An Improved Fast Algorithm for Transient Simulation of Microwave Circuits with Nonlinear Electronics

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The computational analysis of electromagnetic field coupling into, or radiation from, shielded circuitry calls for an integrated full-wave simulation environment that allows for the simultaneous modeling of slotted enclosures, printed circuit boards, and nonlinear circuitry. Time domain electromagnetic analysis techniques—whether differential- or integral equation-based (e.g. the finite difference/element or marching-on-in-time (MOT) methods)—are prime candidates for driving the basic computational engines of such environments. Indeed, they (i) provide wideband information with a single program run and (ii) can be easily coupled to nonlinear circuit analysis tools.

Previously, we described a fast time domain integral equation solver that used a plane wave time domain-(PWTD) accelerated MOT kernel to model coupling of electromagnetic energy into complex systems comprising conducting surfaces/wires/junctions, potentially inhomogeneous finite dielectrics, and nonlinear loads (K. Aygun, B. Fischer, A. Cangellaris, E. Michielssen, "Fast time domain analysis of nonlinearly loaded printed circuit board structures," National Radio Science Meeting, University of Colorado at Boulder, January 9-12, 2002, Boulder, CO). During each simulation step, this PWTD-augmented MOT solver classically accounts for "near-field interactions". "Far-field interactions", in contrast, are calculated by the PWTD algorithm, viz., by expanding radiated fields into time domain plane waves. Linear/nonlinear lumped circuits in the system are modeled by coupling modified nodal analysis equations to the electromagnetic analysis environment.

Here, further improvements to this solver are presented that aim to increase its efficiency when analyzing realistic geometries that are both electromagnetically large and contain many geometric details. Previously, it was observed that, especially when modeling densely meshed geometries, a significant fraction of the overall CPU time and memory went towards the computation and storage of near-field interactions. The two major improvements to the above referenced solver proposed and described in this presentation are (i) the incorporation of a new prolate-type temporal basis function with superior stability properties compared to polynomial-type basis functions previously used and (ii) a singular value decomposition- (SVD) based compression scheme that significantly reduces the computational time and memory requirements when characterizing near-field interactions. The development and implementation of this SVD-based compression scheme with prolate-type temporal basis functions, all within a PWTD-accelerated MOT framework, constitutes the main contribution of this study. Results that demonstrate the efficiency of the resulting algorithm will be presented.