Empirical Models of Saturation in VLF Triggered Emissions

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During the 1970s and 80s, the VLF triggered emissions phenomenon was explored extensively through the Siple experiment, in which variable frequency VLF waves were generated by the transmitter at Siple Station, Antarctica. The observations from Siple spurred a number of theoretical and numerical studies. One of the principle characteristics of the triggered emissions phenomenon was exponential growth of the triggering signal to a relatively constant saturation level. However, the mechanism that causes this saturation is still not well understood. Previously proposed mechanisms include local destruction of anisotropy in the hot electron distribution due to deep trapping in the potential well of the growing wave, leakage of high-amplitude waves from magnetospheric ducts, and modulational instabilities.

Observations from the Siple experiment suggest that the creation of relatively broadband waves near the triggering frequency destroys the anisotropy of the hot electron distribution in the resonant energy band and thus quenches the growth of the wave. Furthermore, the combination of large-amplitude, broadband waves allows for destruction of anisotropy to occur before the electrons enter the region where they resonate with the waves.

We model the interaction using a simple one-dimensional simulation. The hot electrons are modeled in two dimensions in velocity space and stream counter to the waves. We consider only two effects of the non-linear interaction: the increasing amplification of the waves with time, and the generation of waves at frequencies other than that of the triggering wave. Both of these effects are modeled empirically. Two models for the interaction between the waves and the electrons are developed. The first wave-particle interaction mechanism uses using pitch angle diffusion. Although the diffusion treatment is not rigorously applicable due to the small bandwidth of the majority of the wave power, many of the characteristics of the saturation process are demonstrated, giving good agreement with the data.

The second wave-particle interaction mechanism uses a test-particle approach, allowing treatment of the detailed phase-specific aspects of the interaction. This approach gives similar saturation results from the first mechanism, and additionally reveals a more-detailed development of the electron distribution at saturation, allowing for the explanation of other effects, such as the development of sidebands and triggering of emissions.

Preliminary results from both models indicate that the fundamental cause of the well observed saturation effect may be the destruction of the anisotropy by the amplified and spectrally broadened wave energy.