The BCGS-FFT Method for 3-D Objects in Subsurface Layered Media

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Scattering of electromagnetic waves by penetrable, inhomogeneous objects of arbitrary shape embedded in a planarly layered background is an important research area in subsurface sensing. In particular, such near-surface applications are common to geophysical exploration, environmental characterization, and detection and identification of landmines, unexploded ordnance and underground structures. Simulation of an arbitrary object in such a layered medium is a challenging task because of the complex background and the large number of unknowns associated with realistic targets.

In this work we focus on subsurface sensing of inhomogeneous objects buried in a layered medium. Since the scattering object has an arbitrary inhomogeneity, volume integral equation methods are more suitable (the surface integral equation methods which are amenable to the fast multipole acceleration are in general more appropriate for homogeneous or perfectly conducting objects). Unfortunately, until very recently there has been little progress in the development of fast algorithms for such complicated environment. Most previous efforts have focused on the method of moment (MoM), which requires $O(N^2)$ computer memory, and $O(N^3)$ (direct inversion) or $O(N^2)$ (iterative inversion) CPU time, where N is the number of unknowns.

To solve the volume electric field integral equation for electromagnetic scattering from inhomogeneous objects in a layered medium, we have recently developed the stabilized biconjugate-gradient (Bi-CGSTAB) iterative solver combined with the fast Fourier transform (FFT) (Xu and Liu, *IEEE Antennas Wireless Propagat. Lett.*, vol. 1, pp. 77–80, 2002). This technique is thus called the BCGS-FFT method; it can solve the volume integral equation in the layered medium with $O(N \log N)$ CPU time and $O(N)$ computer memory. We have demonstrated that the BCGS-FFT method is much more efficiently than the CG- and BCG-FFT methods in a homogeneous background. In this presentation, the main theory of the BCGS-FFT method will be summarized and its applications in subsurface measurements of electromagnetic scattering from inhomogeneous objects in planarly layered media will be illustrated.