Fast Simulation of Measurement-While-Drilling Electromagnetic Telemetry Using Thin Wire Kernel and Layered Medium Green's Function

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In oil and gas industry, with horizontal and directional drilling increasing in number, measurement-while-drilling (MWD) which incorporates the measurement tools into the drillstring, can provide real-time data to help geosteering and save time. In standard practices, mud pulse and electromagnetic (EM) telemetry systems are usually employed to transmit real-time data from downhole tools to surface. Compared to mud pulse telemetry, EM telemetry does not require a continuous mud column in the borehole, and will not interrupt drilling process, thus is more effective under certain circumstances.

Many numerical methods has been applied to simulate the EM telemetry system, such as Finite Element Method (FEM), Integral Equation Method and Method of Moment (MoM), Numerical Mode Matching (NMM). However, most of the methods are limited to vertical wells in layered medium, in which EM simulations can be simplified as two-dimensional axisymmetric problems. When directional drilling is considered, modeling EM telemetry becomes fully three dimensional, and much greater computational costs will be incurred using any of the aforementioned numerical techniques.

Here, we will employ the thin wire kernel (D. R. Wilton and Nathan J. Champagne, IEEE Antennas Propagat. Mag, 54, 1200-1206, 2006) to model the drill stem whose surface is assumed as perfect electric conductor (PEC), and mixed potential layered medium Green's function (MP-LMGF) to get electrical field integral equation (EFIE). Direct term and reflection terms which are highly singular are extracted from MP-LMGF to remove the singularity of LMGF when source and observation points are in the same layer. The thin wire kernel can then exactly evaluate the removed singularity terms. The remaining term of LMGF decays exponentially and can be recognized as constant along the azimuthal direction of drill stem. With these procedures, the whole problem can be reduced to a 1D integral equation even when the drill stem is deviated underground. Thus, CPU time and memory cost will be greatly reduced. The application of thin wire kernel and LMGF is very efficient in modeling an EM telemetry system with a long drill stem inserted in large scale layer media. The fast simulation of EM telemetry can help to make real-time decision in drilling procedure.