

# Design and Analysis of Microstrip Moisture Sensor for the Determination of Moisture Content in Soil

Sweety Jain<sup>1\*</sup>, Pankaj Kumar Mishra<sup>2</sup> and Vandana Vikas Thakare<sup>3</sup>

<sup>1</sup>Department of Electronics, ASET, Amity University Gwalior – 474011, M.P, India;

1502sweety@gmail.com

<sup>2</sup>Department of Applied Physics, ASET, Amity University Gwalior – 474011, M.P., India;

pmishra@gwa.amity.edu

<sup>3</sup>Department of Electronics, MITS, Gwalior – 474011, M.P, India;

vandana@mitsgwalior.in

## Abstract

**Objectives:** To design new multiband antennas based on slotted rectangular patch antenna moisture sensor with comparative results to each other. The moisture sensors is compact size, easy design, low cost and have high quality responses which can be applied for determination of soil moisture measurement. A frequency reconfigurable antenna is presented with operating frequency between 2GHz to 5GHz. **Methods/Statistical Analysis:** A reconfigurable microstrip patch sensor is designed by using a slotted rectangular patch antenna for determination of soil moisture measurement. The length and width of the ground and patch is 30mm and 25mm as well as three slotted on the patch for accuracy. It is designed on FR-4 substrate with a relative dielectric constant 4.4 and thickness 1.6mm which is simulated by CST software as well as gets the magnitude and phase of modified design. **Findings:** The proposed antenna exhibits multi-frequency behavior. The modified antenna is capable for measuring the moisture between 2GHz to 5GHz. At these frequencies slotted rectangular patch antenna moisture sensor produces return loss 25dBi and capable for measure the moisture in soil with accuracy. When the resonant frequency is decreased with increase the moisture level. It will be designed for measuring the accuracy with a less time as well as triple resonant frequencies. The moisture content can be minimum and maximum at different frequencies and that can be considered for the better implementation of the approach by using the vector network analyzer. **Applications/Improvements:** In this paper a compact frequency reconfigurable microstrip patch antenna as a moisture sensor is presented with good return loss as well as resonant frequency for measuring the moisture in soil with accuracy as compare with the conventional one.

**Keywords:** CST, Microstrip Patch Antenna, Moisture Sensor, Return Loss, Resonant Frequency, Vector Network Analyzer

## 1. Introduction

Moisture content is a measure of the quantity of water in a product. Moisture content provides information about texture since increasing level of moisture provides water mobility<sup>1</sup>.

The moisture contents in materials like grains, seeds, food products. It is also important factor to determining

the market price because the dry matter of spices has more value than the water it contains<sup>2</sup>.

Sensor system is an important tool aimed at improving soil performance and soil quality. Moisture content in soil is essential characteristics in agricultural, civil, and hydrology<sup>3</sup> and the rectangular patch sensor as given Figure 1.

\* Author for correspondence

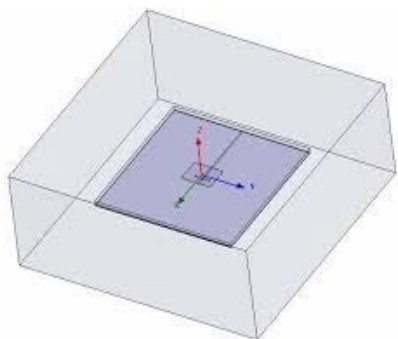


Figure 1. Rectangular Patch Sensor.

## 2. Principle of Moisture Soil Measurement

The various techniques have been used for measurement of microwave properties of materials in the time and frequency domain. It was good Measurement accuracy, simple, easy to design, dimensions are small and the measurement frequency range is as wide possible and it has swept frequency capability<sup>4-6</sup>.

The different types of the techniques have been used such as Transmission/Reflection techniques, Cavity resonator techniques, Slotted line techniques, Free-space techniques etc. In all the method, the preparation of the sample usually take much more time than the actual process of measurement but in the free space technique will eliminate the primary step of preparing the sample before measurements. It results in saving the time for measurements besides this increase in speed and simplicity the advantages were that there are no errors. It was used for measure the dielectric properties of moist popular materials at microwave frequencies. It was very useful in terms of non-destructive and non-contact measurement of the moisture content<sup>7-10</sup>.

