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Laboratory measurements of dielectric permittivity and electrical conductivity as a function of water content of soils in the intermediate frequency domain (100 kHz – 10 MHz)

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Abstract:

This study focuses on the measurement of the electrical properties of soils in the intermediate frequency range (100 kHz – 10 MHz). The mapping of the soil moisture, necessitating the mapping the electrical properties in situ, requires preliminary laboratory measurements conducted under controlled conditions. The effective electrical conductivity $\sigma(\omega)$ is usually measured in the low frequency range ($<$ 100 kHz), and mainly related to the clay content of the soil. The effective dielectric permittivity $\varepsilon(\omega)$ is generally obtained at high frequency ($>$ 50 MHz), and related to the water content of the soil. In the intermediate frequency range both parameters depend on water and clay content. The determination of the water content thus requires estimating the effect of the clay content. To reach that goal, a series of laboratory measurements on artificial and natural samples have been undertaken.

These laboratory measurements were carried out using a capacitive cell and an electrical square quadripole. The complex effective relative dielectric permittivity ε* is measured with the capacitive cell, and defined as follow: ε*=ε'(ω)+i[ε"(ω) $-$ $\sigma(\omega)$/$\omega.\varepsilon_0$], where ω corresponds to the pulsation and ε_0 is the dielectric constant of the vacuum. The objective is to study the contribution of water and clay content on the following parameters: ε'(ω) the real relative dielectric permittivity, ε"(ω) the dielectric losses, and $\sigma(\omega)$ the real electrical conductivity. Moreover, using the electrical square quadripole enables to measure the "direct-current" electrical conductivity σ_{DC}. These two types of measurements allow to discriminate the factor linked with conduction phenomena (equal to σ'(ω)/$\omega.\varepsilon_0$) in the imaginary part of ε*, strongly dependant of the clay fraction in the sample.

Measures on sandy samples, coupled with theoretical modeling (effective medium theory) show that the H.F. relationship between ε'(ω) and the water content can be extended until 1 MHz. In presence of clay, it is possible, using the measured σ_{DC}, to separate the factor linked with conduction phenomena from the dielectric losses.

Keywords:

dielectric permittivity, electrical conductivity, water content, capacitive cell measurements