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A non-conformal multi-resolution preconditioner in the MoM solution of large multi-scale structures

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The extension of the surface integral equations (SIEs) [1] to non-conforming meshes has ignited intense research in the last years with the goal of finding a versatile and accurate method to address large and multi-scale complex problems, greatly simplifying computer-aided-design (CAD) generation and meshing processes.

Discontinuous Galerkin (DG) implementations of the SIEs [2] are the most popular approach to deal with this kind of problems. Other SIE non-conforming schemes alternative to DG are the monopolar-RWG [3] and the very recently presented Multibranch Rao-Wilton-Glisson (MB-RWG) [4]. The MB-RWG basis functions can be easily integrated into existing MoM codes without need of penalty terms, additional volumetric integrals or artificial surfaces. They are very convenient for h-refinement techniques and are div-conforming basis functions, allowing the construction of a solenoidal basis as linear combination of them [5].

SIE methods also have some inconveniences. They suffer from the ill-conditioning of MoM applied to realistic high-fidelity models that include multi-scale features. The physics-based preconditioners take advantage of the physical properties of the problem to improve the convergence in an iterative solver scheme. An example of dense-discretization stable physics-based preconditioner is the multiresolution preconditioner (MR) [6].

The MR preconditioner introduces a set of multi-level basis functions able to keep the different scales of variation of the solution, improving then the matrix conditioning in particular in the case of multi-scale structures [7]. This set of functions improves the spectral properties of the original MoM matrix system with an automatic quasi-Helmholtz decomposition by splitting the current into solenoidal and non-solenoidal parts.

In this work we present a multiresolution preconditioner realized with multibranch RWG functions for computing the electromagnetic solution of complex multi-scale problems discretized with non-conformal meshes, providing a method to automatically construct all solenoidal and non-solenoidal functions, including the topological (global) solenoidal ones. The proposed approach fully generalized the MR basis generation to non-conforming meshes without the need of any specific treatment of the mesh cells related to non-conforming triangles. Moreover, the obtained MR-MB preconditioner is a multiplicative preconditioner that can be easily inserted in any fast MoM code. Numerical experiments will be shown to illustrate the great flexibility of this approach for the solution of small-frequency and large multi-scale objects with non-conformal meshes.

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