The design has been proposed used by free space technique for the measurement of complex permittivity of wheat over a very broad frequency range<sup>11</sup>.

The method for dielectric properties and moisture sensor measurement of the seeds were introduced in terms of direct method and indirect method. Mostly, the proposed designs were introduced by the direct method. Water is an important component of many natural and man-made material understanding water behavior is fundamental in improving and preserving the quality of many of materials<sup>12-15</sup>.

RF/Microwaves technique was the direct method which was more suited for rapid determination of moisture content for automated industrial process and growing need for real time decision making<sup>16-20</sup>.

The moisture content expressed as -

$$M(\%) = \{M_w/M_w + M_d\} * 100$$

Here,

$M_w$  = Mass of water

$M_d$  = Mass of dry material

## 3. Sensor Configuration

The rectangular patch sensor is fabricated using the microstrip line feeding method and used FR4 substrate. The patch sensor is designed to provide dual resonant frequencies at the frequency between 4GHz to 5GHz by using the CST software.

The proposed is designed is a minimum sample thickness required to assume an infinite medium are investigated based on analysis and simulation results. The length and width of the ground and patch is 30mm and 25mm as well as three slotted on the patch for accuracy. The proposed is designed as given Figure 2.

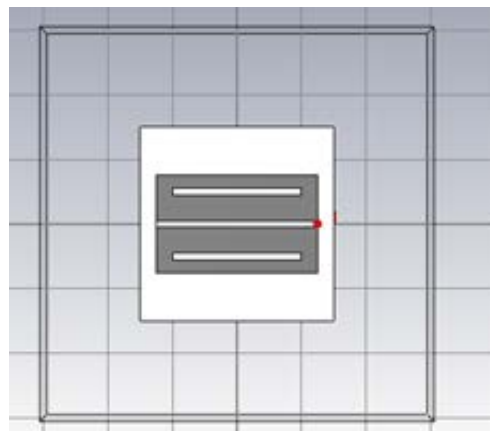


Figure 2. Conventional of Rectangular Patch Sensor.

The proposed is designed with the result by using the CST software. The simulation results are got between 4GHz to 5GHz as well as good return loss for measuring the moisture of soil, magnitude and the phase of sensor as shown Figure 3, 4, 5.

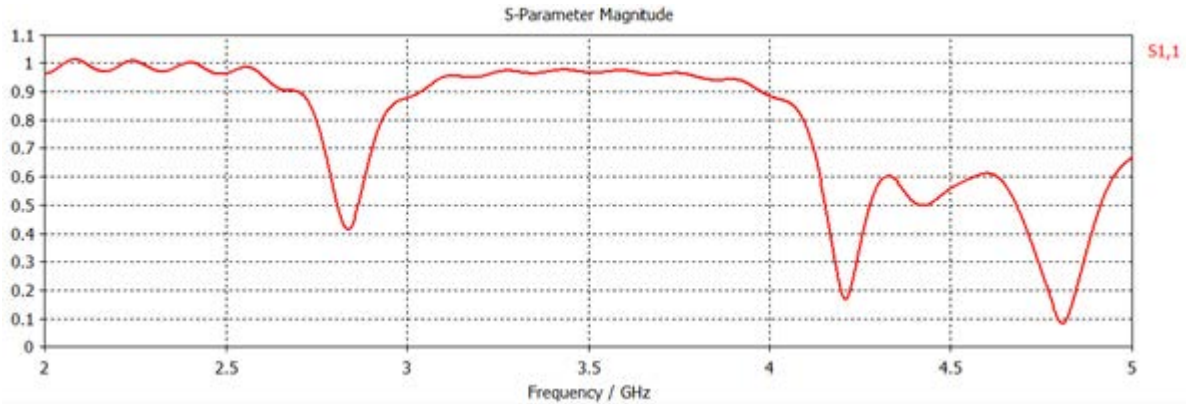


Figure 3. Return Loss of Conventional of Rectangular patch sensor.

