Theory and Simulations of VLF Chorus Emissions

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We develop a nonlinear wave growth theory of VLF chorus emissions [1], taking into account the spatial inhomogeneity of the static magnetic field and the plasma density variation along the magnetic field line. We derive theoretical expressions for the nonlinear growth rate and the amplitude threshold for the generation of self-sustaining chorus emissions. We assume that nonlinear growth of a whistler mode wave is initiated at the magnetic equator where the linear growth rate maximizes. Self-sustaining emissions become possible when the wave propagates away from the equator during which process the increasing gradients of the static magnetic field and electron density provide the conditions for nonlinear growth [2]. The amplitude threshold is tested against both observational data and self-consistent particle simulations of the chorus emissions. The self-sustaining mechanism can result in a rising tone emission covering the frequency range below the equatorial electron gyrofrequency. During propagation, higher frequencies are subject to stronger dispersion effects that can destroy the self-sustaining mechanism. We obtain a pair of coupled differential equations for the wave amplitude and frequency. Solving the equations numerically, we reproduce a rising tone of VLF whistler mode emissions that is continuous in frequency. Chorus emissions, however, characteristically occur in two distinct frequency ranges, a lower band and an upper band, separated at half the electron gyrofrequency. We explain the gap by means of the nonlinear damping of the longitudinal component of a slightly oblique whistler mode wave packet propagating along the inhomogeneous static magnetic field.

Keywords: wave-particle interaction; nonlinear; whistler; VLF; simulation

References

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