 3-30 kHz) these localized conductivity changes act to scatter energy within the confines of the earth-ionosphere waveguide. Early/fast amplitude and phase perturbations, occurring within 20 msec of the causative flash (early) and exhibiting rapid onsets under 20 msec (fast), have been observed coincidentally with various optical observations of transient luminous events (TLEs), including elves, sprites, and sprite halos, each of which have temporal characteristics consistent with the typical early/fast event. It remains an open question, however, as to whether the conductivity changes associated with a specific TLE are responsible for the commonly observed early/fast event.

We present new spectral observations of early/fast VLF events, in conjunction with modeled theoretical predictions, which shed light on this open question. A spread-spectrum technique, capable of estimating the amplitude and phase changes at particular frequency components, is applied to broadband recordings of 200 Hz bandwidth VLF transmissions. Early/fast VLF scattering observations, each identified with causative lightning flash logged by the National Lightning Detection Network (NLDN), are analyzed using this technique to determine the amplitude and phase changes as a function of time and frequency. These results are compared to the predictions of the Long-Wave Propagation Capability (LWPC) code, a three-dimensional earth-ionosphere waveguide propagation and scattering model. Results indicate that the observed amplitude and phase changes result from a combination of waveguide propagation effects and scattering source properties, and are sensitive to frequency and location of the scatterer and receiver. Observed amplitude changes are more consistent with modeled perturbations associated with sprite halos than those associated with elves.