Design and Analysis of Moisture Sensor for Agricultural Application Based on Patch Antenna

[1] Sweety Jain, [2]Pankaj Kumar Mishra, [3]Jyoti Mishra, [4]Vandana Vikas Thakare
[1]Research Scholar, [2]Associate Professor, [3]Associate Professor, [4]Associate Professor
[1]Department of Electronics and Communication,
[1]Amity University Madhya Pradesh, Gwalior, India

Abstract : The proposed sensor was designed and analysis the determination of moisture content of wheat. The microstrip moisture sensor based on microstrip patch antenna. It ws used to design FR-4 substrate with relative permitivitty (ε_r), loss tangent (tanδ) and thickness (h) were 4.4, 0.001 and 1.676. The moisture sensor compact size was 11mm ×11mm. The microstrip moisture sensor (MMS) was designed at operating frequency 3.1GHz with achieved the better reflection coefficient -30dB, as well as maintained the VSWR (VSWR≤2) 1.06 at the operating frequency. The microstrip patch antenna as a sensor was discussed all the parameters of antenna such as E-Field, current density, power loss density, far field, magnitude and phase as well as reflection coefficient method. It was concluded that, the proposed sensor will be fabricated on FR-4 then sensor will be worked proper with accuracy by using the standard oven drying technique. The oven drying technique is easy to operate, high accuracy and sensitivity for detecting the moisture content.

IndexTerms **- Moisture Content (MC), Microstrip Patch Antenna, Reflection Coefficient, Wheat.**

I. INTRODUCTION

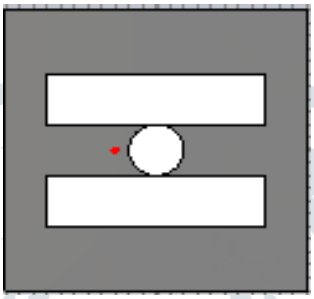
Microstrip patch antenna as a sensor is more useful in agricultural field [1]. The moisture content (MC) is an important factor in grains, when the moisture content is present in the grains then it can be destroy suddenly [2]. Wheat is more harvested between 20% and 14%. The most accurate detect the moisture content many techniques have been done such as free space technique, resonance technique and many techniques [3]-[4]. Many sensors have been designed but due to time consuming and expensive. After the oven drying technique has been introduced but few designs introduced in agricultural field The proposed design to determine the moisture content by the unknown materials as well as discussed the insertion loss and the complex permittivity [5], presented the optimal design based on three layers for detecting the moisture content of grains as well as analysis the computing and experimentally results for finding the effects of geometrical and electrical parameters [6]-[9], proposed the rice moisture sensor based on resistance type and developed the predictive model [10]-[13], designed the microstrip sensor for detecting the moisture content of oil palm fruit ripeness as well as determined the insertion loss of proposed design [14]-[17]. Recently, Microstrip antenna has widely used in communication system, industrial area, etc. But in the last few decades microstrip antenna as moisture sensor is also using in the agricultural field, industrial field, medical, and communication etc [18]-[22]. The proposed design will be determined the moisture from the rice grains. It will be worked on dual frequency at a same time Dielectric materials play an important role in our daily life especially every electronic circuit, which needs a dielectric medium to build the circuit. Typically high frequency electronics circuits are built on dielectric materials and the operation of all high frequency circuits depends on the dielectric properties of the material. In order to design high frequency circuits it is essential to have vital understanding of the properties of the dielectric materials especially the dielectric constant (real part of complex permittivity) and loss tangent at the operating conditions. [23]-[26]. The Co-axial feed technique is used to supply the signal source in the microstrip moisture sensor [27]. This feed is easy and direct contact to the patch as well as minimize the spurious radiation. The coaxial feed is important because this is influence the input impedance [28]. In microstrip patch sensor, there are many factors which is affect the performances of sensor such as size of the sensor, shape, room temperature, feed techniques, fabrication, etc. The calibration equation and regression is also the important role for detecting the moisture content. Numerically it can be detected the moisture. When the highest regression value will be present then the moisture is more available. The sensor is very useful in agricultural field and it can be measured by the vector network analyzer as well as dielectric properties is important parameter of sensor such as dielectric constant (ε_r) and loss tangent (tanδ) [29].

