Introducing a new method for FDTD modeling of electromagnetic wave propagation in magnetized plasma

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Computational investigations of electromagnetic wave propagation in the upper atmosphere are important for studying space weather hazards, such as geomagnetically induced currents (GICs). GICs are currents generated in gas/oil pipelines, railroads, and electric power networks due to solar storms and the consequent modification of the ionospheric current system. In the upper atmosphere where the collision frequency of the charged particles becomes negligible, the medium is magnetized and anisotropic. The difficulty in modeling wave propagation in magnetized plasma is due to the difficulty in accurately calculating the electric current. The electric current can be found from the momentum equation. However, a fast and efficient method is required to find the electric current perpendicular and parallel to the geomagnetic field.

Finite-difference time-domain (FDTD) computational modeling of wave propagation in anisotropic magnetized plasma is the subject of this presentation. Previous FDTD magnetized plasma modeling methodologies suffer from difficult implementation, high memory requirement, and low computational speed. Thus, it is not possible to model a large altitude range using these formulations. A new method is introduced in this presentation that overcomes all of the previous restrictions. This method is based on the Boris algorithm, an algorithm that is borrowed from particle-in-cell computational modeling. Using this new method, the momentum equation is easily incorporated into the Ampere's law equation. One of the advantages of this new algorithm is that it is possible to use two different time steps for solving the momentum equation and the Maxwell's equation. This is very helpful for simulating altitude ranges where collision frequencies are relatively high. Details of this new method are discussed in this presentation.