**Development of impedance spectroscopy based in-situ, self-calibrating, on-board sensor with inbuilt energy efficient wireless transceiver for ionic detection in multi-phase mixtures like soil**

*Abstract:*

Real time and accurate measurement of sub-surface soil moisture and nutrients is critical for agricultural and environmental studies. This work presents a novel on-board solution for a robust, accurate and self-calibrating soil moisture and nutrient sensor with inbuilt wireless transmission and reception capability that makes it ideally suited to act as a node in a network spread over a large area. The sensor works on the principle of soil impedance measurement by comparing the amplitude and phase of signals incident on and reflected from the soil in proximity of the sensor. The permittivity of the soil dielectric mixture which is calculated from these impedance measurements is used as input parameter to the dielectric mixing models which are used to estimate the ionic concentration in soil. The inbuilt wireless transceiver system is connected to a specially designed metamaterial inspired small antenna in order to reduce the sensor size while keeping the path losses to a minimum by using a low frequency. This composite right-left handed (CRLH) antenna for wireless transmission at 433 MHz doubles up as an underground, sensing element (external capacitor) and integrates with the on-board sensor for soil moisture and nitrate determination. The input impedance of the CRLH sensor, surrounded by the soil containing moisture and nitrate ions, is measured at multiple frequencies in the lab setting. It is shown that the change in moisture and nitrate can be successfully detected using the sensor. The inbuilt self-calibrating mechanism makes the sensor reliable at different environmental conditions and also useful for remote, underground and hand-held applications. A multi-power mode transceiver system has been designed to support the implementation of an energy efﬁcient medium-access-control.