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DETERMINATION OF MOISTURE CONTENT IN SOIL BASED ON OVEN DRYING METHOD USING A MICROSTRIP PATCH SENSOR

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Abstract:

The proposed design is analyzed of a pentagon shape of microstrip sensor for determination the soil moisture measurement. The proposed design is useful in agricultural field as well as measured the moisture with accuracy and it is designed on FR4 substrate with 1.676 thicknesses. Many methods are used for detecting the moisture but oven drying method is very cheap and easy to install. A new 2.3 GHz soil moisture sensor using microstrip transmission line is presented with good return loss -28dB and gain 3.2dB. The main advantages of the proposed sensor will be its high accuracy, quickness of measurement, low cost and ease of implementation. Since the sensor has low power consumption.

Motivation/Background: The microstrip moisture sensor is helpful for detecting the moisture content of soil. The proposed patch sensor design is being beneficial in real time agricultural field for the determination of soil moisture content (MC). The actual moisture content in soil is determined using conventional, standard an oven drying method at operating frequency 2.3GHz with compact and low cost. The work has done at frequency range between 1GHz to 2GHz for detecting the soil moisture by using the cavity resonator technique and impedance bridge technique. These techniques are expensive, complex, no more accuracy and time consuming.

Method: The proposed design has fabricated on FR4 substrate with 1.676mm thickness. The simulation analysis has carried out with the help of CST software and the experimental values will be measured by vector network analyzer. The experiment will be performed on the samples of soil and the results shows that the proposed method will be able to detect the high moisture content with high sensitivity and accuracy.

Results: The proposed design, it will be very helpful for agricultural field because of got the good return loss as well as gain -28dB and 3.2dB at 2.3GHz and it can be fabricated and measured by the vector network analyzer

Conclusions: The proposed design is analyzed for detecting the moisture content with the suitable parameters with the help of CST software as well as used the direct (oven drying) method, this is very easy and less time consuming.

Keywords: *Microstrip Sensor; Moisture Content; CST; Vector Network Analyzer; Reflection Coefficient; Magnitude and Phase; Gain.*

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1. Introduction

When water is present in soil is called the soil moisture. The relation of soil and plant growth is important for plants as well as human beings also. In the other hand if we talk about the agricultural field soil is the important part of the vegetables, fruits, etc. Suppose when the soil is not good there is moisture present then we are cropping the plants that soil after sometimes plants will be decomposed it will be harmful. So, this is important how to check the soil this is good or not so we can detect the moisture with the help of microstrip patch sensor this process is very easy and less time consuming. Sometimes, some plants are capable for growing in wet soil but there will be effect on nutrients, proteins etc. They cannot be balance everything in soil water contained. The determination of soil water content is the important factor of to improve the efficiency of the plants growth. For irrigation, time is the important factor. It should be less time consuming as well as take decision suddenly.

Soil water acts as a nutrient itself. Soil water regulates soil temperature, soil forming processes and weathering depend on water. Microorganisms require water for their metabolic activities. Soil water helps in chemical and biological activities of soil. It is a principle constituent of the growing plant. Water is essential for photosynthesis retention of water by soil: The soils hold water (moisture) due to their colloidal properties and aggregation qualities. The water is held on the surface of the colloids and other particles and in the pores.

2. Materials and Methods

The design and analysis of a pentagon shape of microstrip sensor is designed for moisture measurement at design frequency of 2.3 GHz. The sensor is etched using the substrate FR-4 with the dielectric constant εr=4.4, $\tan\delta$ = 0.001 and h= 1.676 as well as defected the ground plane and cut the circle with outer radius 3mm and inner radius 1mm on patch as shown in figure 1 with the help of CST software and discussed all the parameters which is related to pentagon shape of moisture sensor as well as define the different parameters such as return loss, magnitude, phase, gain, smith chart. The antenna parameters are given below:

Table 1: Antenna parameters

Parameters	**Value**
Operating frequency	2.3GHz
Dielectric substrate	FR4
Dielectric constant	4.3
Substrate thickness	1.676
Substrate loss tangent	0.001

When the plants is absorb more water then they will be decomposed and not grow the vegetables and fruits so this is important factor firstly check completely the soil there will be cropped the plants they will give good results or not they will not be decomposed so this proposed sensor will be beneficial for detecting the moisture.

