Two Dimensional Full-wave Modeling of Propagation of Low-altitude Hiss in the Ionosphere

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Plasmaspheric hiss is generally known as an incoherent broadband structureless electromagnetic whistler mode emission inside the plasmasphere over the frequency range from 200 to 2000Hz, which plays a significant role in the dynamics of the radiation belts. A recent ray tracing simulation study suggests that it is physically possible that a fraction of plasmaspheric hiss can propagate out of the plasmasphere, reach downward to the ionosphere and gradually evolve into low-altitude ionospheric hiss often observed from the DEMETER and Freja satellite. A subsequent conjugate observation on both ionospheric and plasmaspheric hiss waves (350Hz-900Hz) from DEMETER and THEMIS satellite further serves as the evidence to support this mechanism of the generation of ionospheric hiss. However, due to the fact that the Wentzel-Kramers-Brillouin approximation used in ray tracing can fail at the low-altitude ionosphere, it is necessary to perform a full-wave simulation of the low-altitude hiss in the ionosphere to analyze its propagation properties thoroughly.

A full-wave model using dipole coordinate system is utilized in our two dimensional simulation in the meridian plane, where a magnetic dipole field and a diffusive-equilibrium multiple-ions plasma density model including electron, O+, H+ and He+ are adopted. We show that when launched with a moderate initial normal angle and a frequency larger than the local proton gyro-frequency in the upper ionosphere, the wave starts to propagate downward in right-handed mode. When encountering the H+ and He+ crossover frequency, the wave experiences a sudden polarization reversal from right-handed mode to left-handed mode. Near the cutoff frequency, part of the wave reflects upward while the other wave energy continues to propagate further downward across the cutoff frequency in right-handed mode, which indicates a mode conversion. This phenomena is new compared to ray tracing simulation and clearly explains the tunneling of the ionospheric hiss to the region where wave frequency is much lower than the cutoff frequencies in the high latitude ionosphere. The reflected portion propagates upward and slightly equatorward, experiences another reflection at higher altitude due to the strong negative plasma density gradient and turns downwards again. Subsequent tunneling wave tends to be weaker than previously, which explains the observation that the ionospheric hiss energy tends to be above the cutoff frequency in the low latitude ionosphere.