Study of characteristics of whistler-mode chorus wave generation by electron hybrid simulation

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Recently we reproduced the generation process of whistler-mode chorus emissions with rising tones by the large-scale electron hybrid simulation, and the nonlinear wave growth theory has been proposed for the generation mechanism. The simulation results showed that chorus elements with rising tones are successively generated from the magnetic equator. The generated chorus elements propagating away from the equator undergo further nonlinear growth, while the wave frequency of each element is almost constant during its propagation. This result revealed that the frequency variation of chorus elements takes place at the region very close to the magnetic equator.

Based on the theoretical consideration and the analyses of the simulation result, the nonlinear wave growth theory has been proposed for the generation mechanism [*Omura et al.*, 2008]. Based on the proposed theory, Omura et al. derived the expression showing that the frequency sweep-rate of a chorus element is related to the saturation level of the wave amplitude through the linear growth stage due to the instability driven by the anisotropic velocity distribution of energetic electrons in the region close to the magnetic equator. In the present study, we performed simulations so as to discuss the validation of the theory of the chorus generation process.

In the simulation reproducing the chorus generation, we assumed that the initial velocity distribution function of energetic electrons has a loss-cone distribution with a temperature anisotropy. In the early stage of the simulation, a band of whistler-mode waves were generated through the instability driven by the temperature anisotropy. After the saturation of the linear growth, the chorus elements with rising tones were successively generated from the band of the whistler-mode waves. Therefore in the present study, we performed five simulations with different number densities of energetic electrons assuming the same initial velocity distribution function so as to discuss the relation between the sweep-rate of chorus elements and the saturation level of the linear wave growth due to the anisotropic energetic electrons.

We found in the simulation results that chorus emissions with rising tones are clearly generated in each simulation run except for the simulation assuming the lowest number density. In the simulation results, the saturation level of the linear wave growth varied proportional to the assumed number density of energetic electrons. By using the obtained saturation level, we estimated the frequency sweep-rate using the theoretical expression and found that the estimated sweep-rates are consistent with those of chorus elements observed in the simulation results. The result of the present study serves an important clue in understanding the generation mechanism of chorus emissions and validates the proposed nonlinear wave growth theory.