Review Paper on Determination of Moisture Content of Soil using Microwaves

Miss. Yogita T. Patil1 Dr. Uttam L. Bombale2
1M. Tech. Student 2Associate Professor
1,2Department of Electronics Engineering
1,2Shivaji University, Kolhapur (416004) Maharashtra, India

Abstract— In this paper moisture content of soil is determine using microwaves. Many types of moisture measurement methods are used such as evaporation method, chemical reaction method etc. These methods are very cheap and easy to use but there are some drawbacks they are more time consuming as well as energy consuming. To resolve these problems microwave is used to determine the moisture content of soil. In this method microwaves are incident on soil sample on one side and received power is measured at other side. If the moisture content in the soil is more then it will absorbs more microwave power. Received power decreases. Received power is proportional to moisture content.

Key words: Soil Moisture Content, Patch Antenna, Printed Circuit Board, Vector Network Analyzer, Display

I. INTRODUCTION

Water contained in soil is called soil moisture. The water is held within the soil pores. Soil water is the major component of the soil in relation to plant growth. Hence, soil moisture content has quite significant influence on engineering [1], soil science, agronomic [2,3], geological, ecological, biological, industrial quality monitoring, and hydrological behavior [4-6] of the soil mass. Furthermore, it has a major role to play as far as the plant growth [3], organization of the natural ecosystems and biodiversity [7] is concerned. The determination of soil water content is of the vital importance efforts to improve growth and water efficiency in agriculture. In agriculture sector, application of adequate and timely moisture for irrigation, depending upon the soil-moisture-plant environment, is essential in crop production. If the moisture content of a soil is optimum for plant growth, plants can readily absorb soil water. Space–time evolution of the soil moisture content is controlled by topography, landscape position, slope, vegetation, soil structure and texture and human-made structure above the soil. Soil moisture content is also used as an important parameter for water balance studies, slope stability analysis and performance evaluation of various geotechnical structures such as pavements, foundations, earthen dams, retaining walls, compacted clay liners, hazardous and toxic waste disposal repositories. [4,6, 8-11]. It plays a major role in casting industries also known as foundries. The sand casting method also known as molded casting, is used to produce the required objects. Here the sand is used as molding material. In this casting method sand is mixed with bonding agent usually clay is mixed. The mixture is moistened typically with water to develop strength and plasticity for molding. Maintaining the proper moisture levels when producing sand molds guarantees bonding takes place between materials to create the right cohesiveness, permeability, refractoriness, surface finish, flow ability, and chemical inertness. Without achieving these properties, the quality of castings becomes compromised [27]. In this context, earlier researchers have developed several techniques for measuring the soil moisture viz., thermo gravimetric [5,7,12], neutron scattering, soil resistivity, dielectric techniques like time domain reflectometry, frequency domain reflectometry and capacitance etc. However, these techniques are quite intricate, expensive (due to quite elaborate circuitry and paraphernalia) and hence beyond the reach of many.

So in order to overcome all these hurdles the system uses microwave sensors. Microwave sensors emerged as effective tools for real-time, nondestructive [14–17].

II. THEORETICAL MODEL

The properly said “soil material” is composed by particles of different sizes, classified in the three categories of sand (“large” particles), silt (“average” particles) and clay (“small” particles) [5]. Sensors system is an important tool aimed at improving soil performance and soil quality. Generally, the sensors used in monitoring the soil quality are based on the physical and chemical properties of the soil. The physical properties include color, texture, structure and moisture content in the Soil. The water-holding capacity of a soil depends on its type, organic matter content, and past management practices, among other things [5]. Soil can be classified into dozen of texture classes. This classification is dependent on the sand, silt and clay percentage. Sand is the largest, then comes the silt and smallest particle is clay. Using soil moisture measurements is one of the best and simplest ways to get feedback to help make improved water management decisions. However, the installation, calibration, and interpretation of the data from these instruments is often overwhelming for most busy growers. Here’s an attempt to provide practical recommendations for using these sensors to improve your operation.

III. VARIOUS METHODS USED IN MEASURING SOIL MOISTURE

The level of water in the soil can be expressed as soil water content and water potential. Soil water content can further be classified in the aspects; percentage water by weight, percentage water by volume. The soil moisture content can be determined by the two ways. One is fill method and the second one is using sensors and meters.

