A FULLY POLARIMETRIC BOREHOLE RADAR BASED NUMERICAL MODELING: FULLY POLARIMETRIC RESPONSE TO SYNTHETIC NATURAL FRACTURES AND "FLUID SUBSTITUTION"

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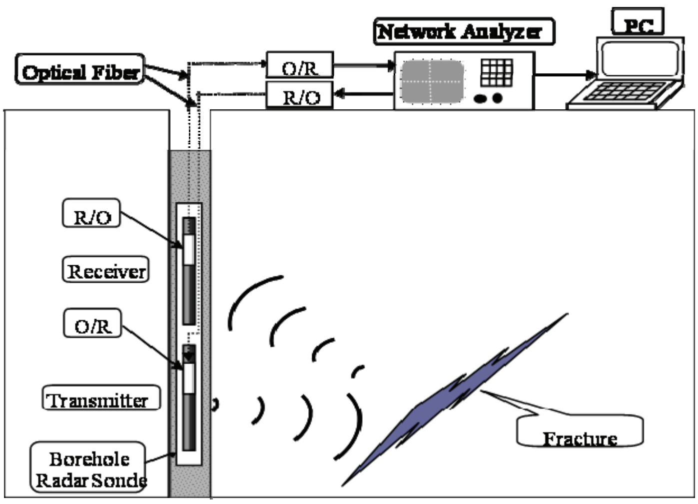
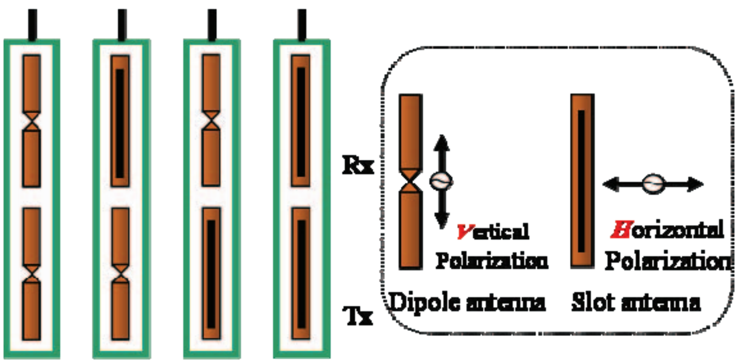
A fully polarimetric borehole radar system with four combinations of dipole and cylindrical slot antennas, as shown in Fig. 1, was developed to acquire fully polarimetric data sets in drilled boreholes [1]. The system in conjunction with a methodology of radar polarimetry analysis, proposed in previous



(a) Measurement configuration



(b) Antenna arrangements for polarimetric data collection

Fig. 1. Fully Polarimetric Borehole Radar System: (a) Measurement configuration, and (b) Antenna arrangements for polarimetric data collection.

research [2], has proved to be a potential tool for physical characterization and classification of subsurface fractures. Also, several different polarimetry techniques including Pauli decomposition, eigenvector-based decomposition, Durden-Freeman decomposition and polarmetric anisotropy parameters methods are implemented to analyze fracture characterization and classification, and we demonstrated that such different radar polarimetry analysis techniques provided comparable performances [1].

Despite of such progress, current polarimetric research on subsurface targets like fractures is restricted to qualitative analysis. This motivates us to explore more quantitative approaches to characterize the fractures in real world environmental engineering projects by using fully polarimetric borehole radar signal properties. To achieve this goal, in this work, we utilize a procedure of computer numerical modeling to systematically investigate polarimetric scattering mechanism or fully polarimetric radar response to fractures with different conditions. First, synthetic fractures with different roughness are generated on a computer via fractal theory based simulation techniques [3]. Quantitative assessment for the roughness of synthetic fractures is possible by use of three main parameters: the fractal dimension, the rms roughness at a reference length, and a length scale describing the degree of mismatch between the two fracture surfaces, allowing future detailed study of mechanical and transport properties of fractures and fully polarimetric radar response on them. Next, a 3D sub-grid FDTD [4] numerical simulation is used to synthesize both constant-offset and multiple-offset fully polarimetric data sets with synthetic fractures as primary reflectors. Based on the synthetic data sets, it is possible to relatively quantitatively evaluate the applicability of different radar polarimetry analysis approaches to physical characterization of subsurface fractures. Also, it enables us to study the fully polarimetric radar "AVO" response to "fluid substitution" (fluid content changes from freshwater to brine, oil etc. within fractures)[5].

We conclude that synthetic fully polarimetric data sets through computer forward modeling allows us to quantitatively investigate polarimetric scattering mechanism from synthetic natural subsurface fractures with known roughness parameters, and research on "AVO" response to "fluid substitution" through multi-offset fully polarimetric data sets is important to fluid characterize and classification within fractures. The simulation research is conducive to practical field data processing and interpretation.

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