

Acceleration of the Hybrid FDTD Algorithm using Signal Processing Techniques

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The hybrid Finite-Difference Time-Domain (hybrid FDTD) technique (K. Sharma, R. Mittra, “A Novel Dipole-Moment Based Hybrid Technique for Numerically Efficient Solution of Multi-Scale Problems,” 2018 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting, Jul. 2018) utilizes time domain numerical convergence as the criterion for termination; therefore, the associated computational cost is high when accurate results are needed for multi-scale problems which involve high Q structures, low frequencies, or dispersive media. In this paper, we propose an efficient hybrid FDTD algorithm, which utilizes signal processing techniques to significantly reduce the computational run time associated with the hybrid FDTD technique, especially for the situations mentioned above.

Time domain numerical convergence has been used as the termination criterion for the hybrid FDTD algorithm. When amplitude of the field is used to check for termination, it is compared against a threshold value that should be attained to obtain results within an acceptable tolerance limit. When the field amplitude reaches the threshold minimum, it is assumed that the system has reached the steady state and therefore, numerical convergence has been achieved. Alternatively, a specified number of time steps has also been used for terminating the hybrid FDTD simulation, wherein the number of time steps specified for truncating the simulation is usually greater than the number of time steps needed when the signal level is used as the termination criterion instead.

The proposed algorithm implements the convergence of the simulation in the frequency domain (K. Panayappan, “Novel Frequency Domain Techniques and Advances in Finite Difference Time Domain (FDTD) Method for Efficient Solution of Multiscale Electromagnetic Problems,” PhD Dissertation, The Pennsylvania State University, May 2013) instead of imposing the termination criterion directly in the time domain. In the first step, we check for the number of zeros obtained for a certain number of recent past samples of the time domain signal. If the number of zeros obtained is insufficient, we compute the discrete Fourier transform (DFT) of these samples. This helps to avoid pre-matured termination for large problems where the value of the time domain signal might become zero only at a particular point inside the computational domain. Then, we check for the amplitude of the DFT values obtained for time domain samples. The proposed efficient hybrid FDTD algorithm is terminated if the amplitude of DFT values is sufficiently low else, it is executed until the difference between the successive DFT values becomes negligible.

A limitation of the hybrid FDTD technique is that while it can generate accurate results for higher frequencies, say above 1 GHz, the technique begins to suffer from accuracy problems when we seek accurate results at lower frequencies, typically below 1 GHz. This is attributable to the fact that the results at low frequencies are corrupted by non-physical numerical artifacts introduced by the exorbitantly large number of time steps required by the hybrid FDTD algorithm for accurate calculation of the results at low frequencies. To mitigate this problem, we first obtain results in the high frequency region, say above a threshold frequency f_L , by using the hybrid FDTD technique, employing the DC gaussian pulse as the excitation source. Next, we use signal processing techniques to extrapolate the results to lower frequencies below the threshold frequency f_L using the results obtained in the high frequency region. A comparison of the numerical results obtained from the proposed efficient hybrid FDTD technique and different commercial electromagnetic solvers will be discussed during the presentation.