TD-AIM-MOD Method for Simulating Large-Scale Electromagnetic Transients

Jian-Yao Zhao*[(1)], Eric Michielssen[(2)], Wei Luo[(3)] and Wen-Yan Yin[(1,3)]
[(1)]Centre for Optical and EM Research (COER), State Key Lab of MOI,
Zhejiang University, Hangzhou 310058, CHINA
[(2)]Department of Electrical Engineering and Computer Science,
University of Michigan, Ann Arbor, MI 48109 USA
[(3)]Key Lab of Ministry of Education of Design and EMC of High-Speed Electronic Systems, Shanghai Jiao Tong University Shanghai 200240, CHINA

Time-domain electric field integral equations (TD-EFIE) are widely used for analyzing transient scattering from perfect electrically conducting surfaces. There exist two widely used schemes for solving these equations: the marching-on-in-time (MOT) and marching-on-in-degree (MOD) methods (Z. Ji, T. K. Sarkar, B. H. Jung, M. Yuan, and M. Salazar-Palma, IEEE Trans. on Antennas Propagat., vol. 54, no. 1, 258-262, Jan. 2006). Both schemes have their strengths and weaknesses. MOT methods are prone to late time instabilities while MOD schemes appear highly stable in the high-order limit. On the other hand, MOT methods apply to nonlinear structures whereas MOD methods do not.

Both MOT and MOD methods suffer from a high computational cost. MOT methods call for a costly space-time convolution of (past) sources and time domain Green's functions. Their computational cost can be reduced by using fast convolution schemes such as the plane wave time domain or time domain adaptive integral method (TD-AIM) (A. E. Yılmaz, J. M. Jin, and E. Michielssen, IEEE Trans. on Antennas Propagat., vol. 52, no. 10, 2692-2708, Oct. 2004). The latter convolves source currents with time domain Green's functions using a 3D spatial FFT and a "blocked" 1D temporal FFT. MOD methods, on the other hand, call for a costly dense (impedance) matrix-vector product. Recently, their computational cost has been lowered by using a blocked 1D FFT for computing all "temporal" (order) convolutions (M. D. Zhu, X. L. Zhou, and W. Y. Yin, IEEE Antennas Wireless Propagat. Lett., vol. 9, 436-439, 2010).

This paper reports on a new hybrid TD-AIM-MOD scheme for analyzing transient scattering from the perfect electrically conducting structures. The scheme reduces the computational complexity of a classically formulated MOD solver from $N_o^2 N_s^2$ to $N_o log^2 N_o \, N_s^{1.5} log^2 N_s$ – here N_o is the maximum order of the Laguerre polynomials used to expand the temporal current signature. Just as in MOT-TD-AIM solvers, the scatterer is embedded in a 3D regular grid and sources are projected onto this grid via moment matching. Next, fields are propagated on this grid by using a 3D spatial FFT and a blocked 1D "temporal" (order) FFT. Finally, fields at observers are obtained by interpolating their values from the regular spatial grid, followed by a near field correction operation. The accuracy and stability characteristics of the TD-AIM-MOD method are demonstrated via its application to large-scale scattering problems