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Analysis of Sidebands from Whistler Mode Triggered Emissions and Implications for Nonlinear Wave Growth

Mark Golkowski* (1) Jamie Costabile (1) and Maria Spasojevic (2)
(1) Department of Electrical Engineering University of Colorado Denver, Denver, USA
(2) Department of Electrical Engineering, Stanford University, Palo Alto USA

Extended Abstract

The Siple Station Antarctic Transmitter was operated during 1973-1988 to inject ELF/VLF waves into the Earth's magnetosphere to study whistler mode wave-particle interactions. As shown in Fig. 1a, waves were injected into the magnetosphere from a ground based antenna. The waves were subsequently observed at the conjugate point in Canada after propagating in the ducted mode and experiencing nonlinear growth and triggering of emissions driven by cyclotron resonance interactions with radiation belt electrons [1]. To date the Siple Station experiment stands out as unique in terms of the kilowatts of controlled ELF/VLF radiated power available for prolonged scientific investigation. The large dataset from this experiment was never fully analyzed and recent digitization efforts have made it available for analysis with modern signal processing tools [2]. In a subset of the observations single frequency input waves were seen to trigger quasi-symmetric sidebands with 20-70 Hz separation from the injected frequency tone an example of which is shown in Fig. 1b.

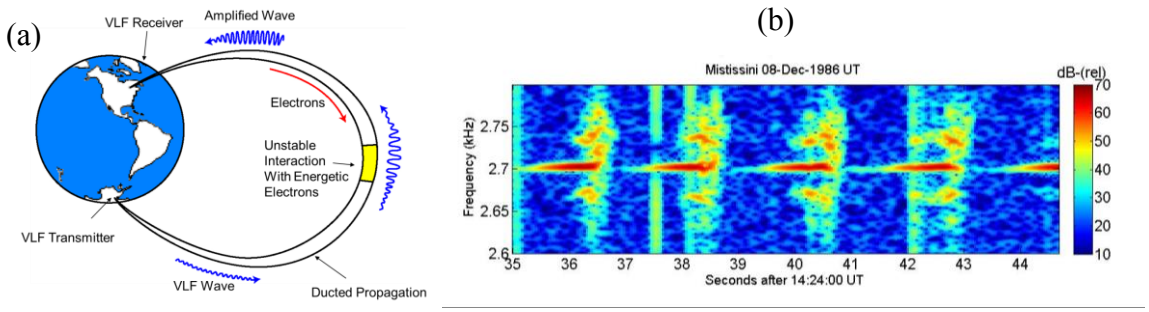

Figure 1. (a) Schematic of Siple Station Antarctic Trasnmitter experiment where ELF/VLF waves are injected into the magnetosphere and propagate along geomagnetic field lines. (b) Observation at conjugate point of sidebands generated about a 2.7 kHz input signal.

While the amplitude of such magnetospherically generated sidebands has been treated before [3], little work has examined the relative phase of the sidebands. We analyze the sidebands using concepts from communication theory of amplitude (AM) and frequency (FM) modulation. We use a hybrid AM/FM model along with the MINUIT minimization package to quantify the relative phase of the observed sidebands and its evolution as the main input frequency undergoes nonlinear growth. The results are discussed in the context of the nonlinear whistler mode growth theory based on particle phase trapping and formation of an electron phase-space hole. Coherent oscillations of electrons in a phase trap are shown to generate sidebands similar to those in observations. Observations of sidebands can be used to put bounds on the collective inhomogeneity parameter and the degree of phase coherence in the trap.

References

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