APPLICATION BASED WIRELESS SENSOR NODE FOR UNDERGROUND MOISTURE SENSING FOR PRECISION AGRICULTURE

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Abstract— In this paper, we are attempting to examine the WUWSN (wireless underground water sensor node*) for precision agriculture. The development and function of this sensor along with its software application is described in this paper. The equipment is under testing and the laboratory results and interpretations are discussed in this paper. This equipment is based on the new concept of sensing underground soil moisture. The sensor is cost effective sensor and has a long life span without any drawbacks of contamination of soil and it's surrounding environment. This system helps in precision agriculture and irrigation in monitoring 18 inches underground water for green house or the targeted field. It gives the status of the water required by the crop. It thus enhances the analysis and decision making system for controlling the growth and quality of yield. This equipment is based on the principal of measurement of a dielectric value of the surrounding media. In this case it is soil. We explore the different parameters such as the moisture content which affect the dielectric value of the soil. In future we would further focus on various other parameters such as pH value, electric conductivity, temperature, etc using the same equipment.

Wireless underground water sensor node contains sensors and communication unit. This node can detect the underground water with wireless communication capability. This is an innovative approach for determining the soil moisture content and to update the information to the server through RF. This system is more useful for precision agriculture in finding the exact requirement of water for different crops. The sensor works on the principle of change in capacitance which occurs due to the change in dielectric property of the soil. This change is acquired by data acquisition system and the data is transferred through the communication unit. It is transmitted to the collection point for further analysis and decision making of the system. The communication of each node is based on the application based protocol for wireless sensor network. This node is useful in various application sectors for remote underground water sensing and monitoring. *Patented IPI 453/MUM/2013

Keywords—Soil moisture sensor, Wireless Sensor for underground water sensing.

Estimation of soil moisture content is important in precision agriculture especially during irrigation scheduling. Changes in the percentage of soil moisture during the irrigation event can be controlled by indicating the amount of applied water to soil. Continuous monitoring of soil moisture content within and below the rooting zone can facilitate optimal irrigation scheduling, aimed at minimizing both- the effects of water stress on the plants, and also leaching of water below the root zone which can have adverse environmental effects.

I. INTRODUCTION

Soil moisture content impacts the crop growth directly and also influences the fate of agriculture chemicals applied to soil. One of the key components in managing irrigation scheduling is by determining the moisture content in soil. Zazueta and Xin (1994) reported that soil moisture content may be determined via its effect on dielectric constant by measuring the capacitance between electrode pairs implanted in the soil. Other than that, the physical condition of the soil plays an important role in soil moisture determination. In normal soil condition, air and water is filled in the pore spaces of soil. Thus the dielectric constant of the soil-water-air mixture can be measured. If we know the dielectric constant of air (1) and that of water (80) at a specific temperature (25°C), then the dielectric of the soil can be found out.

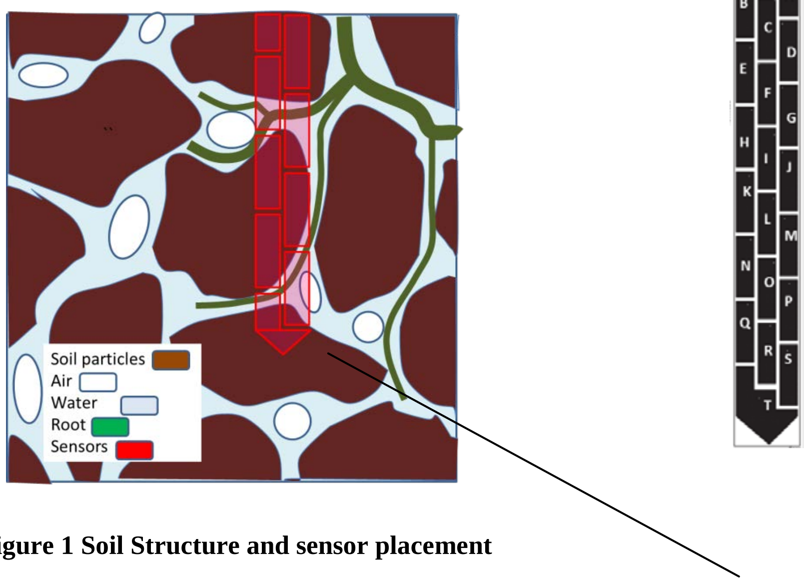

Figure 1 Soil Structure and sensor placement

Figure 1 shows that the unsaturated soil is composed of solid particles, organic materials and pores. The contact between the sensor plates and the medium is also depicted in the figure. The pore spaces of the soil contain air, water and roots.

