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Effects of magnetospheric ducts on the propagation and amplitude variation of whistler-mode waves in radiation belts

Miroslav Hanzelka (1,2) and Ondřej Santolík (2,1)

(1) Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic, (2) Department of Space Physics, Institute of Atmospheric Physics, CAS, Prague, Czech Republic

Intense whistler-mode emissions have been shown to play an important role in the radiation belt dynamics. In most simulations and theoretical works, wave vectors parallel to the local magnetic field line are assumed in the equatorial source region, as well as a graduate change of the wave vector direction toward to become highly oblique during the propagation of the waves to higher latitudes. This clearly contradicts experimental results. In this study we analyze properties of field-aligned plasma density increases – magnetospheric ducts – that can be responsible for guiding whistler waves. We determine a lower limit on the relative density increase and the maximum width of the ducts. Most importantly we show that lower-band whistler waves can be ducted by density variations which are below resolution of available spacecraft instruments. Using these weak ducts we conduct a ray tracing analysis and propose the minimum occurrence of ducted propagation which would be necessary to explain experimental observations of low wave normal angles in low- and midlatitudinal range. The effects of Landau and cyclotron damping are discussed. We conclude that about half of the observed lower-band whistler-mode waves in radiation belts must be ducted in order to match the simulation results with spacecraft data.