A Parallel Time-Domain Adaptive Integral Method-Accelerated Single-Boundary Finite Element-Boundary Integral Solver

Ali E. Yılmaz[(1)]*, Zheng Lou[(1)], Eric Michielssen[(2)], and Jian-Ming Jin[(1)]
[1]Center for Computational Electromagnetics and Electromagnetics Laboratory
Department of Electrical and Computer Engineering
University of Illinois at Urbana-Champaign, Urbana, IL 61801, USA
[2]Radiation Laboratory
Department of Electrical Engineering and Computer Science
University of Michigan, Ann Arbor, MI 48109, USA

The finite element-boundary integral (FE-BI) method is a popular technique for analyzing scattering and radiation from complex inhomogeneous structures residing in unbounded regions. The standard FE-BI method embeds the structure of interest in a mathematical (boundary) surface that divides the problem space into an interior and an exterior domain throughout which fields are modeled by finite elements and boundary integrals, respectively. The FE-BI method's appeal can be attributed to its uncompromised accuracy, efficiency, and modeling flexibility, which it derives from advances in both pure finite element and integral equation methods. Over the last decade, for example, FE-BI solvers have benefited directly from the development of edge-based higher-order finite element and fast integral equation algorithms [Jin, J., The Finite Element Method in Electromagnetics, New York: Wiley, 2002]. While FE-BI solvers can be formulated in both the time and frequency domains, frequency-domain formulations are far more commonplace; this is in part because of the historical lag in the development of accurate, stable, and efficient time-domain integral equation kernels.

This paper describes a new time-domain FE-BI solver with three notable improvements over its direct predecessor [Jiao, D. et al., IEEE Trans. Antennas Propagat., vol. 50, no. 9, 1192-1202, 2002]. (i) The FE and BI solver components are hybridized using a single surface that potentially coincides with the analyzed structure's surface. The single surface interface minimizes the extent of the computational domain and greatly facilitates the modeling of flush-mounted structures such as aperture and conformal antennas. In this work, a combined-field integral equation and a dual-field formulation based hybridization approach are considered; these constitute time-domain extensions of recently introduced frequency-domain approaches that avoid internal resonances [Sheng, X.-Q. et al., IEEE Trans. Antennas Propagat., vol. 46, no. 3, 303-311, 1998], [Botha, M. M. and Jin, J.-M., IEEE Trans. Antennas Propagat. vol. 52, no. 11, 3037-3047, 2004]. (ii) The BI solver component is accelerated by the time-domain adaptive integral method as opposed to the plane wave time domain method, thereby further accelerating the scheme when applied to quasi-planar boundaries [Yılmaz, A. E. et al., IEEE Trans. Antennas Propagat., vol. 52, no. 10, 2692-2708, 2004]. (iii) The solver is parallelized by distributing the FE and BI operations among different groups of processors that communicate using the message-passing interface. The performance of the proposed parallel time-domain adaptive integral method accelerated, single-boundary FE-BI solver for open-region scattering and radiation problems will be studied and demonstrated through a number of examples.