A Symplectic Runge-Kutta Scheme for Spectral-Element Time-Domain Method in Electromagnetic Simulation

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Time-domain simulations of electromagnetic problems have received much attention recently because of the increasing interests in the analysis of transient electromagnetic fields and the broadband characterization of communication and sensing systems. Compared with Finite-Difference Time Domain (FDTD) method, Finite-Element Time-Domain (FETD) method owns more flexibility of modeling arbitrary geometries and materials, but the expensive implementation of calculating the inversion of mass matrix for FETD restricts this method to small and medium-sized problems.

In this paper, based on our earlier Spectral-Element Time-Domain (SETD) method (J. Lee and Q. H. Liu, IEEE MTT., 55, 983-991, 2007), spectral elements based on Gauss-Lobatto-Legendre polynomial are employed for spatial discretization. By using this element, the mass matrix will be diagonal or block-diagonal, which will greatly reduce the computational burden of inversion in the time domain method. Moreover, with a systematic way of constructing vector basis functions for spectral elements on quadrilaterals and hexahedrons, we can easily realize both p- and h-refinement and obtain high-order accuracy in time integration.

After casting the discretized problem into Hamiltonian system by Legendre transformation, we choose symplectic Runge-Kutta method for time integration for the time-dependent system equation. Symplectic method is considered as a 'clean' algorithm and will not introduce artificial dissipation in computation, thus is superior to the conventional non-symplectic method in some aspects like capability of tracking long time evolution. Numerical results of lossless and lossy problems by this symplectic spectral-element time-domain method will be presented, from which the spectral accuracy of SETD and spurious-dissipation-free property of symplectic integration method are clearly observed.