A 3-D Stochastic FDTD Model of Electromagnetic Wave Propagation in Magnetized Ionosphere Plasma

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A stochastic finite-difference time-domain (S-FDTD) algorithm is presented for electromagnetic wave propagation in anisotropic magnetized plasma. This new algorithm efficiently calculates in a single simulation not only the mean electromagnetic field values, but also their variance as caused by the variability or uncertainty of the electron and ion content of the ionosphere. The structure of the ionosphere is often too variable and / or uncertain for electromagnetic wave propagation problems to be solved using a deterministic formulation. The ionosphere can depend not only on the altitude, time of day, and season, but also on the latitude, longitude, sun spot cycle, and occurrence of space weather events.

A useful approach to such a complex problem is to consider it as a random medium problem. Numerical electromagnetic techniques, however, typically use only average (mean) values of the constitutive parameters of the materials and then solve for expected (mean) electric and magnetic fields. The Monte Carlo method is a well-established and widely used brute force technique for evaluating random medium problems via multiple realizations. Depending on the nature of the statistical correlation, random medium problems may require tens or hundreds of thousands of realizations. S-FDTD, however, efficiently provides both the mean and variance of electromagnetic fields from a single simulation. S-FDTD has been previously applied to Maxwell's equations. Here, we extend the S-FDTD modeling methodology to ionospheric magnetized plasma, involving Maxwell's equations coupled to current equations derived from the Lorentz equation of motion. This new S-FDTD ionosphere model has wide potential utility. For example, it could be used to determine the confidence level that a communications or remote sensing or radar system will operate as expected under abnormal ionospheric conditions.