

Public Abstract

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Some nondestructive testing (NDT) techniques in civil engineering applications employ electromagnetic (EM) wave methods. These techniques have proven to be effective for many applications including investigating and characterizing the subsurface (Bowders et al., 1982a), identifying steel reinforcement locations in pavements and testing the integrity of concrete foundations. Civil engineering subsurface characterizations typically propagate EM waves in the radio to microwave range (3 kHz to 300 GHz). The dielectric constant of a soil determines the velocity of EM waves traveling through the soil. Dielectric constant is the real part of the relative permittivity of soil and is a measure of the soil's ability to be polarized by an electrical field. Several empirical models exist to predict the dielectric constant of soils and all show the dielectric constant to be strongly related to the soil's volumetric water content.

The objective of this project is to quantify the accuracy of forecasted dielectric constants of soil by comparing with in situ measured dielectric constants. A field test site at McBaine, Missouri (MO) was instrumented with commercially available sensors for measuring soil and meteorological conditions. Sensors measured the soil's dielectric constant, temperature, electrical conductivity, volumetric water content (using the measured dielectric constant in Topp et al's, 1980, predictive model), air temperature, relative humidity, solar irradiance, wind speed, and precipitation. Measurements of meteorological and in situ soil conditions began on April 24th, 2012 and have been recorded for over one year.

The meteorological conditions at McBaine, MO and the soil properties associated with the field site were documented in this study. Measured meteorological conditions and soil properties were used in the moisture migration model and existing empirical dielectric constant models to forecast the dielectric constant of soil. The forecasts were compared with in situ measurements of dielectric constant.

Forecasted and measured dielectric constants were different and the soil with the higher clay content had the least agreement (percentage difference between 80 to 100 percent), while the soil with the higher sand content had the best agreement (percentage difference less than 20 percent).

The differences lead to a discussion of the variables affecting forecasted and measured values. The laboratory characterization of McBaine, MO soils and what was observed at the field site indicated the soil's tendency to shrink-swell during wetting and drying events. The expansive nature and blocky structure created macropores thus enabling preferential flow of water through the soil. The inability of WinUnSat-H to model moisture migration through soils with macropores and the model uncertainty associated with the dielectric constant predictive models was indicated by the differences between forecasted and measured dielectric constants.

The discussion brought to light elements of the McBaine, MO field site that were not accounted for in the forecasted dielectric constants, but were factors in the measured dielectric constants. Substituting the one-dimensional moisture migration model (WinUnSat-H) with a two- or three-dimensional model, as well as measuring the in situ volumetric water content as a starting point for simulations may improve the accuracy of forecasted dielectric constants.