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Nonlinear wave growth theory of whistler-mode chorus emissions and EMIC chorus emissions in the magnetosphere

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In analogy with whistler-mode chorus emissions, we develop a nonlinear wave growth theory of electromagnetic ion cyclotron (EMIC) chorus emissions observed in the inner magnetosphere. We first derive the basic wave equations from Maxwell's equations and the momentum equations of electrons and ions. We then obtain equations describing nonlinear dynamics of resonant protons interacting with an EMIC wave. The frequency sweep rate of the wave plays an important role in forming the resonant current controlling the wave growth. Assuming an optimum condition for the maximum growth rate as an absolute instability at the magnetic equator, and a self-sustaining wave growth through propagation, we obtain a set of ordinary differential equations describing nonlinear evolution of a chorus element generated at the magnetic equator. Using the physical parameters inferred from the waves, particles, and magnetic field data of the Cluster spacecraft, we determine the dispersion relation of the EMIC waves. Integrating the differential equations numerically, we obtain a solution showing the amplitude and frequency of a chorus element at the equator. Assuming saturation of the wave amplitude, as found in the observations, we find a good agreement between the numerical solution and the wave spectrum of the EMIC chorus emission.

Keywords: whistler-mode wave, EMIC wave, nonlinear wave-particle interaction, chorus emissions, inner magnetosphere, electromagnetic ion cyclotron wave