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AGWAT-4662; No. of Pages 8

ARTICLE IN PRESS

Agricultural Water Management xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Temperature compensation in a low cost frequency domain (capacitance based) soil moisture sensor

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ARTICLE INFO

Article history:
Received 2 July 2016
Received in revised form 30 October 2016
Accepted 1 November 2016
Available online xxx

Keywords:
TDR
Irrigation water management
Calibration
Sustainability

ABSTRACT

Frequency Domain Analysis is a well established technique in soil moisture determination, using the change in electrical capacitance of probes inserted into the soil caused by the presence of water. However it is known that temperature affects the determination of this capacitance. Here two different techniques are used, the first passing a fixed frequency through the soil via insulated probes, then measuring the amplitude of the resultant signal. The second uses the soil capacitance as the controlling component in a variable frequency oscillator, measuring the resultant times to charge and discharge. The measured capacitance is seen to be affected both by the temperature of the soil and, due to the sensitive nature of the monitoring electronics, also the temperature of critical components in the measurement circuits. Results from these experiments show that these two effects are complementary, soil temperature adding to the measured capacitance, whilst electronics temperature effectively decreases the measured capacitance. The daily profiles of the soil and electronics temperatures, whilst both rising during the day, and falling at night, show significant phase difference and therefore do not simply cancel out. Further, the strength of temperature compensation required is shown to vary with technique and moisture level. This paper explores these phenomena using results from a recently developed, four probe Frequency Domain capacitance based sensor costing around 12 Euros. These measurements are compared to those achieved by a commercial soil moisture system costing over 250 times this price. Preliminary results are presented from temperature compensation algorithms intended to minimize these effects.

1. Introduction

In irrigation management, the determination of water requirements of a crop over time is based on soil water balance measurements, plant measurements and meteorological data. The entire parameters are used for estimating the irrigation water scheduling in a specific crop. The irrigation water scheduling of a crop determines the quantity of water and the time when this quantity is applied. One part for determining the soil water balance is the measuring of soil moisture. The use of soil-based water measurements have been adopted as an adequate strategy for water balance estimation and many methodologies to measure water fluxes from crops have been traditionally developed (Ojha et al., 2015; Jaguey et al., 2015; Navarro-Hellin et al., 2015; Tarange et al., 2015).The ultimate objective of these techniques is to provide farmers with information about the most appropriate volumes of irrigation to apply in each phenological period of the crop, depending on the desired yield levels and other parameters. For determining soil moisture, a great range of sensors are used (Vienken et al., 2013).

There is a wide range of electrically based soil moisture measurement techniques well established in the fields of geophysical surveying (Linck and Fassbinder, 2014; Lehmann et al., 2014) and agronomy (Fatas et al., 2014; Baghdadi et al., 2014) These including resistivity based methods such as the Wenner (Jiao-Jun et al.,2014) and Schlumberger Arrays (Mosuro et al., 2012), and capacitive based methods such as Frequency Domain Reflectometry (FDR) (Al-Asadi and Mouazen, 2014; Jaria and Madramootoo, 2013) and Time Domain Reflectometry (TDR) (Janik et al.,2014) as well as Radiation based techniques such as the Neutron Probe (Kodikara et al., 2014). Whilst low cost implementations of resistive based sensors have been suggested in the past (Igboama and Ugwu, 2011), commercial implementations of these units (for example the Landviser Landmapper) are expensive (typically $500–$1600), lack integrated data-logging capabilities, or are simply unavailable.

Previous experiments (Oates et al., 2014) have established the baseline potential of a low cost resistivity based Wenner Array sensor design, giving highly correlated results (>95%) with a commercial Hydra II probe. Further, a simple compensation formula has

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http://dx.doi.org/10.1016/j.agwat.2016.11.002
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Please cite this article in press as: Oates, M.J., et al., Temperature compensation in a low cost frequency domain (capacitance based) soil moisture sensor. Agric. Water Manage. (2016), http://dx.doi.org/10.1016/j.agwat.2016.11.002

been derived and published by the authors (Oates et al., 2015) to compensate for changes due to temperature. However this resistivity based technique is well known to be susceptible to a variety of differing soil conditions such as composition (Hanson and Peters, 2000; Kibria and Hossain 2014), texture (Hadzick et al., 2011; Nadler, 1991), varying pH (Ishada and Makino, 1999; Islami et al., 2012), salinity (Austin and Rhoades, 1979; Velstra et al., 2011; Read and Cameron, 1979) and temperature (Afa and Anaele, 2010; Everwand et al., 2014; Newill et al., 2014). As the FDR technique depends on the dielectric constant of the soil (i.e. its electrical capacitance) rather than its conductivity (reciprocal of resistivity), it is theoretically less susceptible to the salinity of the soil. Thus low cost Frequency Domain sensors were constructed to explore this technique.

The principle of operation of the Frequency Domain capacitance probe relies on the fact that the dielectric constant between water and air differs by a factor of 80. Thus the presence of water in the soil between the probe plates produces a highly significant change in its capacitance, the higher the water concentration, the higher the capacitance. This capacitance can then be measured by electrical means. As the probe is electrically insulated, there is no direct current flow within the soil, and thus the conductive effect of ion based salts in the soil is minimized.

