Numerical Evaluation of the Drill Collar, Borehole, and Invasion Effects on MWD Tools for Oil and Gas Exploration

Y.-K. Hue[1*], B. Donderici[1], F. L. Teixeira[1], L. San Martin[2], and M. Bittar[2]

[1]ElectroScience Laboratory and Department of Electrical Engineering,
The Ohio State University, Columbus OH 43212

[2]Halliburton Energy Services, Houston TX 77032

The neglect of the effect of the drill collar, antenna geometry, borehole and invasion in the modeling of wave propagation measurement-while-drilling (MWD) tools for oil and gas exploration in dipping and horizontal wells has been motivated, in addition to the inherent technical difficulty, by the realization that in oil-based mud these effects are known to be very small. However in conductive mud, the combined effect of the metal collar, antenna geometry, the borehole fluid and invasion on the measurement can become significant. The 1-D approximation is no longer acceptable in this situation.

A systematic study in horizontal wells of these effects is presented. This study is carried out with a 3-D PDE-based code in cylindrical coordinates that is tested by comparison with analytic and semi-analytic solvers. This 3-D EM solver is matrix-free and has a low, *O(N)* computational complexity (where *N* is the number of unknowns) both in terms of CPU time and memory requirements. The 3-D cylindrical grid is made quite compact around the tool by implementing a PML absorbing boundary condition directly in cylindrical coordinates. The new 3-D code incorporates the effect of the metal collar and the exact antenna geometry. This code has enabled us, for the first time, to evaluate systematically the combined effect of the drill collar, antenna geometry, borehole conductivity and invasion on the measurement in horizontal well environments.

We first evaluate the results in oil-based mud and compared the results against 1-D code results. Next, we evaluate a vertical well case and compared the results with a 2-D semi-analytic code. These two cases serve to establish the accuracy of the new approach. We then study the effect of mud conductivity and tool standoff on the MWD measurements in a horizontal well. After that, the effect of invasion is included. Symmetrical and non-symmetrical circular and elliptic invasion, in horizontal wells, are evaluated.