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Combined vector network analyzer and impedance analyzer for broadband determination of complex permittivity spectrum of glass beads with talc

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Soil complex dielectric permittivity is frequency dependent. At low frequencies soil dielectric spectrum exhibits relaxation effects mainly due to interfacial phenomena caused by water strongly bounded to solid phase particles surfaces, double-layer effects and Maxwell-Wagner effect. At frequencies of several GHz and above, the influence of dielectric dispersion of free water dipoles can be observed. Since dielectric soil moisture meters operate at frequencies from kHz up to several GHz, their output can be affected by these phenomena.

Currently, there is a variety of commercial sensors that operate at various frequencies from kHz up to several GHz. Most popular are TDR sensors with frequency band up to 1-2 GHz and capacitance/impedance sensors that operate at a single frequency usually from the range 1-150 MHz. Therefore, the knowledge of the broadband complex dielectric permittivity spectrum can help to improve the existing and develop new methods and devices for soil moisture and salinity estimation. Also, accurate characterization of complex dielectric permittivity spectrum of porous materials in the broadband frequency range is required for modeling of dielectric properties of materials in terms of moisture, salinity, density, mineralogy etc.

The aim of the study was to measure the complex dielectric permittivity of glass beads with 5% talc moistened with distilled water and saline water (electrical conductivity of 500, 1000, 1500 mS/m). The experiment was carried out using a seven-rod probe connected to an impedance analyzer (IA) and a vector network analyzer (VNA) using a multiplexer in the frequency range from 40Hz to 110MHz (IA) and 10MHz to 500MHz (VNA). The glass beads (90-106 μm, Fuji Manufacturing Industries, Japan) with 5% talc (Sigma Aldrich) in 4 different moisture and 4 different salinity values were examined. The results obtained from the IA and the VNA were combined and modeled with complex conductivity and dielectric permittivity model. The influence of water content and electrical conductivity on broadband complex dielectric spectra and the fitted model parameters was examined.

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