Field Measurement of Permittivity, Electrical Conductivity, Magnetic Susceptibility, and Topographic Relief of Soils in Donbass, Ukraine for Robotic, Multi-Sensor, Humanitarian Demining System Design

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Extended Abstract

In order to confirm previously-estimated [1] electromagnetic properties of soils in the Donbass (UA) conflict zone for design of a multi-sensor humanitarian de-mining robot, we collected coincident permittivity (dielectric constant), DC electrical resistivity, and magnetic susceptibility at 2 m intervals along six profiles, totaling ~1.5 lineal km, in fields containing representative soils (dominantly chernozemic) approximately 4 km from the contemporary (August, 2016) conflict front. Permittivity was measured using both a Spectrum Technologies “Field Scout 300” time domain reflectometer (TDR), and a patented [2] bistatic impulse ground penetrating radar (GPR) system (2 GHz center frequency) designed to eliminate direct transmitter-receiver coupling. The TDR directly measures permittivity, while the GPR system records reflection coefficient (from matching readings for the bare earth and a totally-reflecting aluminum sheet) from which permittivity can be derived. Magnetic susceptibility was measured using a Bartington MS2 meter with an MS2F borehole probe inserted 10 cm into the soil. DC electrical resistivity was measured using a Wenner 4-point array consisting of 3-cm electrodes at a constant spacing of 10 cm, attached to a LaCoste & Romberg MiniRes meter. Along randomly-selected profile segments, representing a total of 120 m, topography was measured at 10-cm intervals in order to characterize the surface relief that might be encountered by the intended robotic sensor platform.

In general, while large-scale trends in permittivity matched between the two measurement methods, TDR readings indicated permittivities larger than those estimated from reflection coefficients by a factor varying between two and four. In addition, the TDR readings show lesser variability across short lateral distances. Both of these effects may be due to a higher moisture content in the shallow soils measured by TDR as opposed to the exposed and variably-desiccated surface characterized by GPR reflection coefficients. The surficial GPR permittivities were generally between 4 and 8, while shallow TDR permittivities were between 10 and 40. The low surficial permittivities suggest incident signal partitioning that will provide sufficient initial signal transmission into these soils.

Magnetic susceptibilities for the measured Donbass soils ranged between 1950 and 2560 10^{-8} m^3/kg, while conductivities (based on the field resistivity measurements) ranged between 1.8×10^{-1} and 3.6×10^{0} S/m. Combining all of these parameters, the GPR skin depth [3] for shallow subsurface Donbass soils using a 2 GHz signal should be approximately 1 to 5 dB/m.

Calculation of the radius of curvature for variously-smoothed versions of the topographic profiles is providing guidance for the selection of wheel size and numbers for the robotic platform.

References

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