In the earlier times when the technology was not much developed, the farmers used their hands to know that how much water content present in soil. From the appearance of soil, they tried to guess the water content. This method was approximation method. As the technology gets advanced, new technologies emerged and new sensors and meters came into origin. These methods provide...
accurate results and are quite efficient. Proper placement of sensors is also critical to represent soil moisture in the root zone and obtain meaningful data for effective irrigation management [18]. Therefore, proper care should be taken while placing sensors in the soil.

We can improve, Determination of soil moisture using microstrip antenna. This method is best suitable for soil moisture content. The results will be shown in minimum fraction of time as the whole system is controlled by electronic means, the circuit operates at very low voltage and power as the antenna will be operating in the microwave range. Other systems does not give results quickly.[20]

IV. SOIL MOISTURE MEASUREMENT TECHNIQUES

Soil moisture measurements are difficult to carry out on a consistent and spatially comprehensive. Non-destructive methods that can be used to directly estimate moisture content and give precise results with higher accuracy and resolution are required to enhance our understanding of water movement in soil and to determine the water content in it. The techniques are classified as follows,

- Gravimetric method
- Neutron probe moisture meters
- Time domain reflectometry
- Oven drying method
- Tensiometers

A. Gravimetric Method

In gravimetric method of moisture measurement, the moisture content is expressed by ratio as weight of water to the weight of dry soil. This is very basic method of soil moisture calculations. Determination of water content removed is done using several methods. The simplest method to determine water content removed is by measurement of loss of weight of the sample. Sample water content can also be determined by collection of the water through distillation or absorption in a desiccant. Extraction of substances which replace sample water and measurement of a physical or chemical property of the extracting material that is affected by water content is another method. Finally, sample water content can be determined by quantitative measurement of reaction products displaced from a sample. In each of these methods the water and soil are separated and the amount of water removed is measured or inferred.

\[
\text{Moisture content} = \left( \frac{\text{Weight of original sample} - \text{Weight of dried soil}}{\text{Weight of original sample}} \right) \times 100
\]

1) Advantages
Gravimetric technique is accurate and simple, and involves low cost process, No need of specific calibration[21].

2) Disadvantages
Tedious method, involves more labor, destructive for soil and sometimes very difficult to take samples from rocky soil. Affected by environmental conditions like heat, humidity etc[21].

B. Neutron Probe Moisture Method

The neutron probe moisture method is an indirect way of determining soil moisture content. This method measures the moisture content of the soil by measuring the thermal or slow neutron density. A probe is fed deep into the soil and connected to power supply, microcontroller, display and keypad via wire. The probe contains a source and detector. The fast neutrons are emitted by the source and the detector detects the neutrons that come back after collision and absorption with nuclei of soil and water. The number of neutrons that come back to probe depends upon the hydrogen and oxygen atoms present in the soil. When a neutron comes into contact with the hydrogen atom, it loses energy. So this collision slows down the emitted neutrons, some looses energy to such extent that they cannot come back to the detector. Boron tri fluoride gas is used in the detector.

1) Advantages
Neutron probe method gives fast and reliable measurement. Repeated measurements can be taken at any depth of soil and at any location[21].

The method is portable and commercial units are simple to use. However, a permit for radioactive material is required.

2) Disadvantages
The major disadvantage of neutron moisture meter is involvement of radioactive element. This radioactive element requires extensive care to handle and licensed, efficiently trained operator. The equipment is of very high cost and extensive calibration is required. The presence of salts also affects the readings of meter. This method is time consuming. This method requires specific calibration. This method cannot be automated handled[21].

C. Time Domain Reflectometry Systems

The time domain reflectometry system measures the travel time of the electronic pulse through the waveguides (two or more probes), which is surrounded with the soil. The water content of the soil is calculated by using the travel time readings. The TDR system consists of pulse generator that generates a square wave, and an oscillator that captures the reflected pulse, from many points along the probe (fig 2). The probes are inserted into the soil; the travel time depends upon the complex permittivity of the soil [22]. The reflection of the original signal will occur when there is any change in the impedance. The water present in the soil will change the dielectric constant of the soil. Due to change in dielectric the impedance variations occurs and affect the shape of the reflected signal. The reflected signal’s shape is used to obtain the information about the water content present in the soil.

