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## Assessment of a low-cost Handheld Vector Network Analyzer to Measure the Broadband Complex Permittivity of Soils

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Soil moisture is of major relevance in agricultural and environmental monitoring, having a direct impact in crop growth and yield, and playing an important role in soil conservation and landscape management. Several well-known techniques are widely used to determine soil moisture, but dielectric methods are notable for their automation potential and integration in monitoring and irrigation control systems. Measurement of dielectric properties in moist porous substances, such as soils, has been shown to provide reliable estimation of water content. However, frequency domain dielectric spectroscopy seems to reveal information about other useful physicochemical properties of soils. Dielectric spectroscopy measurements are normally restricted to laboratory setups and limited for low budgets due to the high cost, bulk and weight of the equipment. We evaluated the performance of a low-cost, handheld, open-source VNA (Vector Network Analyzer) for the measurement of the complex permittivity of soils in the 1 MHz to 900 MHz frequency range. The tested device was compared with a commercial model using a low-cost, self-manufactured, open-ended coaxial probe to measure the broadband dielectric properties of organic liquids. An empirical method based on known dielectric properties of standard fluids was used to calibrate the probe. The tested low-cost VNA paired with the experimental probe was found to provide accurate and reliable measurements of the broadband complex permittivity from 50 to 700 MHz. The broadband complex permittivity of mineral soils of varied textures was obtained for a range of bulk densities and water contents from dry to water-saturated conditions.