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Dielectric Dispersion: A New Wireline Petrophysical Measurement

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Abstract

Dielectric measurements and interpretation, introduced with great promise in the 1980s, have not found widespread use owing to measurement limitations, moderate accuracy, and insufficient quality control. This paper presents a new-generation dielectric tool that overcomes these limitations and brings extra information for more accurate petrophysical formation-evaluation.

One of the revolutionary advances offered by this tool is the continuous measurement of dielectric dispersion (variation of formation dielectric properties as a function of the frequency) at 1-in vertical resolution. The tool uses multi-spacings antenna arrays operating at multiple frequencies in the MHz to GHz range. Moreover, transmitter and receiver antennas have colocated longitudinal and transverse polarizations.

The wealth of recorded data will allow interpreters to both adapt the answer product to the reservoir fluids and geology, and also to provide acquisition quality-controls and error estimates on the results.

Carbonate and heavy oil reservoirs are becoming more and more important. In these two environments, the new tool provides unique answers to better characterize these reservoirs. This tool also addresses traditional dielectric formation-evaluation in fresh water and thinly laminated sands.

Answer products offered by this new tool can be classified in three categories.

1. Pore-fluid analysis from the muti-spacings high frequency measurements
    - Hydrocarbon residual saturation and invaded zone water salinity
    - Invasion profile: hydrocarbon saturation profile in heavy oil reservoir
2. Matrix analysis from dielectric dispersion
    - Carbonates: textural information (Archie m cementation factor)
    - Shaly sands: high resolution clay volume and anisotropy
3. Geological structure analysis from the muti-polarizations and high resolution
    - Thin beds analysis
    - Structural anisotropy measurement in very thin beds
    - Geological features extraction
    - Carbonate classification

This paper reviews the dielectric dispersion physics, then describes the tool's architecture, measurements, and data processing chain. Field test examples illustrate the enhanced interpretation potential of dielectric dispersion measurements from this tool.

Introduction to dielectric dispersion physics

The permittivity quantifies the sensitivity of a medium to an electric field excitation. Three main physical phenomena contribute to the permittivity: the displacement of the electronic cloud of atoms, the coherent orientation on pre-existing microscopic electric dipoles and the polarization effect at the interfaces. These phenomena are illustrated in Figure 1.