Null-Field Generation Method Applied to Double-Higher-Order Method of Moments Solver

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The method of moments (MoM) is inherently inefficient in solutions of large problems due to the necessity of generating, storing, and solving a large non-sparse system matrix. This paper presents the application of the null-field generation method (NFGM) (T. N. Killian, S. M. Rao, and M. E. Baginski, "Electromagnetic Scattering From Electrically Large Arbitrarily-Shaped Conductors Using the Method of Moments and a New Null-Field Generation Technique," IEEE Transactions on Antennas and Propagation, vol. 59, February 2011, pp. 537-545) to the double-higher-order (DHO) MoM (M. Djordjevic and B. M. Notaros, "Double Higher Order Method of Moments for Surface Integral Equation Modeling of Metallic and Dielectric Antennas and Scatterers," IEEE Transactions on Antennas and Propagation, vol. 52, August 2004, pp. 2118-2129) to introduce sparsity in an otherwise full system matrix.

In the NFGM, the structure is first geometrically preprocessed by dividing the structure into disjoint sub-structures, or groups, that are about 1 wavelength in size. In this paper, we apply a specially developed distance sorting technique by which geometrical grouping of the DHO quadrilateral patches in the object mesh based on their spatial locality ensures data locality in the dense system matrix (A. B. Manic, F.-H. Rouet, X. S. Li, and B. M. Notaros, "Efficient EM Scattering Analysis Based on MoM, HSS Direct Solver, and RRQR Decomposition," Proceedings of 2015 IEEE International Symposium on Antennas and Propagation, July 19-25, 2015, Vancouver, BC, Canada, pp. 1660–1661). Therefore, the outcome of the geometrical preprocessor is that MoM unknowns belonging to the same mesh group, besides its spatial locality, exhibit the data locality in the matrix system of equations.

After the full system matrix is generated using the DHO-MoM, the matrix is partitioned into blocks corresponding to the aforementioned groups. We focus here on mutual interactions between any mesh group and all the elements surrounding it (the so-called near-field blocks). The NFGM replaces the original set of basis functions defined on a mesh group by new basis functions obtained as a linear combination of the original functions such that they create null-fields everywhere around the mesh group within a certain radius. In our DHO-MoM-NFGM algorithm, the radius is adopted to be about two to three wavelengths. Thus, the dominant near-field interactions between each mesh group and the neighboring elements are effectively eliminated. This leaves only the diagonal blocks, representing the strong interactions within a group, and the weak far-field interactions. As the system matrix is now sparse and block-diagonally dominant, it can be solved with much more ease than the full system matrix by using an iterative method.

Because the process of generating the coefficients for the basis transformation only depends on a certain block and its neighbors, this method can very easily be applied in a parallel scheme. Furthermore, the DHO-MoM-NFGM technique has been shown to have very good agreement with the direct DHO-MoM solution, as well as analytical and other numerical solutions.