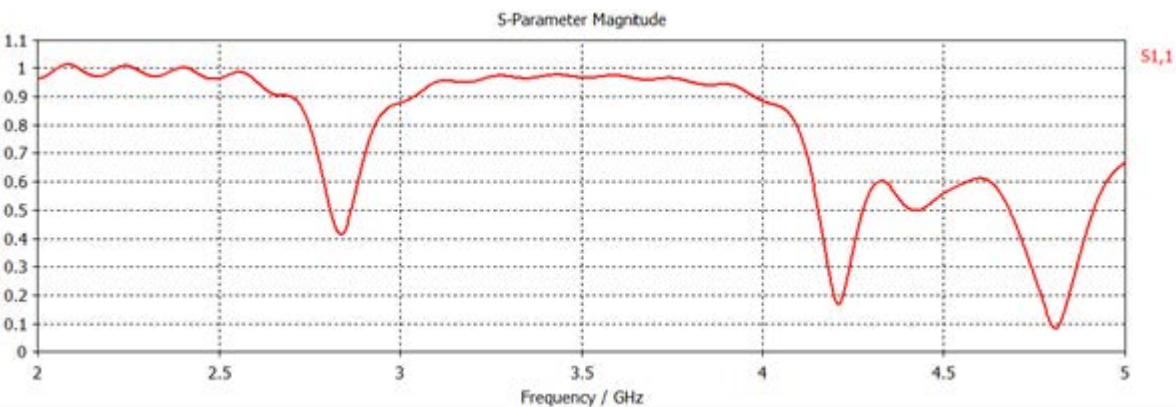


Figure 4. Magnitude of Conventional of Rectangular Patch Sensor.

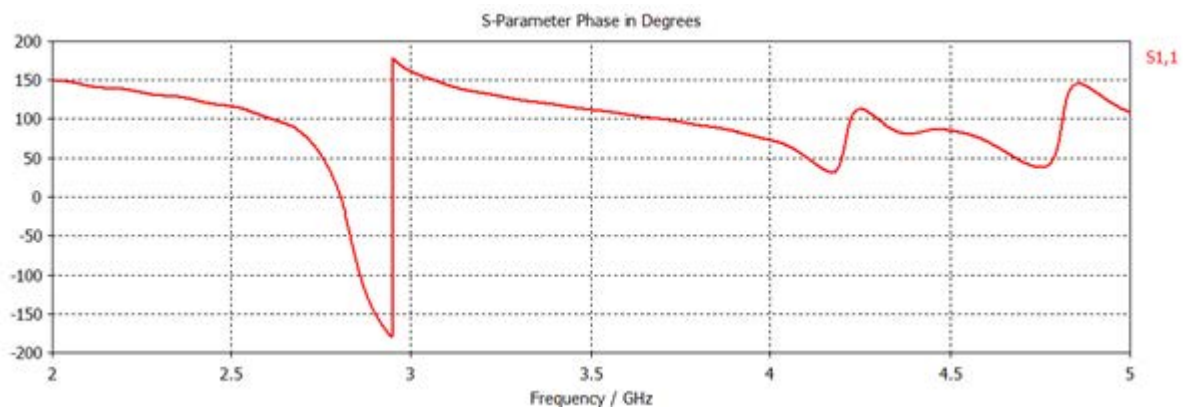


Figure 5. Phase of Conventional of Rectangular Patch Sensor.

The conventional design is modified a rectangular patch sensor for getting the more accuracy with the minimum time. In this design four slotted on the patch. The length and width of the patch is 25mm as shown Figure 6.

The result is simulated between 2GHz to 5GHz as well as triple resonant frequencies which will be used for detecting the moisture content measurement as well as understood by the magnitude and phase of the modified rectangular patch sensor as shown in Figure 7, 8, 9.

