Frequency-Time Signatures of Very Low Frequency Triggered Emissions

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Very low frequency triggered emissions are spectacular manifestations of cyclotron resonance wave-particle interaction between whistler mode waves and energetic electrons in the radiation belts. Emissions are triggered following significant temporal growth (up to 30 dB) of the parent signal, and are observed to have a menagerie of shapes, including risers, fallers, and long enduring hooks. The complicated frequency-time shapes of the free running triggered emissions have defied explanation, and have not been analyzed in detail. In this paper we study the rich data set of VLF emissions triggered by waves injected into the magnetosphere from Siple Station, Antarctica and received at the geomagnetically conjugate point, Lake Mistissini, Quebec. The Siple wave injection experiment carried out by Stanford University acquired the most comprehensive data set on VLF triggered emissions from 1973 until 1989. The vast data set of analog recordings stored on reel to reel magnetic tapes has recently been digitized, allowing examination using modern digital signal processing techniques that were not previously available. Several hundred triggered emission cases have been examined in order to characterize the properties of free-running emissions. One important property analyzed is the frequency versus time evolution of the free-running emissions, focusing on the slopes of falling and rising emissions. Additional emphasis has been placed on the points where emissions reverse from positive to negative slopes, as understanding of this reversal is essential to complete characterization of the underlying physical mechanism by which the emissions are generated and sustained. Further investigation of this reversal is conducted through examination of the evolution of the phase of the emission as df/dt changes. Another important property that is examined are temporal growth rates. For all of the properties examined, we investigate those features which remain constant from day-to-day and case-to-case, versus those which exhibit temporal variations. As one example, initial analyses indicate that the down-going and up-going slopes of the so-called hook emissions exhibit a remarkable and surprising degree of repeatability. Identification of such features may provide clues for theoretical understanding of this fascinating nonlinear phenomena.