Three-dimensional Cross-hole EM Modeling using the Extended Born Approximation

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Abstract: This paper presents an efficient three-dimensional (3-D) modeling algorithm was developed using the extended approximation to an electric field integral equation. Numerical evaluations of Greens tensor integral are performed in the spatial wavenumber domain. This approach makes it possible to reduce computing time, to handle smoothly varying conductivity model and to remove singularity problems encountered in the integration of Greens tensor at a source point. The 3-D modeling algorithm developed in this study is compared with the full integral equation for a thin-sheet EM scattering. The extensive analyses on the performance of modeling algorithm are made with the conductivity contrasts and source frequencies. These results show that the modeling algorithm are accurate for the conductivity contrast of 1:16 and the frequency range of 100 Hz-100 kHz. The extended Born approximation, however, may produce inaccurate results for some source and model configurations in which the electric field is discontinuous across the conductivity boundary. We performed the modeling of a composite model of which conductivity varies continuously and this shows the modeling algorithm developed in this study is efficient for 3-D EM modeling. For a cross-hole source-receiver configuration a composite model of which conductivity varies continuously can be successfully simulated using this algorithm.

Keyword: 3-D modeling, integral equation, Greens tensor, spatial wavenumber, extended Born approximation

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Fig. 1 Modeling of a vertical fracture using extended Born approximation to integral equation. The sources and receivers are moving parallel down two boreholes. Horizontal and vertical secondary magnetic fields $H_z$ due to HMD sources are shown in (b), (c) and corresponding components due to VMD sources in (d), (e), respectively.
Fig. 2 Composite model which consists of two conductors of conductivity 0.5 and 1.0 S/m, respectively. The conductivity of background medium is 0.1 S/m. Conductivity varies smoothly across the boundary in the form of a sine function. The conductivity profile along x-axis (a) and y-axis (b) are also shown. The real (c) and imaginary (d) component of secondary vertical magnetic field \( H_z \) obtained from the extended Born approximation of EFIE are shown, respectively.