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.

1. R.F. Harrington, “Field Computation by Moment Method”. NJ, USA: IEEE Press, 1993.

2. Z. Peng, K. H. Lim, and J. F. Lee, “A discontinuous galerkin surface integral equation method for electromagnetic wave scattering from non-penetrable targets”, IEEE TAP, vol. 61, no. 7, pp. 3617-3628, 2013.

3. E. Ubeda and J. M. Rius, “Novel monopolar MFIE MoM-discretization for the scattering analysis of small objects,” IEEE TAP, vol. 54, no. 1, pp. 50–57, 2006.

4. S. Huang, G. Xiao, Y. Hu, R. Liu, and J. Mao, “Multibranch rao–wilton–glisson basis functions for electromagnetic scattering problems,” IEEE TAP, vol. 69, no. 10, pp. 6624–6634, 2021.

5. S. Huang, G. Xiao, Y. Hu, R. Liu and J. Mao, "Loop-Star Functions Including Multibranch Raw-Wilton-Glisson Basis Functions," in IEEE TAP.

6. F. P. Andriulli, F. Vipiana, and G. Vecchi, “Hierarchical bases for nonhierarchic 3-d triangular meshes,” IEEE TAP, vol. 56, no. 8, pp. 2288–2297, 2008.

7. F. Vipiana, M. A. Francavilla, and G. Vecchi, “EFIE modeling of highdefinition multiscale structures,” IEEE TAP, vol. 58, pp. 2362–2374, jul 2010.