Accurate Simulation of Electromagnetic Waves Scattered by 3D Objects in a Multilayered Medium by a Surface Integral Equation Method

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The simulation and analysis of electromagnetic scattering by metallic and dielectric objects of arbitrary shape in the presence of a layered medium is a subject of practical interest in subsurface sensing. There exist two classes of basic solvers: differential equation solvers and integral equation solvers, that can be chosen for this purpose. However, the differential equation solvers, such as FEM and FDTD, are not so effective because they require the discretization of the entire computational domain including the layers. The integral equation solvers that involve smaller number of unknowns are preferable for this case. Previously, we developed a BCGS-FFT technique for simulations of the scattering by 3-D dielectric scatterers in a layered medium. The basic idea of the BCGS-FFT is to use the stabilized biconjugate gradient method combined with fast Fourier transform to speed up the iterative solution of a volume integral equation. This method is capable of solving large-scale electromagnetic scattering problems with arbitrary inhomogeneous objects embedded in a multilayered medium. However, at present, the object has to locate completely within a single layer, and there are stair-casing errors associated with discretization in the BCGS-FFT method.

In this work we investigate a surface integral equation technique to simulate the radiation and scattering by metallic and dielectric objects of arbitrary shape in the presence of layered media. We focus on the cases where scatterers straddle different layers in the multilayered medium. The alternative form of the mixed-potential integral formulation and multilayered-medium Green's function representation is utilized, with the singularity subtraction technique (Simsek et al., IEEE T-MTT, vol. 54, no. 1, pp. 216-225, Jan. 2006) to accelerate the Sommerfeld integrals. As a result of this succinct expression, the Green's function can be calculated efficiently.

Several numerical examples will be presented to verify the layered-medium surface integral equation solver, including cuboid, cylindric and spherical dielectric scatterers, as well as phantoms used in microwave biomedical imaging applications. The results of scattered field from these targets embedded in layered media are compared with those from independent BCGS-FFT and FDTD method to show the accuracy improvement.