Radar frequency dielectric dispersion in geological media

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Abstract

Most radar interpretation and forward modelling software is based on the assumption that geological media are non-dispersive, i.e. the radar velocity and attenuation is independent of frequency. However, previous modelling work has shown that potentially, frequency dispersion in the radar frequency range can have a large effect on the interpretation of data collected using conventional bandwidth antenna. Frequency dispersive behaviour can also have a significant influence on the accuracy of water saturation estimates for soils, aquifers and oil reservoirs using dielectric methods (GPR, TDR and dielectric logging), which rely on the existence of unique relationships between dielectric constant and volumetric moisture content.

Reported here are a series of laboratory investigations of the radar frequency dielectric behaviour of geological materials and artificial mixtures, aimed at quantification and modelling of their frequency dispersive behaviour and dielectric constant-moisture content curve. The equipment used, a large one port co-axial cell, and the method of data interpretation are described, and the accuracy and sources of error in the measurement technique are discussed. Results are presented for an aquifer material (Sherwood Sandstone) and for artificial mixtures of clean sand and various finer particles, including clay minerals montmorillonite, kaolinite, attapulgite and silica rock flour.

It is shown that the frequency dispersive response of clay-rich Sherwood Sandstone units is likely to arise from polarisation mechanisms associated with montmorillonite clay. The dispersive response of montmorillonite is not shown by the other clay minerals or silica rock flour, which indicates that it is associated with restricted ion migration in water trapped within the clay mineral lattice. Application of a dielectric dispersion model shows that the frequency of dispersion (50-1000MHz) is compatible with migration of ions within water in the interlayer spaces of montmorillonite. The implications for appropriate processing of radar data geological media containing clays, and prediction of moisture content from dielectric data are discussed.
Figure 1. Dielectric constants versus frequency from one-port co-axial cell, for a mixture of montmorillonite clay and sand saturated with de-ionised water. Above about 500MHz several dielectric constant values produce the observed cell refraction coefficients, but the true value is identifiable because it is a continuous function of frequency.

Figure 2. Dielectric data for sand: montmorillonite mixtures compared with dielectric dispersion model by Schurr (1964). Model parameters: particle radius $6 \times 10^{-9}$m; Diffusion co-efficient $2 \times 10^{-9}$m$^2$/s; monovalent ions; solid dielectric constant 4. Mixing behaviour is modelled using the CRIM.