Simulation study on the generation mechanism of VLF triggered emission

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We study the generation mechanism of VLF triggered emissions by a self-consistent particle code with a dipole magnetic field.

Observations both on the ground stations and onboard satellites reveal that narrow band whistler mode waves are periodically generated by triggering waves which are emitted from the ground station at high latitude region. These secondary generated waves of frequency of VLF band are known as VLF triggered emissions, and they often consist rising tones. For several decades, several models have been proposed by theories and simulations to explain the generation mechanism. In recent years, it has been widely accepted that the triggering mechanism is deeply related to the nonlinear cyclotron resonance between narrow band whistler mode waves and energetic electrons. Recent simulations suggest that both wave amplitude and wave frequency of coherent whistler mode waves are strongly affected by nonlinear resonant currents formed by resonant electrons in an inhomogeneous magnetic field. Although the frequency rising/falling of triggered emissions have been reproduced by several models, there are unresolved problems of the triggering process because the previous models assumed only a single monochromatic (or band-limited) waves. There remain uncertainty of the frequency variation of triggered emissions.

In the present study, we perform a self-consistent particle simulation to investigate the physical process of the triggering mechanism. The evolution of a wave packet propagating along a reference magnetic field line is solved by Maxwell's equations while the bounce motion of energetic electrons in the non-uniform magnetic field is taken into account. By using Electron Hybrid Model, we simulate nonlinear wave particle interaction between the narrow band whistler mode waves in a cold plasma medium and energetic electrons having a loss cone distribution with temperature anisotropy.

Our model successfully reproduces the triggered emissions with a rising tone. The simulation result reveals that triggered emissions are generated near the equatorial region after the wave packet passes through the magnetic equator, and 25.9% rising from the frequency of the triggering wave packet is reproduced. The generation process simulated in the present study is explained by the role of resonant currents in association with the electromagnetic electron hole in the phase space due to the nonlinear effect. The simulation result suggests that the phase bunching of untrapped electrons is essential in the triggering mechanism. It is also clarified that our model has an enough potential to investigate the detailed physics of VLF triggered emissions.