Vectorial Low-Frequency MLFMA for Fast Error-Controllable Low-Frequency-Stable Evaluation of Electric and Magnetic Field Integral Operators

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In various applications solution of large scale scattering problems is required in a broad range of frequencies. The Method of Moments (MoM) solution of such problems can be obtained with aid of Multilevel Fast Multipole Algorithm (MLFMA). The MLFMA however breaks down at low frequencies when Rokhlin's plane wave translators are utilized for the field representation (Coifman, et.al., IEEE AP Mag., pp. 7-12, 1993). In this work instead of utilizing the plane wave expansions we expand the field over scalar spherical harmonics. Such expansions are known to be stable at both low and high frequencies. The novel aspect of this work is in treatment of vectorial fields in conjunction with MLFMA based on the scalar spherical harmonic expansions (Aronsson, et. al., IEEE AWPL, pp. 532-535, 2011). The method is simpler in formulation and in use compared to the approach of utilizing spherical vector wave functions for E- and H-field expansions. In this work we demonstrate how the first and second order derivatives arising in the Combined Field Integral Equation (CFIE) from the grad-div- and curl-operators can be treated when scalar spherical harmonic expansions for the magnetic vector potential components are available. The discussed scheme for MLFMA acceleration of CFIE solution is shown to provided error controllable approximation of both electric and magnetic fields in CFIE, broadband stability of the vectorial field expansions, and O(N log N) computational complexity for problems spanning up to 110 wavelengths in size. The resultant MLFMA is shown to consume half the memory compared to alternative low-frequency stable formulations. The method is applicable to rapid application of both surface and volume integral operators arising in classical integral equations of electromagnetics.
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