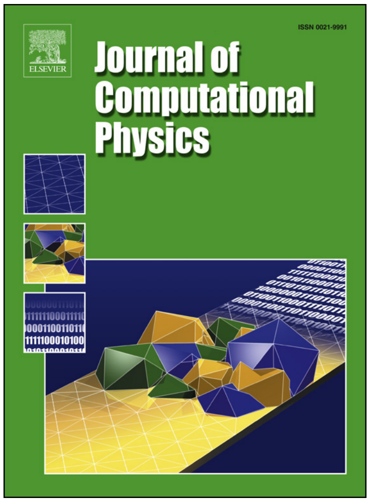

A review of hybrid implicit explicit finite difference time domain method

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A review of hybrid implicit explicit finite difference time domain method

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Abstract:

The finite-difference time-domain (FDTD) method has been extensively used to simulate varieties of electromagnetic interaction problems. However, because of its Courant–Friedrich–Levy (CFL) condition, the maximum time step size of this method is limited by the minimum size of cell used in the computational domain. So the FDTD method is inefficient to simulate the electromagnetic problems which have very fine structures. To deal with this problem, the Hybrid Implicit Explicit (HIE)-FDTD method is developed. The HIE-FDTD method uses the hybrid implicit explicit difference in the direction with fine structures to avoid the confinement of the fine spatial mesh on the time step size. So this method has much higher computational efficiency than the FDTD method, and is extremely useful for the problems which have fine structures in one direction. In this paper, the basic formulations, time stability condition and dispersion error of the HIE-FDTD method are presented. The implementations of several boundary conditions, including the connect boundary, absorbing boundary and periodic boundary are described, then some applications and important developments of this method are provided. The goal of this paper is to provide an historical overview and future prospects of the HIE-FDTD method.

Keywords: FDTD method, HIE-FDTD method, electromagnetic simulation, time stability condition.

1. Introduction

The finite-difference time-domain (FDTD) method [1] has been proven to be a useful tool that provides accurate simulations for varieties of electromagnetic problems. However, as it applies the explicit finite difference scheme, the Courant–Friedrich–Levy (CFL) condition [2] must be satisfied in this method. Therefore, the maximum time step size of this method is limited by the minimum cell size in the computational domain, which results in this method inefficient for the problems where very fine scale dimensions are included.

To overcome the Courant limit on the time step size of the FDTD method, the alternating-direction implicit (ADI)-FDTD method that is unconditionally stable has been developed [3,4]. The time step size of this method is not confined by any spatial cell size, so it's an effective tool for problems where very fine meshes are needed over a large geometric area. However, the ADI-FDTD method exhibits a splitting error proportional to the square of the time step size [5-7], which reduces the accuracy of the ADI-FDTD method severely. Besides, in the ADI-FDTD scheme, three time steps are needed to define the field components and two iterations are required for field advancement. It must solve six tridiagonal matrices and six explicit updates for one full update cycle, which makes the ADI-FDTD method time consuming.

In fact, lots of actual electromagnetic problems only have fine structures in one direction, such as the problems involved in small slots, thin layers, etc. To simulate these problems, it does not need the ADI-FDTD method. The scheme whose time step size is not