Two-Dimensional Full-Wave Simulation of Whistler Mode Wave Propagation

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Energetic particles in the Earth's radiation belts are a major consequence of space weather events and can be damaging to spacecraft hardware and disrupt communication systems. Very Low Frequency (~1-30 kHz) electromagnetic whistler mode waves have been long known to be a key driver of the removal of these trapped particles, from the magnetosphere. Whistler mode waves in the Earth's magnetosphere have been studied for many decades but key parameters are still not fully understood and new observations often challenge long held assumptions. In the context of radiation belt energy dynamics, the propagation of these waves away from source regions must be modeled in a realistic background medium. Raytracing based on the WKB assumption has been the dominant form of propagation modeling of whistler mode waves and recent work has pushed this technique to its limits in trying to model the effects of small cold plasma density structures [1]. Here we employ a full wave finite difference time domain (FDTD) model that is able to resolve density irregularities smaller than a wavelength [2, 3]. The impact of randomly distributed field-aligned density irregularities on whistler-mode wave propagation is investigated and compared to multi-point spacecraft observations. Whistler mode propagation in the presence of small scale density irregularities is shown to agree with spacecraft observations of wave front distortion and spatial amplitude randomization. The simulation results are in good agreement with the observed correlations of whistler wave power and variation of the plasma density from multi-point observations by the four MMS spacecraft and also earlier observations on the CLUSTER spacecraft [4]. The results challenge the often made assumptions of either a smooth plasmasphere or very large duct structures that extend along the entire field line.

References

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