Full 3D Modeling of LWD Resistivity Tools

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Accurate EM modeling of Logging-while-drilling (LWD) resistivity tool responses is key in the interpretation process. Existing modeling codes typically use point magnetic dipole approximation. However, if the inhomogeneities are close to the tool and comparable to the tool size it may be necessary to include the tool details in the model.

In the past decade significant progress has been made in solving tool responses in complex 3D environment using the point dipole model approximation. Most commonly used software is based on finite-difference approximation, optimal gridding and efficient material averaging schemes. Although there is a need for more efficient modeling at propagation tool frequencies (400 kHz and 2 MHz), that is considered to be mature technology, and such codes are highly efficient and often are even run in the inversion loop.

For proper characterization of "near effects" such as borehole effect it is necessary to include the tool details in the model. Very often that becomes a challenging modeling problem, primarily because of the problem scales, conductivity contrast up to 10^5 and necessity to handle tool details of order of mm, as well as formation features. The goal is to compute induced voltages at receivers accurate within a fraction of a percent. The difficulties are following: (1) generating and discretizing the 3D tool/formation model, (2) solving the resulting, usually ill-posed, system of equations, which typically has millions of unknowns, (3) evaluating the accuracy of results, and (4) refining the problem if necessary in order to get the required accuracy.

Two approaches for efficiently solving 3D LWD tool responses are presented. Finite-difference technique is developed in cylindrical coordinate system, using Spectral Lancosz Decomposition method (SLDM) and material averaging scheme. The program allows computation of multiple frequency responses in one step. Material averaging is an effective way of reducing the size of the problem and it may be used in non-metallic domain.

The second approach is based on finite element method (FEM). The program uses multi-grid preconditioning and algebraic multigrid (AMG) solver, combines prismatic and tetrahedral elements, taking special care of anisotropic meshes. The unique feature of the program is dual (goal-driven) adaptive technique, where mesh adaption process is guided in order to get the most accurate solution in the most important part of the domain.

Modeling results are presented for three cases: (1) borehole eccentering responses; (2) responses of the tool to the boundary with the presence of the borehole, and (3) how the presence of nearby metallic objects affect the air-cal. All responses are computed for an array resistivity tool operating at 2 MHz, having transmitter-receiver spacing up to 43".