Finite-Difference Time-Domain Simulation of Magnetized Cold Plasmas

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Electromagnetic (EM) interactions with cold plasma medium especially the magnetized one (e.g., the Earth's plasmarised ionosphere magnetized by the geomagnetic field), can be found in many geophysical activities. Seeking solutions of these problems often rely on accurate simulations of the complex EM behaviors in plasmas consisting of electrons, positive, and negative ions bearing an externally applied magnetic field with arbitrary direction and magnitude. To numerically simulate such a system utilizing the Finite-Difference Time-Domain (FDTD) method, a proper field arrangement in both space and time domain needs to be pre-defined. Spatially, the electric field E and current density J are usually always positioned at same locations to prevent the generation of spurious electrostatic wave, a purely numerically-originated non-physical wave that can destabilize the code at a later time. Temporally however, the E and J components can be either collocated or non-collocated depending on the specific simulation requirements.

For the E-J full-collocation scheme previously developed in (Y. Yu and J. J. Simpson, *IEEE Trans. Antennas and Propagation*, vol.58, no.2, pp. 469–478, Feb. 2010), the E and J fields are temporally collocated at same time-steps, therefore implicitly interrelated with each other, and thus need to be simultaneously solved through a tightly coupled matrix system resulting in a very time-consuming computational process. However, the most appreciable advantage of this scheme is that its stability condition is independent of medium properties (the maximum stable Courant number is unity just as in free space for unmagnetized cold plasmas, and also empirically valid for a magnetized plasma system). This is a very crucial characteristic when modeling ionospheric plasmas.

For simulations whose performance is not limited by the linkage of time-stepping increment with plasma parameters, the computational complexity can then be substantially reduced by adopting the what-we-called E-J semi-collocation scheme (in comparison with the full-collocation scheme above), in which the E and J fields are still spatially collocated but temporally leapfrogged at an interval of half time-step $\Delta t/2$ (Y. Yu, D. Li, Q. Li, and C. E. Png, *IEEE Trans Plasma Sciences*, submitted). By doing so, the to-be-updated E and J fields are no longer interrelated as in the full-collocation scheme and can therefore be explicitly computed through a much easier implementation process.

In this talk, we will report our works and progress on modeling magnetized cold plasma medium using both our previously developed E-J full-collocation method and the current being-developed semi-collocation scheme. The algorithm derivation and technical details as well as some numerical results are to be covered and discussed during the presentation.