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Generation Mechanism of Plasmaspheric Hiss and Associated Energetic Electron Dynamics

Yoshiharu Omura[1], Satoko Nakamura[1], Mitsuru Hikishima[2], Danny Summers[3], Craig A. Kletzing[4]
[1]RISH, Kyoto University, Japan, , [2] ISAS/JAXA, Japan,
[3] Memorial University of Newfoundland, Canada, [3] University of Iowa, USA

Recent observations of plasmaspheric hiss emissions by the Van Allen Probes show that broadband hiss emissions in the plasmasphere comprise short-time coherent elements with rising and falling tone frequencies [1]. Based on nonlinear wave growth theory of whistler mode chorus emissions, we have examined the applicability of the nonlinear theory to the coherent hiss emissions [2]. We have generalized the derivation of the optimum wave amplitude for triggering rising tone chorus emissions to the cases of both rising and falling tone hiss elements. The amplitude profiles of the hiss emissions are well approximated by the optimum wave amplitudes for triggering rising or falling tones. Through the formation of electron holes for rising tones and electron hills for falling tones, the coherent waves evolve to attain the optimum amplitudes. An electromagnetic particle simulation confirms the nonlinear wave growth mechanism as the initial phase of the hiss generation process. We find very good agreement between the theoretical optimum amplitudes and the observed amplitudes as a function of instantaneous frequency. We calculate nonlinear growth rates at the equator and find that nonlinear growth rates for rising tone emissions are much larger than the linear growth rates. From the phase variation of the waveforms processed by bandpass filters, we calculate the instantaneous frequencies and wave amplitudes. We obtain the theoretical relation between the wave amplitude and frequency sweep rates at the observation point by applying the convective growth rates and dispersion factors to the known relation at the equator [3]. By plotting the theoretical relation over scatterplots of the wave amplitudes and the frequency sweep rates for rising tone elements, we find good agreement between the hiss observations and the nonlinear theory. We also find that the duration periods of the hiss elements are in good agreement with the nonlinear transition time necessary for the formation of a resonant current through coherent nonlinear wave-particle interactions. An electromagnetic particle simulation of hiss wave generation shows rapid pitch angle diffusion of energetic electrons, indicating substantial energy transfer from the electrons to the waves through the nonlinear resonance process.

References

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