A Direct Domain Decomposition Method (D^3M) for Finite Element Electromagnetic Computations

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Cutting edge research in computational electromagnetics (CEM) has shifted from fast iterative integral equation (IE) solvers, such as the multilevel fast multipole method (MLFMM) (W. C. Chew, J.-M. Jin, E. Michielssen, and J. Song, Artech House, 2001) to direct IE solvers (H. Guo, J. Hu, and E. Michielssen, IEEE Antenna Wireless Propag. Lett., 12, 31-34, 2013), and from fast uni-processor differential equation (DE) algorithms such as multigrid (MG) methods (Y. Zhu and A. C. Cangellaris, IEEE Press, 2006) to parallel iterative solvers such as domain decomposition methods (DDMs) (G. N. Paraschos, PhD thesis, University of Massachusetts Amherst, 2012).

These research trends have created a unique research opportunity in the area of *fast and parallel direct solvers for DE methods*. To this end, Liu et al. have recently proposed several straightforward combinations of methods from the above-mentioned research trends (H. Liu and D. Jiao, IEEE Trans. Micro. Theory Tech., 58, 3697-3709, 2010), but limited success is achieved. In the authors' point of view, a successful fast direct method for FEM must fully exploit the *underlying physics* of the CEM problem in every step of the modeling/computation process, starting from the boundary value problem (BVP) casting, not only by using "black-box" acceleration methods in the solution stage of FEM matrix.

In contrast to all iterative DDMs that try to improve conditioning via transmission conditions, the proposed direct DDM (D^3M) will re-cast the decomposed BVP in a symmetric and interior resonant-free manner. To this end, specific "auxiliary" variables would be used to cast the direct solver problem. To attain maximal parallel performance, the auxiliary problem fully leverages blocked-matrix versions of multi-frontal solvers. Results on scattering and radiation problems with multiple excitations will be presented. The method will be benchmarked on various 3D problems that involve 1D, 2D and 3D decomposition topologies.