Fast Integral-Equation-Based Analysis of Transient Scattering from Doubly Periodic Perfectly Conducting Structures

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A fast time domain integral equation (TDIE) based solver pertinent to the analysis of transient scattering from doubly periodic, perfect electrically conducting (PEC) structures, is presented. The proposed solver relies on a fast scheme for evaluating transient electromagnetic fields generated by doubly periodic and temporally bandlimited source distributions that hinges on Floquet decomposition concepts as well as more classical accelerators.

Transient scattering from doubly periodic structures traditionally has been analyzed using finite difference methods. Unfortunately, when the structure under study is obliquely excited, classically constructed finite-difference solvers require future fields values, i.e., noncausal data, to update current ones, and therefore cannot be applied. Most fixes to this problem are either hard to implement or limited in scope. A recently developed TDIE-based solver resolved the issue of noncausality through the introduction of time-shifted temporal basis functions and a prolate-like extrapolation scheme for bandlimited signals [N.-W. Chen, B. Shanker and E. Michielssen, *IEE Proceeding-Microwaves Antennas & Propagation.*, 2002, in press]. Unfortunately, this solver is computational expensive in the sense that its computational cost scales as $O(N_s^2 N_t^2)$, where N_s and N_t denote the number of spatial basis functions describing the currents on PEC elements in the mothercell—viz. where the integral equation is being enforced—and the number of time steps in the analysis, respectively. This scaling law precludes the application of this solver to the analysis of complicated structures.

The computational cost of this solver can be attributed largely to its need to evaluate the scattered field, viz. the field radiated by the currents on the periodic structure, for every time step. The proposed fast TDIE-based solver reduces this cost by expressing the scattered field in terms of time domain Floquet waves. Only a small number of Floquet waves suffices to represent the field provided that it is generated by quiescent bandlimited sources. The Floquet waves therefore cannot account for fields produced by sources in the immediate vicinity of the mothercell. As a result, fields in the mothercell are split into two components. First, there are the fields associated with sources in cells in its immediate vicinity: they are evaluated classically, using a low-frequency plane wave time domain algorithm [K. Aygün et al., *Proc. Int. Conf. in Electromagnetics in Advanced Applications,*769-782*,* 2002], or by a time domain AIM scheme [A. Yilmaz et al., *IEEE APS Symp. Dig.*, 166-169, 2002]. Second, there are the fields produced by sources that do not reside in the immediate vicinity of the mothercell: they are evaluated using the aforementioned Floquet expansion. By doing so, the computational complexity of the scheme scales as $O(N_{\text{mode}} N_s N_t \log^2 N_t)$ where N_{mode} denotes the number of modes used in the Floquet expansion. Numerical results that demonstrate the efficiency and accuracy of the proposed scheme will be presented.