There are different methods to determine the soil moisture. Few of them such as Time-domain reflectometry (TDR) method, frequency domain reflectometry (FDR) method, amplitude-domain reflectometry (ADR) method and capacitive method are the current methods available for the electrical measurements of the dielectric constant. e.g. TDR instruments use measured pulse travel times to determine the apparent soil dielectric permittivity. Some of the researchers found that the capacitance probe method was independent of soil type within wide ranges of soil moisture levels. However, these methods do not determine the exact distribution of the moisture in the observation field of soil. Whereas, in this system of ours, the underground soil moisture distributions over the target field can be observed remotely.

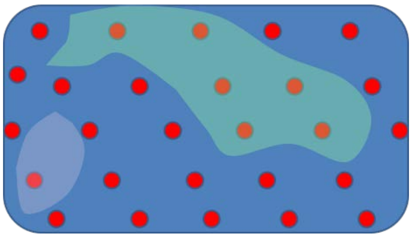

Figure 2 Wireless sensors in targeted field area

Figure 2 shows the targeted field and the sensors' placement over the field. The sensor measures the distribution of permittivity of the soil moisture and sends this data to the server wirelessly. Individual WUWSN "wireless underground water sensor node" is used to measure soil moisture content based on the moisture distribution in soil. The soil moisture measurement is based on the concept of the dielectric constant in a dry material consisting soil particles and air. This dielectric soil constant is relatively small (1.5 to 4) as compared to the dielectric water constant (80 at room temperature). The small amount of water in the soil causes the dielectric constant of the resultant soil-water-air mixture to exhibit a composite dielectric constant that can be related to the soil moisture content through a simple calibration procedure [1].

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II. DESIGN THEORY

The theory of moisture content states that "Water content of the soil is the ratio, expressed as percentage, of the mass of 'pore' or 'free' water in a given mass of soil to the mass of the solid particles". The moisture content in soil can be analyzed by knowing the physical conditions of the soil. The soil's bulk density, D_b is weight of dry soil to the unit volume (solids and pore). Particle density, D_p involves measuring the weight of dry soil and the volumetric soil particle i.e. only solid and no pore space. From both - bulk density and particle density values, the soil porosity can be calculated by using equation (1) [5].

$$Soil\ Porosity = 1 - \frac{D_b}{D_p} \qquad \ldots(1)$$

Moisture content, θm determines the amount of water with a given mass of soil. Moisture content is calculated by dividing the weight of water in the soil by the weight of dry soil. The expression of water content in terms of volume of water per volume of soil can be determined as volumetric water content, θv using equation (2):

$$\theta v = Db \times \theta\ m \qquad \ldots(2)$$

From the ratio of volumetric water content and soil porosity, the amount of pores filled with water i.e. soil saturation can be calculated.

III. WUWSN

WUWSN "wireless underground water sensor node" is as illustrated in figure 3. It consists of 18 micro plates of sensors for soil moisture in 18 inches length as detection device. The data acquisition unit processes the data. The wireless communication units are the other parts of this unit. This can be interfaced to a personal computer for data storage, plotting process.

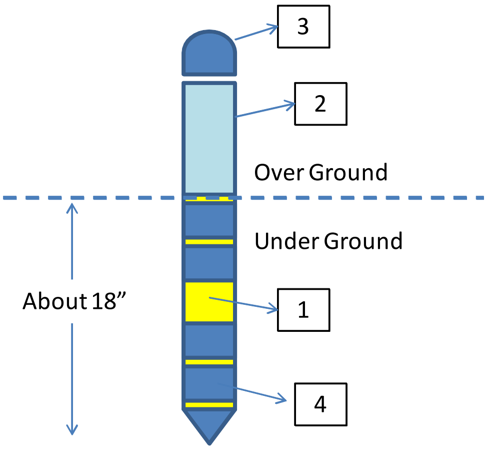


Figure 3 WUWSN

WUWSN "wireless underground water sensor node" is as described briefly in figure 3. In the given figure it is shown in three parts, the significance of each of which is as follows:

- Part 1 is the sensor part shown in yellow color, which will be under ground. The length of this part will be approx 18" inches, width will be 2.5" inches, and its thickness is about 0.25 inch. It is the group of sensors, shown in part 4. There are 18 sensors to be placed in 18 inch.
- Part 2 shows the interconnection between part 1 and part 3.
- Part 3 of the figure shows the communication unit.
- Part 4 shows the block of sensors and pre processor.

Working principal and flow of the wireless underground water sensor:

Part 1 is the group of sensors and pre processing unit. Each sensor senses the surrounding moisture content of the soil and the raw value fetched to the pre processor part. The raw value is based on the dialectic value of the material surrounded by the sensor. In this case, it is dependent on the moisture contents in the surrounding soil (shown as part 5 in figure 4). Next block: part 6 is the further processing of the raw data collected from each sensor. It further carries out their relative analysis including data collection with a certain time interval, standard deviation, averaging and the comparing with previous as well as standard values, thresholding and noise elimination.

