Broadband measurement of soil dielectric permittivity

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Dielectric sensors are a popular choice for in situ soil moisture θ (m^3/m^3) measurement, especially operating at frequencies below 300 MHz. Soil complex dielectric permittivity $\varepsilon^* = \varepsilon' - j\varepsilon''$ at such frequencies is affected by multiple dielectric relaxation mechanisms stemming from the existence of bound water, electrical double layer and other interfacial phenomena Presented is the impact of salinity and measurement frequency on ε^* for silt loam soil in frequency range from 20 MHz to 3 GHz. Soil samples were measured in laboratory conditions at 25±1°C with the use of a two-port coaxial transmission line cell (Figure 1e) connected to a vector-network-analyzer. Soil samples were prepared by mixing the air-dry soil material with KCl solutions of electrical conductivity σ_s = 0.52 and 1.50 S/m in order to achieve target five volume water content values θ. Frequency spectra for the wet soil samples are presented in Figure 1a)-d). The conversion from the measured S_{21} transmission parameters to ε^* of soil samples and the calibration details of the measurement system are given in [1].

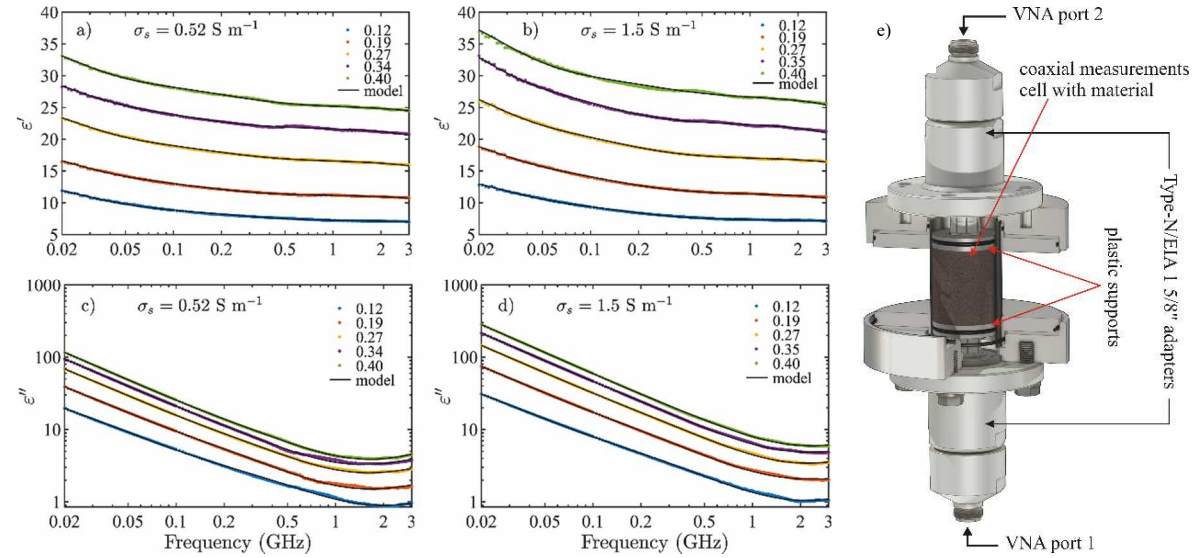

Figure 1. Real (a), (b) and imaginary (c), (d) parts of the complex dielectric permittivity spectra for two measurement series of silt loam soil samples moistened with the KCl solutions of $\boldsymbol{\sigma_s}$ given in the plots. Volumetric water content values $\boldsymbol{\theta}$ are given in the legend. Part e) shows the measurement cell connected to the Type-N/EIA 1 5/8" adapters. Solid black lines represent the fitted data according to a three-pole Debye model [2].

In case of the measured soils, the impact of soil salinity on the $\theta - \varepsilon'$ relation was the smallest at frequencies of several hundred MHz and above. Thus, the most accurate soil moisture determination based on dielectric permittivity measurement with the use of a general calibration function is possible at frequencies above at least 250 MHz. More detailed analysis for other soils and salinities in [2] shows that the impact of soil texture at low frequencies is visible, even though the tested soils are of medium texture and do not include high clay content.

Acknowledgments

The work founded by Polish National Agency for Academic Exchange Grant No. PPI/APM/2018/1/00048/U/001.

References

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[2] A. Szypłowska *et al.*, "Impact of soil salinity , texture and measurement frequency on the relations between soil moisture and 20 MHz – 3 GHz dielectric permittivity spectrum for soils of medium texture," *J. Hydrol.*, **579**, 2019, p. 124155, doi: 10.1016/j.jhydrol.2019.124155.