Geophysical Research Abstracts
Vol. 19, EGU2017-15486, 2017
EGU General Assembly 2017

Wireless network of stand-alone end effect probes for soil in situ permittivity measurements over the 100MHZ-6GHz frequency range

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Microwave remote sensing and non-destructive analysis are a powerful way to provide properties estimation of materials. Numerous applications using microwave frequency behavior of materials (remote sensing above land surfaces, non-destructive analysis…) are strongly dependent on the material's permittivity (i.e. dielectric properties). This permittivity depends on numerous parameters such as moisture, texture, temperature, frequency or bulk density.

Permittivity measurements are generally carried out in the laboratory. Additionally, dielectric mixing models allow, over a restricted range of conditions, the assessment of a material's permittivity. in-situ measurements are more difficult to obtain.

Some in situ measurement probes based on permittivity properties of soil exist (e.g. Time Domain Reflectometers and Transmissometers, capacitance and impedance sensors). They are dedicated to the acquisition of soil moisture data based on permittivity (mainly the real part) estimations over a range of frequencies from around 50 MHz to 1 or 2 GHz. Other Dielectric Assessment Kits exist but they are expensive and they are rather dedicated to laboratory measurements. Furthermore, the user can't address specific issues related to particular materials (e.g. organic soils) or specific measurement conditions (in situ long time records).

At the IMS Laboratory we develop probes for in situ soil permittivity measurements (real and imaginary parts) in the 0.5 - 6 GHz frequency range. They are based on the end effect phenomenon of a coaxial waveguide and so are called end effect probes in this paper.

The probes can be connected to a portable Vector Network Analyzer (VNA, ANRITSU MS2026A) for the S11 coefficient measurements needed to compute permittivity. It is connected to a PC to record data using an USB connection.

This measurement set-up is already used for in situ measurement of soil properties in the framework of the European Space Agency's (ESA) SMOS space mission. However, it should be useful to install many probes on the same site to obtain permittivity measurements over a large area. To reach this goal, the probes should communicate with each other to send data to a record device. Furthermore, it is needed to record measurements over a long time period (many months) to study the in-situ dielectric soil property variations according to changing weather conditions and seasonal trends.

The goal of the research work presented is to develop a dielectric sensor system based on end effect probes able to communicate the data using wireless technology. It must be stand-alone from an electric and data recording point of view so it must integrate a VNA circuit instead of the ANRITSU VNA used for the moment.

The LoRa wireless technology has been selected because of its low electric consumption and the large distance between equipment available. LoRaWAN™ is a Low Power Wide Area Network specification intended for wireless battery operated devices. The LoRaWAN data rates range from 0.3 kbps to 50 kbps which is sufficient for our probes' data exchanges. We will present the work done to perform the VNA and the LoRa communication board as well as the work done to improve the probes and the permittivity computation algorithm.