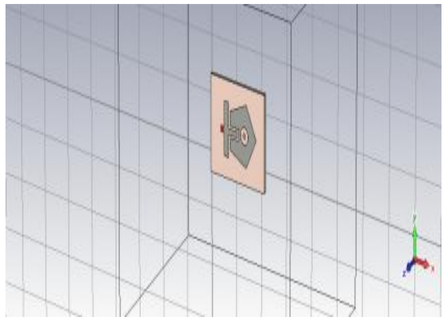

Figure 1: Structure of proposed moisture sensor

The microstrip patch antenna is designed with the help of some formulas such as effective dielectric constant "ε_{reff}", dielectric constant of substrate "ε_r", height of dielectric substrate "h", width of the patch "W" and the moisture will be determined with the help of oven drying method. The moisture content is ratio of the mass of water to dry mass of sample in percentage.
The expression for ε_{reff} is given as:

$$\varepsilon_{reff} = \left\{\left(\varepsilon_r + \frac{1}{2}\right) + \left(\varepsilon_r - \frac{1}{2}\right)\right\}\left[\left(1 + \frac{h}{W}\right)\right]^{-1/2}$$

Where, ε_{reff} = Effective dielectric constant
ε_r = Dielectric constant of substrate
h = Height of dielectric substrate
W = Width of the patch

The dimensions of the patch along its length have now been extended on each end by a distance ΔL, which is given empirically-

$$\Delta L = \frac{0.412h\,(\varepsilon_{eff} + 0.3)\left\{\left(\frac{W}{h}\right) + 0.264\right\}}{(\varepsilon_{reff} - 0.258)\left\{\left(\frac{W}{h}\right) + 0.8\right\}}$$

The effective length of the patch L_{eff} now becomes:
$L_{eff} = L + 2\Delta L$
For a given resonance frequency f_o , the effective length is given as

$$L_{eff} = \frac{C}{2f_\circ\,(\varepsilon_{reff})^{1/2}}$$

For a rectangular Microstrip patch antenna, the resonance frequency for any $_{TMmn}$ mode is given as-

$$f_\circ = \frac{C\,(\varepsilon_{reff})^{1/2}\left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right]}{2}$$

Where *m* and *n* are modes along *L* and *W* respectively.
For efficient radiation, the width *W* is given below-

$$W = \frac{C}{2f_{\circ}\left\{\frac{(\varepsilon_r + 1)}{2}\right\}}$$

The proposed design will be beneficial in agricultural field. The moisture can be detected with the help of oven drying method. Oven drying method is useful for agricultural field and the farmers because this technique is very easy and less time consuming. The moisture can be detected in percentage with the help of percentage moisture formula; it is the ratio of total mass of water to dry mass of sample. The slot in the ground is affected on the result parameters, when the slot is in the ground it will be affected on the capacitance and inductance; increased then return loss will be show the good result.

The complex permittivity also the important parameter of moisture content because the complex permittivity is interact the material. The coaxial feed 50Ω is directly connected to the patch and no more insertion loss.

3. Results And Discussions

The sensor is designed with defected the ground plane as shown in given figure 2 as well as discussed all the parameters which is related to sensor and useful for detecting the moisture as shown in figure 3 to 7. The return loss is good for detecting the moisture -28dB as well as gain is 3.2dB.

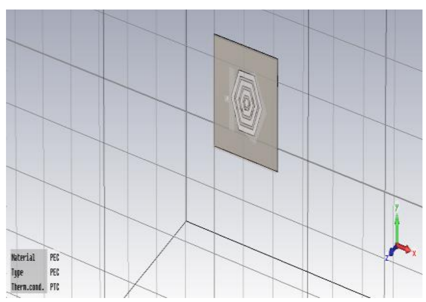

Figure 2: Back side of proposed moisture sensor

The coaxial feed technique is used in this design which is useful for the sensor because this is easy connect to patch, minimize the spurious radiation, and influence the input impedance. The two techniques can be used for detecting the moisture direct or indirect method. The direct method is easy, less time consuming.

