SOIL VOLUMETRIC WATER CONTENT MEASUREMENT SYSTEM

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1. Introduction

In agriculture and climatology, soil moisture is very important property. Understanding of the soil moisture behaviour has significant benefits in improvement of watering management, effective application of chemicals in agriculture, prediction of soil erosive processes, estimation of flood danger levels to save lives and property in public sector. In this contribution, we describe simplified soil impedance measuring technique, which allows monitoring of soil moisture. The developed measurement system based on this method allows long time standalone monitoring of soil moisture, ambient and soil temperatures for typical soil salinity levels.

2. Impedance measurement method

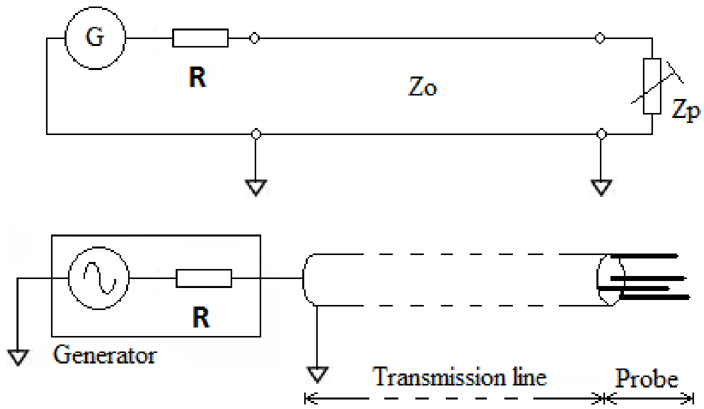


Fig. 1 *Schematic description of impedance measurement method.*

The principle of impedance measurement method is based on standing wave reflection in transmission line ended by probe inserted into a soil of some moisture and so typical impedance [1]. Schematic representation of impedance measuring system is shown in Fig. 1. It comprises of harmonic oscillator of constant frequency (typically 100-300MHz), section of transmission line with typical impedance 75Ω or 50 Ω, and metal probe rods with dimensions required to emulate transmission line impedance. Coaxial line impedance (Z) is dependent on dielectric constant of insulator and dimensions of this line described by equation

$$Z = \frac{60}{\sqrt{K}} \ln(\frac{r_2}{r_1}) \tag{2}$$

where r_1 and r_2 are radii of inner and shield conductor. The probe after insertion into soil acts like part of transmission line with impedance dependent on dielectric constant of surrounding soil. Behavior of electrical insulator (soil in our case) changes with the frequency of the voltage applied across this electrical insulator (soil). The expression describing the dielectric constant (K) is acceptable for wet soil at frequencies of the voltage signal below 1GHz [2]

$$K = K' - i(K'' + \sigma_{dc} / 2\pi f \varepsilon_0) \tag{1}$$

where K' is real and K'' is imaginary part of the dielectric constant K, ε_0 is the permittivity of vacuum, σ_{dc} is the direct current conductivity and f is frequency of excitation voltage. Real part K' represents electric flux density trough insulator and imaginary part K'' represents leakage and losses caused by conductivity of the soil. To minimize K'', frequencies between 30MHz and 1GHz are applied [3]. The signal generated by oscillator travels through the transmission line into the probe. If there is a difference of impedance between transmission line and probe surrounded by soil, part of the incident signal is reflected back through the line towards the signal source which is represented by reflection coefficient (ρ)

$$\rho = \frac{Z_p - Z_l}{Z_p + Z_l} \tag{3}$$

Z_p and Z_l in (3) represent impedance of probe and transmission line. The reflection causes a voltage standing wave, i.e. change in the signal amplitude, therefore relative change in impedance of probe can be acquired by measuring the difference in amplitude [4].

3. Experimental

The developed soil moisture measurement system based on impedance measurement method (Fig. 2) consists of ML2x soil probe manufactured by DeltaT-Devices [5], two thermometers for measurement of ambient T_a and soil T_s temperatures with 0.5K accuracy and 0.1K relative accuracy, and microprocessor-based STAX system [6] for measurement control and data logging. STAX electronic processing unit based on 8-bit microcontroller ATxmega128a3 allows for portability, up to 16 GB data memory space for data logging to μSD card, battery module and optional wireless radio communication interface. The soil probe provides output voltage signal in scale of 0 to 1V representing moisture in soil. The voltage can be converted directly to volumetric water content VWC (in % of weight of water over weight of soil) in soil using the tabulated transfer function [6]. We have used following polynomial approximation for direct calculation of VWC in the voltage range 0 – 1V using STAX:

$$VWC = -0.058 + 7.21.10^{-4} x - 6.99.10^{-7} x^2 + 5.36.10^{-10} x^3 \qquad (4)$$

The achieved accuracy was ±1% in VWC range from 0 to 50%. During the experiments, the sample of soil has volume of about 13 dm^3.

