Geophysical Research Abstracts, Vol. 8, 00743, 2006
SRef-ID:

Time Domain Spectroscopy in Soil Physics

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In standard electromagnetic techniques such as time domain reflectometry, ground penetrating radar and radar remote sensing, the soil water content (θ) is obtained from measurement of the soil dielectric permittivity at a specific or effective frequency. However, natural soils exhibit a distinct dispersive behavior in the frequency ranges at which these techniques operate, with permittivity values also affected by factors such as texture, electrical conductivity and temperature. As limitations to the traditional methods became more apparent, spectroscopy measurements have become more appealing. These provide not only the potential for accurate θ determination under a robust set of conditions, but permit in theory the inference of fundamental soil properties such as specific surface area and perhaps matric potential. Time domain spectroscopy has been successfully used in physical chemistry to measure the frequency-dependent permittivity of materials. However, the methods developed in this field are not directly transferable to soil science, primarily due to substantial differences in the probes applied, materials tested, and equipment used (i.e., whether suited for in-field measurements). We have recently developed a general model based on the impedance analysis, which yields accurate measurements for a range of soil textures and electrical conductivities. This approach offers several advantages over the traditional scatter function method, including: 1) uncertainties related to the input signal are overcome by using a difference reflection method; 2) spurious reflections and distortions due to cable and connectors are precisely taken into account through network analysis of the feeding line; 3) dielectric permittivity is obtained through numerical inversion of the sample impedance rather than by parameter optimization. In this way, no assumption is needed concerning an appropriate dispersion model (e.g., Debye, Cole-Cole, etc.) for the material under investigation. Most importantly, the analysis is applicable to different probe geometries. We obtained accurate measurements with multi-rod probes of varying sizes, including miniature probes 5-mm long. Also, encouraging results were obtained with a fringing field (flat) sensor. Preliminary tests in saline soil materi-

als show that this new technique represents an effective means to accurately measure water content under the range of salt concentrations of interest for most applications.