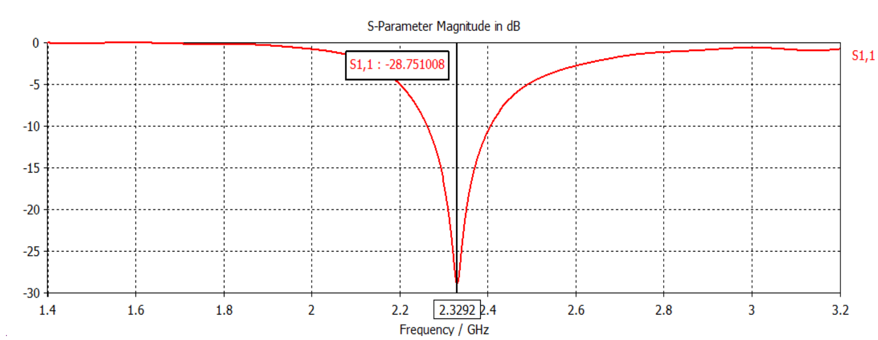

Figure 3: Return loss of proposed moisture sensor

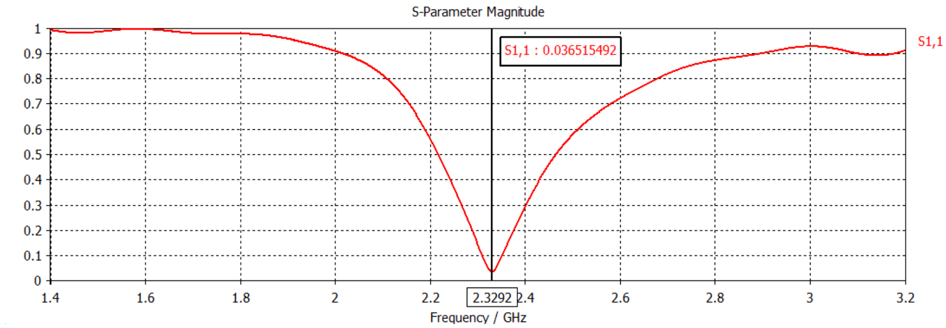

Figure 4: Magnitude of proposed moisture sensor

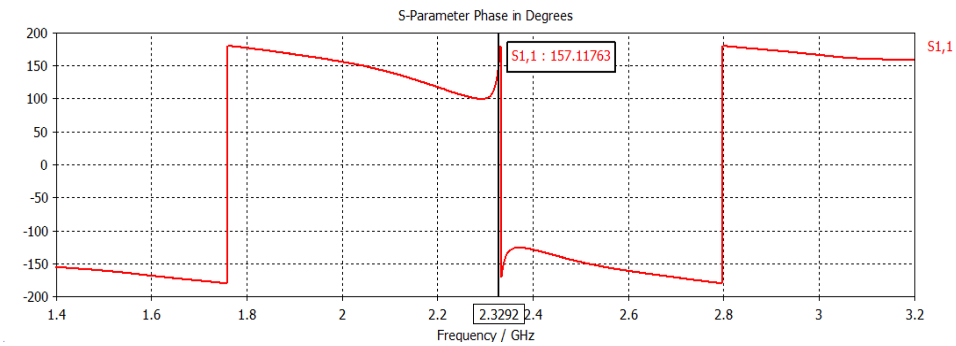

Figure 5: Phase of proposed moisture sensor

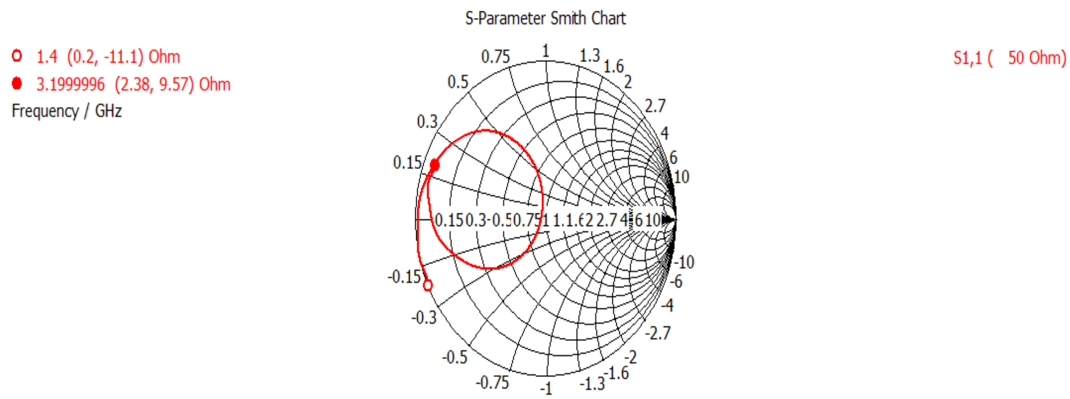

Figure 6: Smith Chart of proposed moisture sensor

Numerically, the moisture can be determined with the help of the calibration equation and regression. When the regression coefficient value will be increased in any frequency it will be show the high moisture content at operating frequency. The magnitude reflection coefficient parameters can be measured by the vector network analyzer.