![Diagram](image)

Fig. 1: Schematic diagram depicting soil moisture testing using TDR

1) Advantages
Simple, accurate and continues measurements are provided. TDR does not need any calibration not affected by salts. Probe of any length can be used, so more deep soil readings can be taken.
I) **Advantages**
It provides direct and continuous readings. No power supply is required. Variable length tensiometers are available to take any variable depth moisture measurement. It is an inexpensive system. This method Avoids electronics and power consumption. This method is Well-suited for high frequency[19].

2) **Disadvantages**
The response time is relatively slow. Careful handling of equipment is required. It requires frequent maintenance [19].

V. **REVIEW OF DIFFERENT SOIL MOISTURE MEASUREMENT TECHNIQUES**
This includes review of four different techniques of soil moisture measurement [25, 26].

<table>
<thead>
<tr>
<th>Technique</th>
<th>Principle used and Methodology</th>
</tr>
</thead>
</table>
| **Gravimetric Method** (GM) | Depends on the weight of original sample and oven dried sample. Take Weight of the original sample (Wt) and oven dried sample (Ws). Calculate % M using the formula: \[
\text{Calculated } \% \text{ M} = \frac{Wt - Ws}{Ws} \times 100
\] |
| **Neutron Moderation** (NM) | Depends on the amount collision between fast neutrons and Hydrogen atoms in moisture. Insert probe into access tube & transmit EM wave. The propagation time required by sensor transmission waveguide gives the reading of % moisture content. |
| **Time Domain Reflectometer (TDR)** | Depends on the propagation time required by EM wave to transmit and reflect back from sensor transmission waveguide. Insert probe into access tube & transmit EM wave. The propagation time required for transmit & reflect back gives the % moisture content depending on the dielectric constant [2]. |
| **Tensiometer** | Depends on the suction produced by water into sealed tube coming into equilibrium with the soil solution through porous medium. Tip of ceramic cup is placed into the soil. Water is drawn out side to form equilibrium a suction is created inside tube. Depending on the amount of suction produced moisture content is indicated. |

Table 1: Technique & Principle used and Methodology

We can improve, Determination of soil moisture using microstrip antenna. This method is best suitable for soil moisture content.

Two microstrip antenna is used for transmitting and receiving the signal. One patch antenna is used as transmitter and other is receiver. Microstrip patch antenna have been designed to give a real-time, simple, sensitive, small size and low cost for soil moisture measurement.

Two rectangular patch sensors have been fabricated using microstrip feeding method and both patches were printed on low cost FR4 board, respectively. The proposed method combines the advantages of TDR-based measurement with the intrinsic non-invasiveness of the patch antenna used as the sensing element. This way, a correlation between the dielectric properties of a material and the reflection scattering parameter of the antenna, loaded with the material, was experimentally investigated [20].

So we have used this above method for measuring the soil moisture content.
Table 2: Methods & Criteria

<table>
<thead>
<tr>
<th>Methods</th>
<th>Cost effectiveness</th>
<th>Accuracy</th>
<th>Spatial scale</th>
<th>Response time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravimetric method</td>
<td>Economical</td>
<td>High</td>
<td>Limited</td>
<td>24 h</td>
</tr>
<tr>
<td>Neutron probe</td>
<td>Expensive</td>
<td>High</td>
<td>Limited</td>
<td>1–2 min</td>
</tr>
<tr>
<td>Time domain reflectometry</td>
<td>Economical</td>
<td>High</td>
<td>Limited</td>
<td>Instantaneous (<em>28 s)</em></td>
</tr>
<tr>
<td>Oven drying method</td>
<td>Inexpensive</td>
<td>High</td>
<td>limited</td>
<td>Relatively slow</td>
</tr>
</tbody>
</table>

VI. CONCLUSION

Irrigation is the biggest consumer of water. So farmers need to use water very carefully. Field can neither be under irrigated nor over irrigated. Accurate and appropriate moisture of soil is required for proper growth of plants and crops. Also, water is essential for survival of mankind, so this is required to be used with utter care and intelligence.

For this purpose the soil moisture measuring techniques can help them a lot. All the techniques have their own advantages and disadvantages. Comparing all techniques, it can be concluded that when one has to make a soil moisture system using antenna and embedded system, the soil moisture sensor is easy to interface. The problems faced by other systems are overcome by this microwave method as the system will give results in minimum fraction of time, accurate, nondestructive.

REFERENCES

[27] A report on Industrial Training, by Sameer Karadkar, Dept. of Technology, Shivaji University, Kolhapur