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Whistler-mode Triggered Emissions in a Homogeneous Magnetic Field

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We perform a self-consistent one-dimensional electromagnetic particle simulation with a uniform magnetic field and open boundaries [1,2]. The plasma environment consists of cold electrons, energetic electrons, and immobile ions. The cold electrons are initialized with the bi-Maxwellian distribution function with a small thermal velocity and the energetic electrons are initialized with subtracted-Maxwellian distribution with relatively large thermal velocities resulting in a temperature anisotropy. By oscillating external currents with a constant frequency 0.2 f_{ce}, where f_{ce} is the electron cyclotron frequency, a whistler-mode wave is injected as a triggering wave from the center of the simulation system, and we investigated the process of interactions between the triggering wave and energetic electrons.

We find that both rising-tone and falling-tone emissions are triggered through the formation of an electron hole and an electron hill in the velocity phase space consisting of a parallel velocity and the gyro-phase angle of the perpendicular velocities. The rising-tone emission varies from 0.2 f_{ce} to 0.4 f_{ce}, while the falling-tone varies from 0.2 f_{ce} to 0.15 f_{ce}.

Under the presence of the electron hole, the resonant current is formed in the anti-parallel direction of the wave magnetic field resulting in the frequency increase, which distort the symmetric structure of the electron hole, resulting in the resonant current anti-parallel to the wave electric field. With $\boldsymbol{J} \cdot \boldsymbol{E} < 0$, the wave grows as forming a new wave packet. The electron hill, on the other hand, forms a resonant current parallel to the wave magnetic field and anti-parred to the wave electric field, resulting in the falling-tone emission.

The generation region of the rising-tone triggered emission starts in the downstream due to the triggering wave and moves upstream generating new subpackets. The generation region of the falling-tone triggered emission also moves upstream generating new subpackets [3].

The simultaneous formation of the electron hole and hill is identified by separating small and large wavenumber components corresponding to lower and higher frequencies, respectively, by applying the discrete Fourier transformation to the wave forms in space. The nonlinear wave growth theory is constructed under the assumption of a single wave packet. When multiple waves are present as in our result, it is essential to separate them in wavenumber and frequency for accurate analysis, and only after the separation, the correct resonant currents and relative gyro-phase angles can be obtained for comparison with the nonlinear wave growth theory.

Based on the simulation results of the whistler-mode triggered emissions, we conclude that the mechanism of frequency variation of whistler-mode chorus emissions works even in a uniform magnetic field.

References

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