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FDTD analysis of ELF radio waves propagating in the Earth-ionosphere waveguide

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We developed an FDTD model of electromagnetic wave propagation in the Earth-ionosphere cavity. We present the results of FDTD calculations assuming axisymmetric system with the source located at the north pole and with no dependence on azimuthal coordinate. Therefore we reduced the Maxwell equations to 2D spherical system of Maxwell equations.

To model the conductivity profile of the Earth-ionosphere waveguide we used two models, namely one- and two-exponential profiles [Mushtak and Williams, 2002]. The day-night asymmetry was introduced by setting different model parameters for the north and south hemispheres. The ground was modeled as a perfect electric conductor. Also the upper boundary for the model was a perfect conductor but it was placed at a high enough altitude to make sure there is no reflection of the waves from this boundary.

We obtained the results for the electric and magnetic field components of the propagating wave in the time and frequency domains and for various locations on Earth along the meridian. In the time domain we analyzed the evolution of the electric and magnetic field components of the radio wave generated by lighting for different probe position, the penetration of the ionosphere by the electromagnetic waves and the reflection of the waves on the terminator. In the frequency domain we analyzed the Schumann resonance spectra in different field components for different location in the computational space, the behavior of the Poynting vector and the wave impedance. We also calculated real and imaginary parts of the characteristic electric and magnetic altitudes for the daytime and nighttime ionosphere. The analysis in the frequency domain was performed up to 1 kHz.

We compared the results of numerical calculations with our analytical model and found a reasonably good agreement between them. The results can be used in the analysis of global thunderstorm activity based on measurements of Schumann resonance spectra.

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