Low-Frequency Electromagnetic Simulation of Targets in Layered Media by a Hybrid Solver Based on Finite Element Method and Current and Charge Integral Equation

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Due to the limitation of any single methodology, simulating the electromagnetic scattering of complex or large targets often resort to hybrid methods. As a popular hybrid method, the hybrid finite element (FEM) and surface integral equation (SIE) method, which is also referred to as the finite element boundary integral (FEBI) method, has been extensively studied over the past decades. However, due to the low-frequency breakdown of the traditional SIE, the hybrid FEM-SIE method does not work at low frequencies. For example, in our numerical simulations, solution accuracy will be contaminated substantially when the frequency is lower than 2 MHz. In this work, the traditional SIE is replaced by the current and charge integral equation, which had been proposed to overcome the low-frequency breakdown about a decade ago. Thus, the resultant FEM-CCIE will work at both high and low frequencies like FEM.

In addition to the above extension, the FEM-CCIE is further improved in two important aspects: 1) FEM-CCIE is implemented in the framework of the domain decomposition method (DDM) so that large or complex targets can be simulated more efficiently; and 2) CCIE is extended to the layered medium scenario so that the hybrid solver can be applied to more practical applications, e.g., geophysical exploration. The resultant hybrid solver may be referred to as LM-DDM-FEM-CCIE or LM-DDM.

In comparison with the pure FEM method, LM−DDM employs CCIE as the exact boundary condition, and thus is immune to the possible instability of perfectly matched layer (PML) or the difficulty of truncating solution domain under some low-frequency, lossy-medium cases. In contrast to the pure SIE method, the inhomogeneity can be well handled by the FEM.

Low-frequency scattering of targets in a layered medium is simulated by the proposed LM-DDM-FEM-SIE solver, and numerical results are compared with the reference results to demonstrate its accuracy and efficiency.