

# Portable Low Cost Six Ports Reflectometer for In Situ Soil Moisture Broadband Spectroscopic Dielectric Characterization

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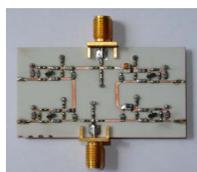
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## INTRODUCTION

Soil water monitoring is of main importance for environmental applications like climate change, agriculture... At the Laboratoire d'étude des Transferts en Hydrologie et l'Environnement (LTHE) in Grenoble, dielectric methods for measuring soil moisture have been developed and tested for many years (TDR [1], capacitive probes). It has been shown then that the operating frequency has to be taken into account for the analysis of the measured permittivity value. In fact, in a moist porous media such as a soil, dispersion and attenuation of the electromagnetic traveling are occurring to variable extends depending on the mineralogy, solute content... To quantify such phenomena, broadband analysis of the complex permittivity has to be performed by impedance spectroscopy. First measurements were done with standard Vector Network Analyzers (VNA) and matched probes, between 10 MHz and 2 GHz, using a simple resonance method [2]. In order to be able to perform this type of measurements in outdoor conditions; a low cost portable six ports reflectometer was designed [3].

## DEVICE REALISATION

Reflectometric six ports system is known since many years to be a good alternative solution to perform vector reflection coefficient measurements [4]. It is only composed of passive elements such as diodes, resistors, inductors and capacitances. It is based on the fact that in a Radio Frequency (RF) circuit ended by an unknown load and fed by a continuous wave, there may be a stationary wave. If the magnitude of this wave is detected at different points of the circuit, it is possible to infer, after a calibration process [5] the complex reflection coefficient of the load and then its impedance. There are indeed six ports connected respectively to the RF source, to the Device Under Test (DUT) and to four power detectors. A prototype has been designed and realized using standard PCB hybrid technology and SMC components (Fig. 1). It is integrated in a stand alone system with a computer that is controlling the external RF synthesized source, the attenuator, the ADC card, the C++ calibration software and the display of the results.

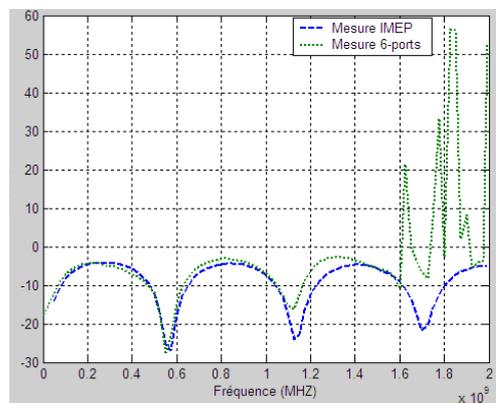


**Figure 1:** Prototype of the Six Ports circuit.

The operating frequency range is between 5 MHz and 2 GHz, with a 5 MHz step. Seven optimized SMA reflective loads are used for the calibration: open, short, load and four other SMC loads.

## TESTS AND CONCLUSION

The device has been tested at different temperatures with a load composed of water saturated glass beads. No significant changes of the measured data were noticed between 20°C and 80°C. Fig. 2 is also showing comparative measurements results of the reflection coefficient magnitude in dB for a load composed of a TDR probe placed in air, with a HP8753C VNA and with the six port system. A good agreement is observed up to 1 GHz. Above 1 GHz, the different phases of the calibration loads might be too close to maintain a good accuracy of the six ports measurement setup.



**Figure 2:** VNA/Six ports comparative measurements of a TDR probe.

A portable and low cost six ports reflectometric apparatus has been made which present good performances between 5 MHz and 1 GHz. Further experiments will be done under outdoor conditions for soil spectroscopic impedance determination.

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