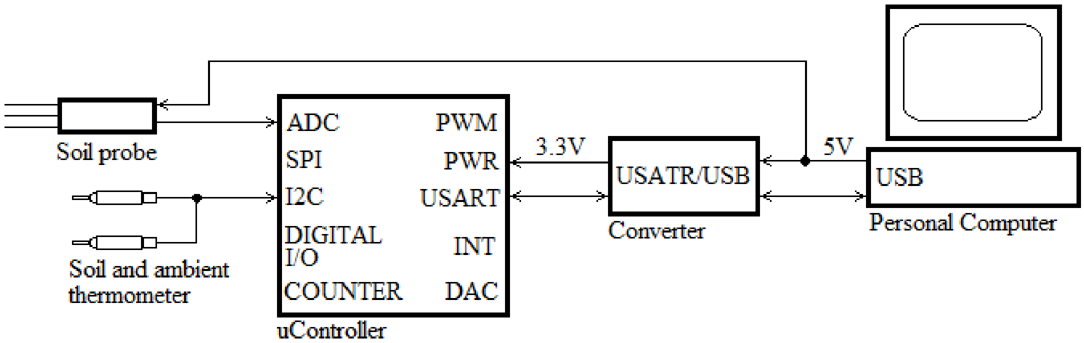
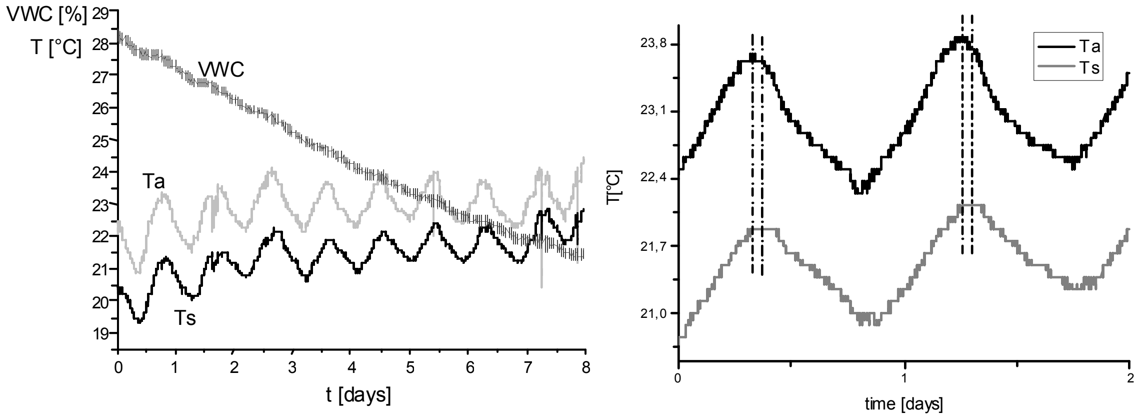


Fig. 2. *Block diagram of developed measurement system*

4. Results and discussion

To study the evapo-transpiration of soil, the water content was measured simultaneously with soil temperature T_S and temperature above the soil sample T_A. At the beginning of the measurement, the VWC in the soil sample was set to 40%. After 18 days of spontaneous drying at room temperature it fell to value of 17.3%. Part of the measured volumetric water content (VWC) during 8 days along with soil and ambient temperatures using 6 seconds sample period is shown in Fig. 3a. Oscillations of night and day temperatures can be clearly seen and also few rapid falls of temperature which were caused by change of ambient temperature due to opened window in laboratory are also remarkable. Noise in the VWC measurement represents inaccuracy of the measurement method and contribution of STAX calculation error. From these measurements gradual, nearly exponential decrease of the soil moisture at usual room temperature and humidity conditions is evident. Using exponential approximation, evaporation time constant of 662 hours has been estimated from the measured data.

Influence of different thermal capacity of ambient air and the soil can be seen from Fig. 3b, where ambient and soil temperatures are periodically fluctuating during the days, and there is approx. 85 minutes delay between the extremes in the temperature fluctuations. Interestingly, this delay has gradually shortened as moisture of the soil continuously decreased.



a) *b)*

Fig. 3 a) *Change of volumetric water content VWC, ambient T_a and soil T_s temperature during 8 days, b) Detail view of soil and ambient temperature change.*

5. Conclusion

In conclusion, soil moisture measurement and monitoring system based on impedance measurement method has been developed. The system was applied for the measurements of the volumetric water content in the soil. Influence of ambient temperature and its fluctuations to the soil temperature and volumetric water content was examined.

Acknowledgement

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