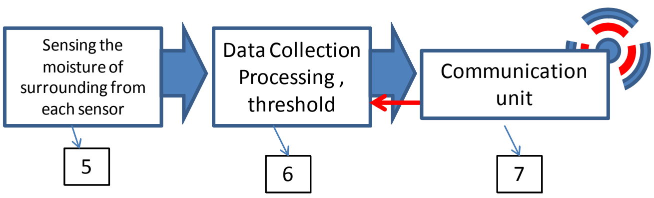
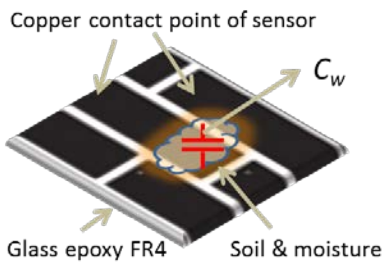


Figure 4 Block diagram for WUWSN working principal

Part 7 is a communication unit, which is controlled by the processor and has the basic component of communication like the antenna, programmable radio & oscillator. This unit works in a frequency range of 2.41 to 2.49 GHz and 83 channels with 802.15.4 standards. It communicates through and fro the server (remote central unit). It uses "*application based protocol*" for peer to peer communication and routing. This protocol is developed specifically for this application. It is due to this protocol that the node "*wireless underground water sensor node*" (WUWSN) can work as reconfigurable architecture and showcase better performance. This helps in changing the testing strategy dynamically on the field which in turn helps to save the power while data acquisition and data communication.



$$C_w = \frac{\varepsilon_o \, \varepsilon_s \; A}{D}$$

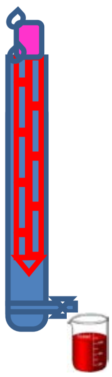
Figure 5 Sensor anatomy

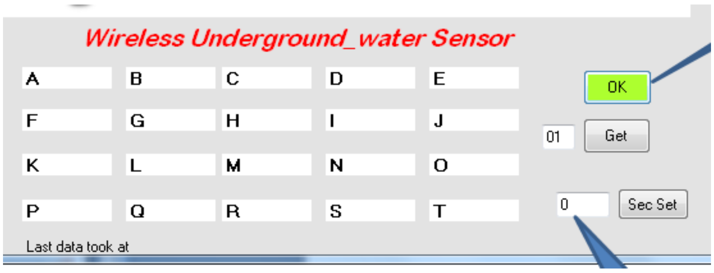
C_w = Capacitance affected by a moisture contain in soil in contact with the sensor pad
ε_s = soil permittivity under testing
ε_o = Dielectric constant epoxy body of sensor
A = Area of covered by the moisture soil
D = Thickness of the sensor body

The body of sensor in made up of the material FR4 (glass epoxy). The copper (Cu) clad has a finite surface area. The group of sensors is mounted on a strip such that the maximum area can be covered under the sensing part. The sensor signal is the change in the sensor response when moisture containing soil comes in contact with the sensor (explored in Figure 5). The output of the sensor is a digital value which represents the capacitance of the successive plates. In this example, the average value without moisture contents in the soil has say XYZ counts. Now, when the moisture containing soil comes in contact with the sensor, the average output increases to XYZ+ABC counts. Because the sensor signal tracks the change in counts due to contact of soil containing moisture, the difference ABC can further calibrate with the percentage of moisture contains. The small difference in the moisture content at different level can be detected by the advance processor capability. The sensitivity of a sensor depends on the placement of a sensor.

III. LABORTORY EXPRIMENT

This equipment is tested under the laboratory setup shown in figure 6. The flask contains the different materials like air, plain water, sand, and clay. The flask has the provision to facilitate the circulation of the water from top to bottom. This is aided by the force of gravity. At the bottom of the flask, there is an outlet provided for the excretion of the water. The different sets of readings for typical clay and the sand with different percentage of water are obtained and displayed in following table by application software.





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22-05-13 2:00	A01	00C8	00C7	00C9	00CD	00CF	00D5	00DC	00E9	00EB	00F5	00FE	0109	0116	0121	012E	013D	014E	015D	01703	0184
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22-05-13 2:02	A01	00C6	00C5	00C8	00CA	00CD	00D4	00DB	00E7	00EA	00F2	00FC	0108	0114	011D	012C	013A	014E	0153	016E	017F
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22-05-13 2:03	A01	00C4	00C4	00C7	00C7	00C9	00D0	00D9	00E4	00E8	00F1	00FB	0104	0112	0109	012B	0135	0147	014E	016B	0176

Figure 6. Laboratory setup with application software and result table

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