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TDR water content inverse profiling in layered soils during infiltration and evaporation

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During the last three decades, time domain reflectometry (TDR) has become one of the most commonly used tools for soil water content measurements either in laboratory or in the field. Indeed, TDR provides easy and cheap water content estimations with relatively small disturbance to the investigated soil. TDR measurements of soil water content are based on the strong correlation between relative dielectric permittivity of wet soil and its volumetric water content. Several expressions of the relationship between relative dielectric permittivity and volumetric water content have been proposed, empirically stated (Topp et al., 1980) as well as based on semi-analytical approach to dielectric mixing models (Roth et al., 1990; Whalley, 1993).

So far, TDR field applications suffered the limitation due to the capability of the technique of estimating only the mean water content in the volume investigated by the probe. Whereas the knowledge of non homogeneous vertical water content profiles was needed, it was necessary to install either several vertical probes of different length or several horizontal probes placed in the soil at different depths, in both cases strongly increasing soil disturbance as well as the complexity of the measurements.

Several studies have been recently dedicated to the development of inversion methods aimed to extract more information from TDR waveforms, in order to estimate non homogeneous moisture profiles along the axis of the metallic probe used for TDR measurements. A common feature of all these methods is that electromagnetic transient through the wet soil along the probe is mathematically modelled, assuming that the unknown soil water content distribution corresponds to the best agreement between simulated and measured waveforms. In some cases the soil is modelled as a series of small layers with different dielectric properties, and the waveform is obtained as the result of the superposition of multiple reflections arising from impedance discontinuities between the layers (Nguyen et al., 1997; Todoroff et al., 1998; Heimovaara, 2001; Moret et al., 2006). Other methods consider the dielectric properties of the soil as smoothly variable along probe axis (Greco, 1999; Oswald et al., 2003; Greco, 2006).

Aim of the study is testing the applicability to layered soils of the inverse method for the estimation of water content profiles along vertical TDR waveguides, originally applied in laboratory to homogeneous soil samples with monotonic moisture distributions (Greco, 2006), and recently extended to field measurements with more general water content profiles (Greco and Guida, 2008). Influence of soil electrical conductivity, uniqueness of solution, choices of parametrization, parameters identifiabilty, sensitivity of the method to chosen parameters variations are discussed.

Finally, the results of the application of the inverse method to a series of infiltration and evaporation experiments carried out in a flume filled with three soil layers of different physical characteristics are presented.

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