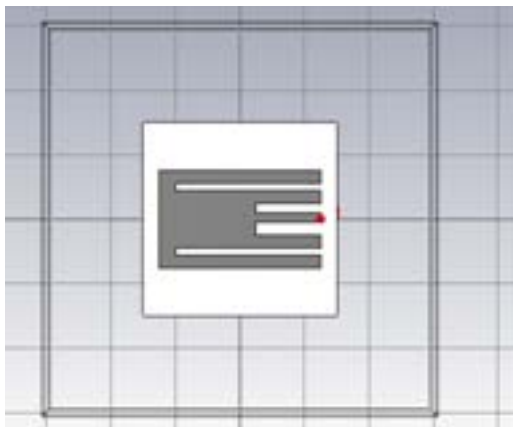


Figure 6. Modified of Rectangular Patch Sensor.

## 4. Results and Discussions

The conventional rectangular patch is designed that result between 4 GHz to 5GHz but return loss is -22. It is measured the soil moisture but there will not be more accuracy as well as measurement between the 4GHz to 5GHz but in the other hand modified rectangular patch sensor is also used for detecting the soil moisture but this is more beneficial such as it will be get accuracy, fastest measurement as well as detecting between the 2GHz to 5GHz as compare to conventional design. The conventional design (a) and modified design (b) as shown in given Figure 10 (a). and (b).

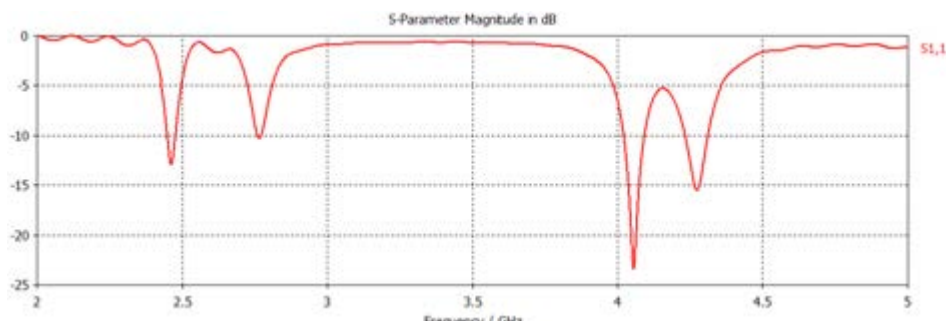


Figure 7. Return loss of Modified Rectangular Patch Sensor.

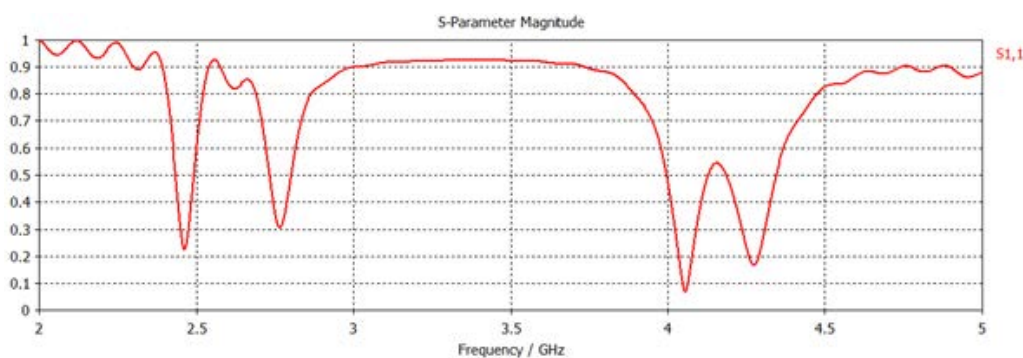


Figure 8. Phase of Modified of Rectangular Patch Sensor.

