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Determination of medium electrical properties through full-wave modelling of frequency domain reflectrometry data

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Accurate knowledge of the shallow soil properties is of prime importance in agricultural, hydrological and environmental engineering. During the last decade, numerous geophysical techniques, either invasive or resorting to proximal or remote sensing, have been developed and applied for quantitative characterization of soil properties. Amongst them, time domain reflectrometry (TDR) and frequency domain reflectometry (FDR) are recognized as standard techniques for the determination of soil dielectric permittivity and electrical conductivity, based on the reflected electromagnetic waves from a probe inserted into the soil. TDR data were first commonly analyzed in the time domain using methods considering only a part of the waveform information. Later, advancements have led to the possibility of analyzing the TDR signal through full-wave inverse modeling either in the time or the frequency domains. A major advantage of FDR compared to TDR is the possibility to increase the bandwidth, thereby increasing the information content of the data and providing more detailed characterization of the medium. Amongst the recent works in this field, Minet et al. (2010) developed a modeling procedure for processing FDR data based on an exact solution of Maxwell's equations for wave propagation in one-dimensional multilayered media. In this approach, the probe head is decoupled from the medium and is fully described by characteristic transfer functions. The authors successfully validated the method for homogeneous sand subject to a range of water contents. In the present study, we further validated the modelling approach using reference liquids with well-characterized frequency-dependent electrical properties. In addition, the FDR model was coupled with a dielectric mixing model to investigate the ability of retrieving water content, pore water electrical conductivity and sand porosity from inversion of FDR data acquired in sand subject to different water content levels. Finally, the possibility of reconstructing the vertical profile of the properties by inversion of FDR data collected during progressive insertion of the probe into a vertically heterogeneous medium was also investigated.

Index Terms: Frequency domain reflectrometry (FDR), frequency dependence, dielectric permittivity, electrical conductivity

Reference:

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