Accelerating Multiscale Finite-Difference Time-Domain Simulations through Model Order Reduction and CFL Limit Extension

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The Finite-Difference Time-Domain (FDTD) method is widely use to solve Maxwell's equations numerically. FDTD has a low computational cost per timestep due to its explicit nature. However, the FDTD timestep cannot exceed the Courant-Friedrichs-Lewy (CFL) stability limit. This condition makes FDTD quite inefficient for multiscale problems, since the presence of small geometrical details imposes a fine grid and, because of the CFL limit, a very small timestep. Since multiscale problems occur frequently in practice, overcoming the CFL limit of FDTD is a major research topic. Examples of multiscale problems are the prediction of electromagnetic compatibility issues in printed circuit boards, and the simulation of electromagnetic propagation in indoor/outdoor environments.

This paper shows how multiscale FDTD simulations can be accelerated beyond the CFL barrier using model order reduction. The complexity arising from the regions with fine details is first significantly lowered using model order reduction. Then, the CFL limit of the obtained models is enlarged via singular values perturbation, in order to run the whole FDTD simulation at a larger timestep.

Numerical tests demonstrate that the proposed method provides substantial speed-ups with respect to existing methods, including standard FDTD, implicit approaches such as the Alternating Implicit Direction method (T. Namiki, *IEEE Trans. Microw. Theory Techn.*,vol. 47, pp. 2003-2007, 1999), subgridding (K. Xiao, D. J. Pommerenke, J. L. Drewniak, *IEEE Trans. Antennas Propagat.*, vol. 55, pp. 1981-1990, 2007), and previously-published techniques combining FDTD and MOR (B. Denecker et al., *IEEE Trans. Antennas Propagat.*, vol. 51, pp. 1806-1817, 2003).