Geophysical Research Abstracts
Vol. 12, EGU2010-14196, 2010
EGU General Assembly 2010

TDR response properties and their use in the estimation of soil permittivity

Stefano Ferraris (1) and Patrizia Savi (2)

(1) Universita' degli Studi di Torino, Dipartimento di Economia e Ingegneria Agraria, Forestale e Ambientale (D.E.I.A.F.A.),Sezione di Idraulica Agraria,Via Leonardo da Vinci - 10095 - Grugliasco (Torino)., (2) Dipartimento di Elettronica, Politecnico di Torino, C.so Duca degli Abruzzi 24, 10129 Torino, Italy, patrizia.savi@polito.it.

Time-Domain Reflectometry (TDR) has been widely applied in soil science, hydrology and agronomy to estimate the permittivity of soils. The two major features of TDR waveforms are the travel time in the probe and the long time amplitude of the response, that are directly related to the apparent dielectric dielectric constant and to the soil electrical conductivity. Several studies in the literature have aimed at determining a good method to evaluate the travel time from the TDR curve.

In order to overcome the difficulties in the determination of the starting and ending point of this time interval, in this paper, an ideal model of the measurements setup and a frequency domain analysis leading a simple formula to evaluate the permittivity is introduced. The inherent properties of the TDR responses have been studied by considering an ideal model where an ideal voltage step (infinite bandwidth) $u(t)$ is applied to the probe. The probe is an open-ended transmission line, whose characteristic admittance and time delay are Y_a and τ_a, respectively. The unknown permittivity is assumed to be represented by the one-pole Debye's relation (ϵ_∞, ϵ_s and $\omega_{rel} = 2\pi f_{rel}$ are the Debye's parameters, and σ the conductivity). The properties of the TDR waveforms pointed out with this analysis yield elementary relations for estimating ϵ_s and ϵ_∞ directly from the characteristic points of the waveform. Elementary relations hold for ϵ_s only, which can be estimated as: $\epsilon_s \sim \left[Y_a\left(1+h\right)/Y_0\left(1-h\right)\right]^2$ where Y_a is the characteristic admittance of the probe, Y_0 the free-space admittance and h is the level of the reflection between the first two edges.

Measurements were performed on various sandy soil with different water contents rates. The samples were inserted in a coaxial probe terminated on a $50\,\Omega$ load (Maury Microwave Airline, model no. 2653S10, length $\ell = 10.5\,\mathrm{cm}$, shield and inner conductor radii $3.5\,\mathrm{mm}$ and $1.5\,\mathrm{mm}$, respectively, dc-resistance of inner conductor $9.4\,\mathrm{m}\Omega/\,\mathrm{m}$). Two different instruments were used in order to measure the time-domain response: a Tektronix 1502B reflectometer with rise time $t_r = 0.3\,\mathrm{ns}$ (horizontal setting $0.1\,\mathrm{m}$ per division and a propagation velocity setting of 0.99) and a digitalizing oscilloscope HP54120B with rise time $t_r = 10\,\mathrm{ps}$. The results obtained by using the proposed method have been compared with standard techniques for the permittivity evaluation as the derivative method for various reference liquid and various sandy soil with different water content. The permittivity estimated via a parametric inversion approach based on an high-order model has also been considered in the comparison.

The main result of this study is that simple and reliable relations to evaluate the low-frequency permittivity directly from the TDR waveforms can be used. These formulas are in good agreement with the results obtained with a method based on the travel time of the TDR signal along the probe and with the results obtained with a parametric inversion approach based on an high-order model. When using the digitalizing oscilloscope instead of a standard reflectometer, due to a better signal to noise ratio, the comparison works better.