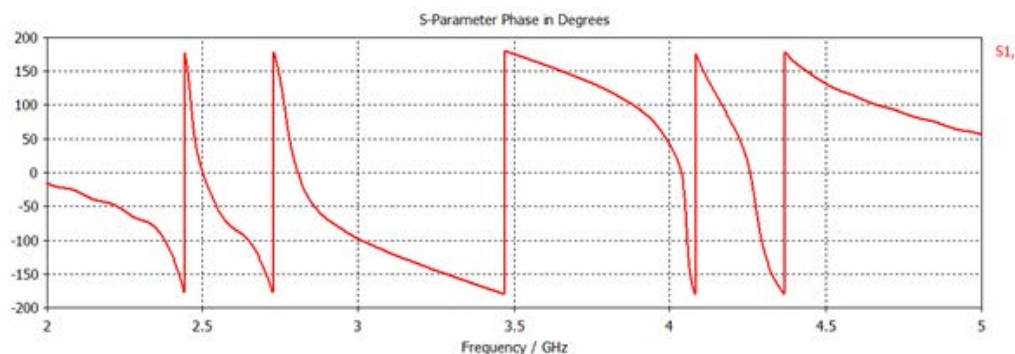
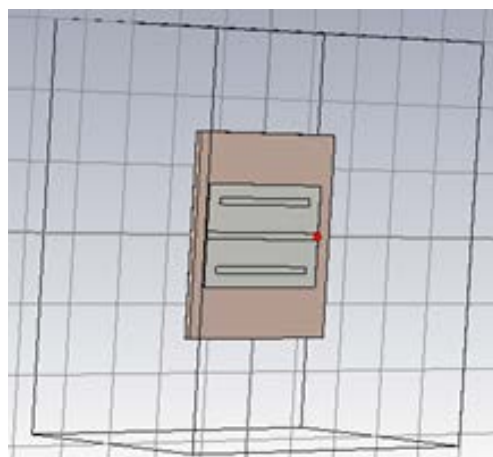
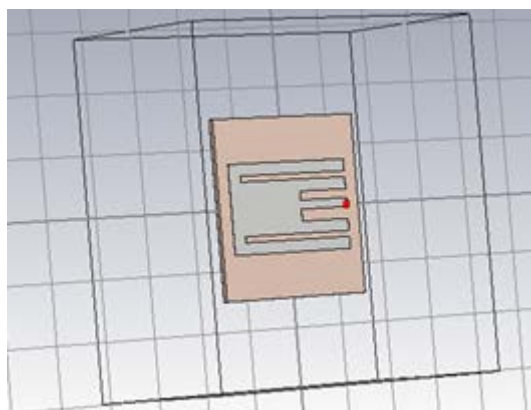


Figure 9. Phase of Modified of Rectangular Patch Sensor.

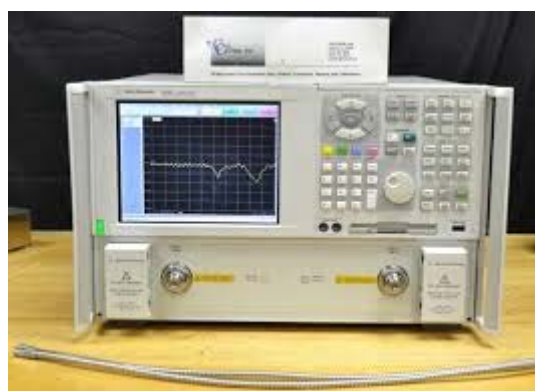




(a)



(b)



(c)

**Figure 10.** (a) Conventional of Rectangular Patch Sensor (b) Modified of Rectangular Patch Sensor (c) Vector Network Analyzer.

The modified rectangular patch sensor are designed that result between 2 GHz to 5GHz but return loss is

-25. The reflection coefficient is important parameter of moisture sensor. It will be measured by vector network analyzer in microwave laboratory. The part of soldering and the quality of SMA connectors are also the important factor to affect the deviation of simulation. The vector network analyzer is used to measure the transmission parameter  $S_{12}$  of the sensor with and without at the desired frequency as shown in Figure 10 (c)

## 5. Conclusion

The modified rectangular patch sensors are designed and analyzed by using the CST software for measuring the soil moisture. When the resonant frequency is decreased then increase the moisture level. It will be designed for measuring the soil moisture with a less time and as well as used in triple resonant frequencies. The moisture content can be minimum and maximum at different frequencies and that can be considered for the better implementation of the approach by using the vector network analyzer.

