Seminar

Institute for Plasma Research

Title : Fast Solution of Time-Domain Maxwell's Equations Using Large Time Steps

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Venue : Online - Join the talk:
https://meet.ipr.res.in/Dr.NikitaMakwana_PDFTalk

Abstract :

The finite volume time-domain method is recast in a large time step (LTS) form to solve the time-domain Maxwell's equations. The LTS method originally proposed by LeVeque, is an extension of classical Godunov's method for the numerical solution of hyperbolic conservation laws. In this method, very large time steps are allowed by an increase in the numerical domain of dependence compared to conventional explicit time-stepping methods constrained by the Courant-Friedrich-Lewy (CFL) stability criteria. The LTS method was initially proposed for solution of nonlinear hyperbolic conservation laws in the form of the Euler equations of gas dynamics and shallow water equations in fluid mechanics. The method not only reduces the overall computational time but can also increases the accuracy of the numerical solution. LTS method can be a very efficient algorithm to simulate practical electromagnetic scattering problems involving large electrical sizes and re-entrant structures. These problems can be prohibitively expensive for full wave solvers used to solve the Maxwell's equations. The large computational time required for such problems is related to very fine meshes due to stringent point per wavelength requirements leading to small time steps and internal reflections in cavity structures.

Basic LTS framework in a finite volume time-domain context is proposed for the propagation of electromagnetic waves in a homogeneous medium and then extended to multilayered media in one dimension. Complexities arising due to boundary conditions and material interfaces are addressed. The method is extended to formal second-order accuracy for electromagnetic wave propagation in 1D homogeneous medium. Later, the method is extended for solution of 2D time-domain Maxwell's equations using a dimensional splitting approach. Analysis of results both with regards to accuracy and efficiency are presented in 1D and 2D. LTS is shown to be unconditionally stable, unconstrained by limitations dictated by CFL criteria for regular finite volume time-domain methods. However, complexities due to material interfaces and errors introduced by dimensional splitting in multidimensions can impose an upper limit on the usable time step.

Keywords: Finite volume time-domain method, Godunov's algorithm, CFL stability criteria, Electromagnetics scattering, Multilayered media, Dimensional splitting techniques