Nonlinear Wave Growth Theory of Whistler-mode Chorus Emissions

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Abstract

Based on a self-consistent simulation study on chorus wave generation [1], we have analyzed the generation process of chorus elements theoretically. Driven by an assumed strong temperature anisotropy of energetic electrons, the initial wave growth of chorus is linear. After the linear growth phase, the wave amplitude grows nonlinearly. It is found that the seeds of chorus emissions with rising frequency are generated near the magnetic equator as a result of a nonlinear growth mechanism that depends on the wave amplitude. We derive the relativistic second-order resonance condition for a whistler-mode wave with a varying frequency [2]. Wave trapping of resonant electrons near the equator results in the formation of an electromagnetic electron hole in the wave phase space. For a specific wave phase variation, corresponding to a rising frequency, the electron hole can form a resonant current that causes growth of a wave with a rising frequency. Seeds of chorus elements grow from the saturation level of the whistler-mode instability at the equator, and then propagate away from the equator. In the frame of reference moving with the group velocity, the wave frequency is constant. The wave amplitude is amplified by the nonlinear resonant current, which is sustained by the increasing inhomogeneity of the dipole magnetic field over some distance from the equator. Chorus elements are generated successively at the equator so long as a sufficient flux of energetic electrons with a strong temperature anisotropy is present. In the process of chorus wave generation, the relativistic effect becomes essentially important for acceleration of resonant electrons. A faction of resonant electrons are trapped by the coherent wave, and they are accelerated to MeV energy through the special acceleration processes of the relativistic turning acceleration (RTA) [3, 4] and the ultra relativistic acceleration (URA) [5]. Both RTA and URA contribute to rapid formation of MeV electron flux of the radiation belts [6]. The nonlinear wave growth works favorable for trapping larger number of resonant electrons and accelerates relativistic electrons through a longer period of interaction time.

References

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