2. Materials and methods

Two electrical methods are used to determine the effective capacitance of the probe (see Fig. 1). The first involves using the

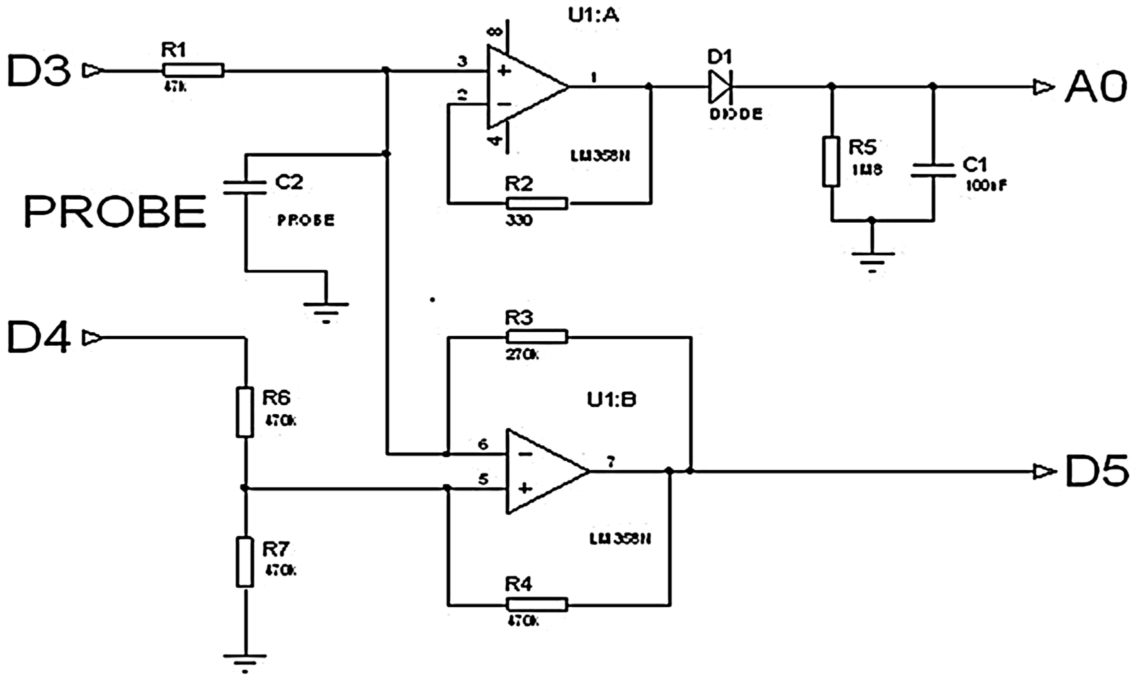

Fig 1. Circuit diagram of the two Frequency Domain capacitive probe methods.

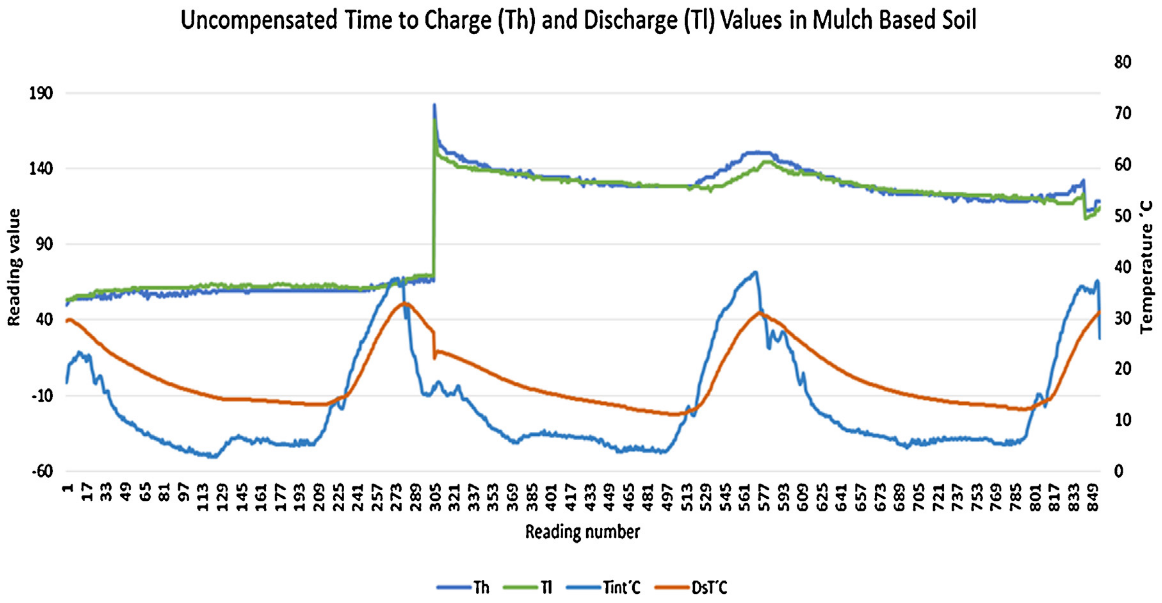

Fig. 2. Uncompensated Charge and Discharge times in Mulch based soil.

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