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Sensitivity volume of monopole antenna for determining soil dielectric permittivity spectrum

Andrzej Wilczek (1), Agnieszka Szypłowska (1), Marcin Kafarski (1,2), Justyna Szerement (1), and Aleksandra Woszczyk (1)

(1) Institute of Agrophysics, Polish Academy of Sciences, Metrology and Modelling of Agrophysical Processes, Lublin, Poland (a.wilczek@ipan.lublin.pl), (2) The State School of Higher Education in Chełm, Chełm, Poland (m.kafarski@ipan.lublin.pl)

Electromagnetic measurement of soil moisture and salinity can be carried out in many ways, including FDR and TDR methods. However, in both cases, due to the natural heterogeneity of the soil, knowledge of the sensitivity zone size of a given measurement method of the selected sensor is required. Dielectric measurement result is an average value in this particular volume. The presence of soil surface layer or another genetic level in the probe's sensitivity zone is an interfering factor. Knowledge of the size and shape of the probe's sensitivity zone avoids methodological errors during probe installation and minimizes measurement error. Moreover, calibration of the sensor should be done in such way that the reference material fill the entire volume of the sensitivity zone. This is important during field measurements where the volume of the tested material is not limited by the walls of the sample container.
It is known that the sensitivity zone depends on the frequency of the measurement signal due to the change in wavelength and the impact of attenuation related to electrical conductivity or dielectric loss. The purpose of this work is to determine the size of the sensitivity zone of the probe with a monopole antenna to determine the spectrum of dielectric permittivity. A sensor (21.5 mm long monopole antenna) with antenna counterbalance in the form of a metal flange with a diameter of 48 mm was selected for the tests. The tests were performed using the vector network analyzer in the 10 MHz - 3 GHz frequency range, measuring the amplitude of the S11 signal. Additional verification was performed based on FEM simulations. Studies showed that the sensitivity zone size increased with decreasing dielectric permittivity and increasing the frequency of the EM signal. Sensitivity zone also decreased with the increase of the material attenuation. Based on the test results, the size of the sensitivity zone for several materials of various dielectric permittivity was determined and a relationship between the size of the sensitivity zone and the maximum frequency of the measurement signal was found.

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