Simulation of nonlinear damping for obliquely propagating whistler-mode wave

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We perform two-dimensional electromagnetic particle simulation to study fundamental characteristics of whistler mode wave-particle interaction involved in chorus emissions propagating oblique to the background magnetic field. We assume periodic (x, y) system with the parabolic magnetic field taken in the x-direction. With the electrostatic components parallel to the magnetic field, which have been neglected in the previous simulation studies on chorus emissions, the distribution function in position can have a great influence on the simulation results. Assuming energetic electrons with anisotropic subtracted bi-Maxwellian velocity distribution function at the equator, we first put particles under harmonic bounce motion under a parabolic magnetic field. We next follow the motions of the particles adiabatically without any waves to obtain an equilibrium state as the initial distribution for the particle simulation. It is necessary to put many super-particles in a grid cell to suppress the thermal fluctuation. With 8,192 particles per cell, we have confirmed a good agreement of the wave growth in the parallel direction with the linear growth rate. We next put an array of antennas perpendicular to static background magnetic field and oscillate the antenna current with phase delay, which satisfy matching condition for wave phase at boundaries. Oblique propagating whistler-mode wave with variable frequency is excited from phased array antenna. In addition to the nonlinear trapping of energetic electrons through the cyclotron resonance, another nonlinear trapping of electrons by the Landau resonance takes place. Structures of the nonlinear trapping potentials changes with a varying frequency, affecting the efficiency of energy transfer between the wave and energetic electrons. We study nonlinear evolution of the wave packet, and competing processes of both resonances in accelerating the energetic electrons to higher energies.