An Efficient Finite Element Scheme for Simulating Subsurface Wireless Telemetry in Well Logging Applications

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Wireless data transmission is an essential part of measurement-while-drilling (MWD) or logging-while-drilling (LWD) in the oilfield well logging industry. It can be achieved by several different technologies including electromagnetic (EM) telemetry, which is based on the propagation of electromagnetic waves between a bottom hole assembly (BHA) and a surface antenna. EM telemetry has been proven to have better reliability and relatively faster data transmission rates compared with other telemetry techniques; however, EM telemetry may suffer severe signal attenuation when conductive formation layers exist between BHA and surface. Accurate and efficient modeling of the EM telemetry system will greatly facilitate make the decision of whether or not to use this technique for a specific oilfield job.

Modeling EM telemetry often means simulations of electromagnetic propagation in layered structures. The underground formation is usually in a layered form. Within each layer the distribution of structure and material can be arbitrary on the cross section near a drilling well because of the existence of drilling pipe, borehole, well casing, and different extents of drilling mud invasion. Full wave simulation techniques such as the conventional finite element method can be used to solve this complicated layered problem, but the efficiency is relatively low.

Here we will employ an efficient layered finite element scheme we have recently developed (J. Chen, Microw. Opt. Techn. Let., 57, 15-18, 2015) to simulate the propagation of electromagnetic wave in layered media, and apply it to understand the behaviors of EM telemetry system. A layered structure is divided into several subdomains homogeneous along one specific direction. The cross section of each layer is discretized by finite elements, and the longitudinal direction is handled by a Riccati equation based integration scheme with a very high precision (W. Zhong, and J. Zhu, J. Num. Meth Comp. Appl., 17, 26-35, 1996). The combination of finite elements for arbitrary cross sections and the high precision integration for the homogeneous longitudinal direction is very efficient in modeling subsurface EM telemetry in well logging applications.