Hamiltonian Single Wave Models to Investigate the Nonlinear Self-Consistent Interaction of Whistler Waves and Electrons[1]

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Whistler mode chorus waves are one of the most important electromagnetic emissions in the Earth's radiation belts. *In situ* particle and wave measurements indicate that the characteristic properties of chorus, namely a chirping frequency, bursty nature, and sub-packet structure, are due to nonlinear wave-particle interactions. Recent laboratory experiments have reproduced many of the spectral characteristics of whistler mode chorus by injecting an energetic spiraling electron beam into a background cold plasma and more or less uniform magnetic field. In this paper, we investigate the nonlinear evolution of a self-consistent Hamiltonian model for the interaction of resonant electrons with whistler waves. We find that in the parallel propagating case there are two classes of solutions. The first class has properties similar to previously derived single wave models and involves a perfectly resonant electron beam. We show that test-particle models in the modulated wave-field indicate that the particles are trapped in a first-order island that tracks the location of the majority of particles. We develop a macro-particle model which explains the small frequency and amplitude oscillations. The second class of solutions involve a slightly off-resonant interaction which leads to an amplitude modulation of the wave that resembles the sub-packet structure observed in both chorus and recent laboratory experiments. In the second class of solution, we show that test-particle models demonstrate that instead of being trapped in the primary resonance particles get trapped in a second-order island chain. The location of the second-order island chain in phase space tracks the location of the majority of electrons. We develop a two macro-particle model which reproduces the amplitude modulation and sub-packet structure due to the self-consistent motion of two clumps of particles.

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