IN-SITU BROADBAND SOIL MEASUREMENTS: DIELECTRIC AND MAGNETIC PROPERTIES

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1. ABSTRACTION

The electromagnetic (EM) properties of soils have been of interest to various research areas for many years. For example, the EM properties of the soils are essential for accurate analysis of the ground penetrating radar (GPR) data, which has been used for investigating underground environments and objects, because GPR signals penetrate through the soil. The EM properties of soils are not only frequency dependence but also dependence of density and water content. Thus, it is important to conduct the EM properties measurement of soil without disturbing soil's density and water contents. Conventionally, researches were focused on measuring only electrical properties (permittivity) of dielectric materials while their magnetic properties (permeability) were assume to be unity. [1] However, because of the recent interests on permeable environments, such as volcanic soil and Martian subsurface, both complex permittivity (ε*) and permeability (μ*) of soil become equally important for accurate/reliable interpretation of GPR data. [2]

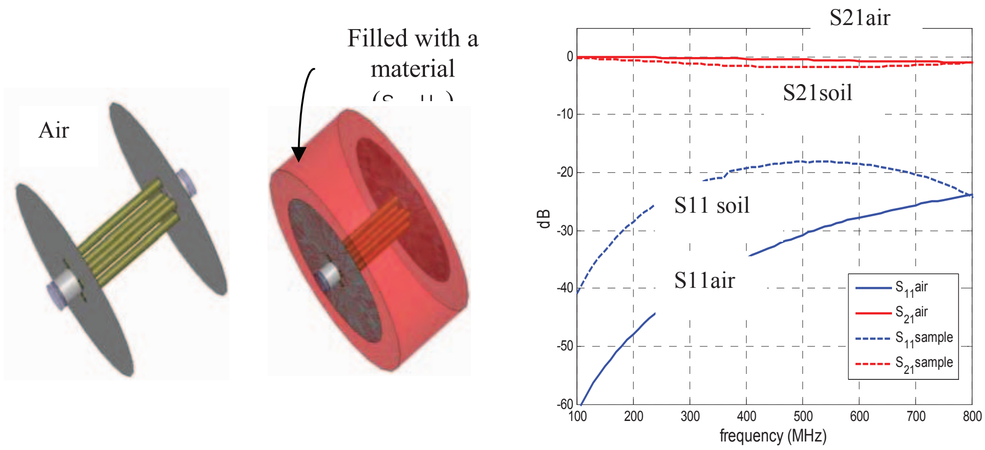
In order to measure both ε* and μ* of the measurements simultaneously at microwave frequency, several microwave methods have been developed and published in material science. [3,4] Among these methods, the reflection/transmission methods were generally used to estimate both ε* and μ* over the broadband frequency range. However, currently available EM properties measurement techniques are based on off-line (laboratory) measurement of collected material samples.

In this paper, we proposed and experimentally verified a noble *in-situ* and broadband measurement technique for the electromagnetic properties of a soil. Concept of the proposed *in-situ* soil probe was originated from a fact that input impedance of antenna immersed in a material a function of EM properties of the material [5]. We combined two monopole antennas with parasitic elements into one piece to achieve reflection (S11) and transmission (S21) measurements simultaneously. (see Figure 1) Measured 2 port S-parameters are converted into ε* and μ* by using a modified Nicolson-Ross algorithm [6]. This technique can evaluate both ε* and μ* and permeability of the material over the broadband frequency range without disturbing its physical condition such as density and moisture contents.

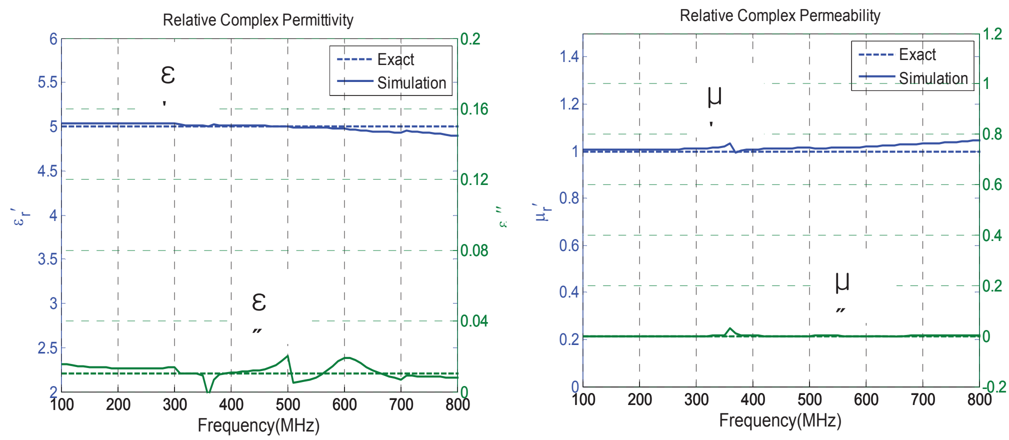
Performance of the proposed noble *in-situ* soil measurement technique was evaluated by numerical simulation using HFSS. (see Figure 2). These simulated S-parameters were applied to the proposed post processing algorithm and the ε* and μ* of the material surrounding the soil probe were estimated. The proposed *in-situ* soil property measurement method provides accurate ε* and μ* of the material within only 1 % of error range over the wide frequencies between 100 MHz and 800 MHz.

The proposed *in-situ* 2 port soil probe and post processing algorithm were preliminarily tested in the laboratory with a soil samples. The soil samples were collected at a typical volcanic red soil area in Oahu, Hawaii and were completely dried. A vector network analyzer was used to measure reflection and transmission coefficients over the frequency range from 100 MHz to 1 GHz. This paper presents the constitutive parameters of the dry Hawaiian red soil measured by the proposed *in-situ* soil probe. (See Figure 3) These measurement results of the dry Hawaiian red soil are in very good agreement with those obtained by a laboratory method which was reported in [7].

Figure 1: A noble *in-situ* and broadband soil probe for both complex permittivity and permeability measurements.



(aa) Simulation setup (b) Simulated S-parameters



(c) Estimated complex permittivity and permeability

Figure 2: Evaluation of the proposed in-situ material measurement performance using HFSS.

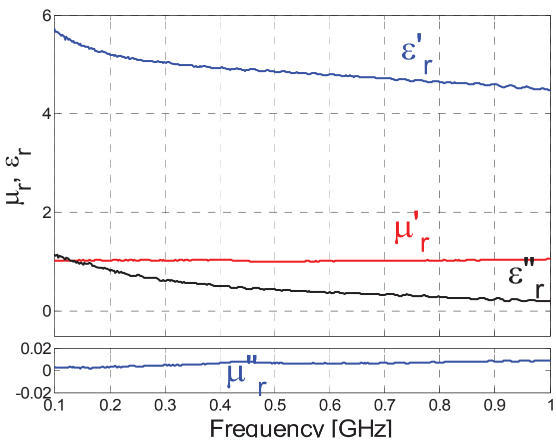


Figure 3: Measurement results of the proposed in-situ soil probe for dry Hawaiian red soil

4. REFERENCES

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