## 6. References

1. Guo C, Li T, Zhang Y. Numerical and Experimental study of a microstrip resonator moisture sensor. *AISS*. 2012; 4(19): 591–600.
2. Jackson B, Jayanthi T. Moisture content determination using microstrip fractal resonator sensor. *Research Journal of Applied Sciences, Engineering and Technology*. 2014; 7(14): 2994–97.
3. Mun HK, You KY, Dimon MN. Rice grain moisture determination using microstrip wide ring and microstrip coupled line sensors. *American Journal of Applied Sciences*. 2015; 12(2): 112–20.
4. Kraszewski AW, Trabelsi S, Nelson SO. Broadband microwave wheat permittivity measurements in free space. *J.MW. Power and Em Energy*. 2002; 37(1): 41–54.
5. Trabelsi S, Nelson S O, Raszewski A W K, Proc. of 19<sup>th</sup> IEEE transaction Instr. and Meas. Tech.; 2002, p. 1381–85.
6. Malathi C J, Thiripurasundari D. Review on isolation techniques in MIMO Antenna systems. *Indian Journal of Science and Technology*. 2015 Sep; 9(35): 1–10.
7. Pandhare RA, Zade PL, Abegaonkar MP. Harmonic control by defected ground structure on microstrip antenna array. *Indian Journal of Science and Technology*. 2015 Dec; 8(35): 1–5.
8. Monti CAG, Benedetto ED, Cannazza G, Tarricone L. A non invasive resonance based method for moisture content evaluation through microstrip antennas. *IEEE Transaction*

- on Instrumentation and Measurement. 2009; 58(5): 1420–26.
9. Dhariwal S, Lamba VK, Kumar A. Simulation and performance analysis of carbon nano-materials based patch antennas. *Indian Journal of Science and Technology*. 2016 Jan; 9(4): 1–8.
10. Nisha ASA. Hybrid coupled feed circularly polarized patch antenna for military applications. *Indian Journal of Science and Technology*. 2015 Nov; 8(29): 1–4.
11. Yeow YK, Abbas Z, Khalid K. Applications of microwave moisture sensor for determination of oil palm fruit ripeness. *Measurement Science Review*. 2010; 10(1): 7–14.
12. Singh D K, Kumar P, Rizvi NZ. Microstrip transmission line sensor for rice quality detection. *IJERGS*. 2014 June-July; 2(4): 589–98.
13. Mezall SY. New compact microstrip patch antenna: design and simulation results. *Indian Journal of Science and Technology*. 2016 Mar; 9(12): 1–6.
14. Rameswarudu ES, Sridevi PV. A Novel triple band planar microstrip patch antenna with defected ground structure. *Indian Journal of Science and Technology*. 2016 Jan; 9(3): 1–5.
15. Sarabandi K, Li ES. Microstrip ring resonator for soil moisture measurements. *IEEE Transaction on Geoscience and Remote Sensing*. 1997 Sep; 35(5): 1223–31.
16. Gao SC, Li LW. Small dual-frequency microstrip antenna., *IEEE Transaction on Vehicular Technology*. 2002 Jan; 51(1): 28–36.
17. Krauss JD. *Antenna and propagation*. 2nd Editions. McGraw-Hill international; 1988.
18. Balanis CA. *Antenna and Theory Analysis and design*. 3rd edition. John Wiley and Sons, Inc.; 2005.
19. Costantine J, Tawk Y, Christodoulou CG, Barbin SB. A star shaped reconfigurable patch antenna. *Proceedings, IMWS; Guadalajara, Mexico; IEEE*, 2009 Feb. p. 19–20.
20. You KY, Salleh J, Abbas Z, You LL. A rectangular patch antenna technique for the determination of moisture content in soil. *PIERS Proceedings; Cambridge: USA*; 2010. p. 850–54.