Broadband Implementation of MLFMA Using Approximate Scaled Diagonalization of the Green's Function

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It is well known that the conventional diagonalization used in the multilevel fast multipole algorithm (MLFMA) suffers from low-frequency breakdowns, which limit the application of this powerful method to multiscale problems involving large objects with small (but important) details in terms of wavelength. Using multipoles explicitly or resorting to alternative expansions incorporating evanescent waves for subwavelength interactions are common techniques for broadband implementations of MLFMA, while all these techniques need extensive efforts and re-programming. Recently, we presented an approximate diagonalization of the three-dimensional Green's function using scaled Hankel functions and plane waves (Ö. Ergül and B. Karaosmanoğlu, *IEEE Antennas Wireless Propag. Lett.*, **13**, 2014, pp. 1054-1056). While its accuracy is limited (e.g., 3-4% in the worst case for the challenging one-box-buffer scheme), the approximate diagonalization provides stable computations of interactions at arbitrarily short distances. As a major advantage, the approximate diagonalization needs only minor modifications in the existing codes, including the parallel programs, to stabilize the conventional implementations for low frequencies.

In this work, we show that the approximate scaled diagonalization of the Green's function can further be used to convert conventional codes of MLFMA to broadband implementations. Using optimal scaling factors depending on the box size, interactions can be performed in a multilevel scheme, leading to linearithmic time and memory complexities. As depicted in the figure below, the developed implementation provides fast and efficient analysis of electrically large objects involving small details and dense discretizations. In this example, 5x20x20 grid of metallic particles (with loxodrome shapes) is illuminated by a plane wave at 3 GHz. The overall size of the metamaterial structure is approximately 0.5x2x2λ, where λ is the wavelength in the host medium. For accurate modeling of the particles, λ/500 triangles are used. The problem is formulated with the magnetic field integral equation and discretized with the Rao-Wilton-Glisson functions, leading to matrix equations involving 5,856,000 unknowns. Broadband MLFMA with 8 active levels is used to solve the scattering problem and to obtain the far-zone electric field on the z-x plane with respect to the bistatic angle θ. It can be observed that both θ and ϕ polarizations of the scattered field are significant due to the exotic characteristics of the metamaterial.