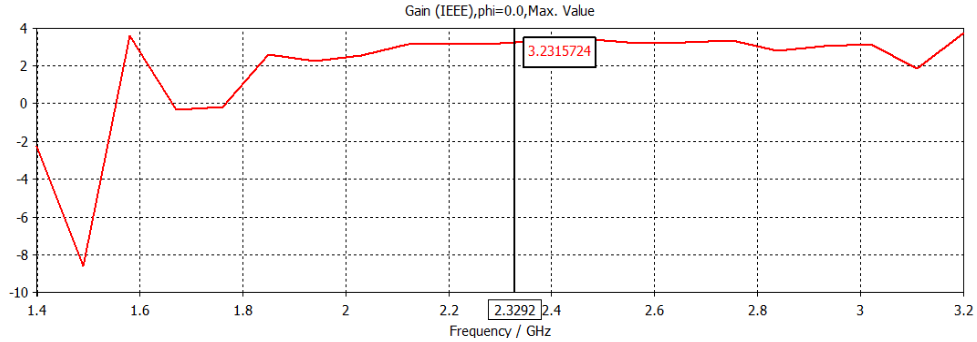

Figure 7: Gain of proposed moisture sensor

The variation with the reflection coefficient with frequency of the moisture sensor as given figure 8

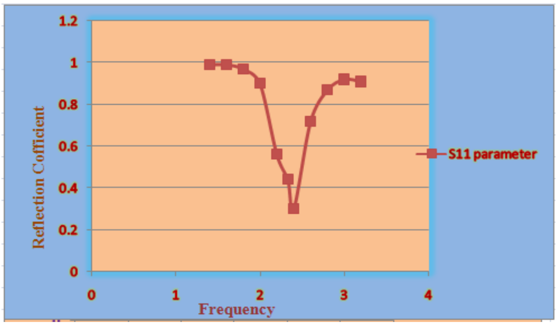

Figure 8: Variation with reflection coefficient with frequency

The comparison of return loss and gain of the microstrip moisture sensor as shown given figure 9.

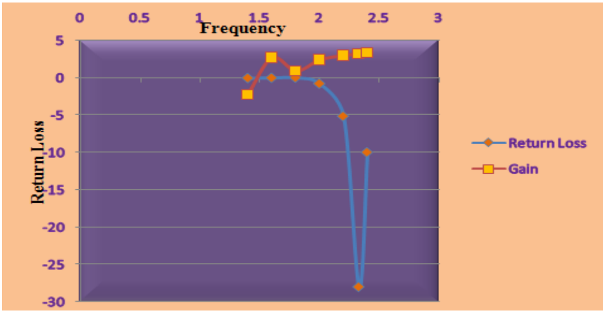

Figure 9: Comparison of Return loss and Gain

After getting the satisfied parameters this design can be fabricated and make the beneficial device in agricultural field. It will be fabricated on FR4 substrate and etching with the help of ferric chloride solution ($FECl_3$), connected the port with the help of soldering. Finally design will be fabricated it will be measured by the vector network analyzer.

4. Conclusion

The proposed design is analyzed for detecting the moisture content with the suitable parameters with the help of CST software as well as used the direct (oven drying) method, this is very easy and less time consuming. The moisture is measured up to the root zone of the crop. Thus it can be used to check the moisture value for any crop. Sensor can be placed vertically in the soil to check the depth of irrigated water and also it can be placed horizontally at different heights in the soil according to the crop. The variation of the magnitude reflection coefficient and the frequency is very important in the terms of moisture sensor.

It is clear that from the proposed design, it will be very helpful for agricultural field because of got the good return loss as well as gain -28dB and 3.2dB and it can be fabricated and measured by the vector network analyzer

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