II. SENSOR DESIGN

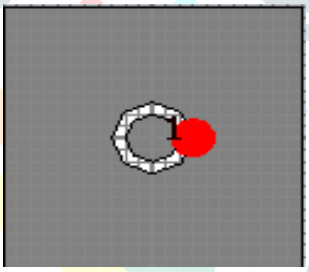
The proposed design is simulated with the help of CST microwave studio suit 10.0. The FR4 substrate with 1.676 mm thick, permittivity of material is 4.4, and loss tangent of 0.001 has been considered in design. The overall size of microstrip moisture sensor is 11×11 mm^2. The top view of the patch sensor with outer radius and inner radius 5mm and 2mm as shown in figure 1 (a). The back view of the patch sensor with outer radius and inner radius are 3mm and 2mm, which is defected in the ground (DGS) as shown in figure 1 (b). It is defected the ground in the back view of proposed design for achieved the better reflection coefficient and compactness.

Table 1 Microstrip moisture sensor optimized dimensions

Parameter	Value
Length of the ground (L)	11mm
Width of the ground (W)	11mm
Length of the substrate	11mm
Width of the substrate	11mm
Relative Permittivity (ε_r)	4.4
Loss Tangent (tanδ)	0.001
Top view outer radius of circle (R_o)	5mm
Top view inner radius of circle (R_i)	2mm
Back view outer radius of circle (R_o)	3mm
Back view inner radius of circle (R_i)	2mm



(a)



(b)

Figure 1. Microstrip patch sensor

III. RESULTS AND DISCUSSIONS

The reflection coefficient achieved the 10dB with -30dB, as well as maintained the VSWR is 1.06 as shown in figure 2 and 3.

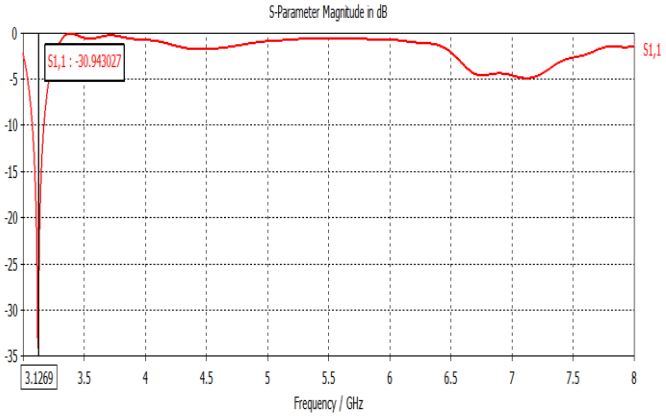


Figure 2. Reflection Coefficient of proposed sensor

The reflection coefficient (Γ) is used to measure the impedance match between the transmission line of Z_o and the terminal load impedance Z_i. The measured (Γ) from terminal impedance Z_i is defined as:

$$|\Gamma| = (Z_i - Z_o)/ (Z_i - Z_o) \quad (1)$$

For a non-magnetic medium, the antenna modelling theorem can be expressed mathematically as,

$$Z_i(\omega,\varepsilon') / \eta = Z_i(n\omega,\varepsilon') / \eta_o \quad (2)$$

Where,

$\omega = 2\Pi f$ is the angular frequency in radians

$\eta = (\mu_o/\varepsilon^*)^{1/2}$ is the complex intrinsic impedance of the dielectric medium

$\eta_o = (\mu_o/\varepsilon_o)^{1/2}$ is the intrinsic impedance of the free space

ε_o = free space of permittivity

μ_o = free space of permeability

$n = (\varepsilon^*/\varepsilon_o)^{1/2}$ is the complex refractive index of the dielectric medium relative to that of air.

The E-Field and H-Field of the proposed sensor are 14676 V/m and 52.4A/m as shown in figure 4 and 5. E-Field is used to determined the as a force per unit magnetic charge, but H-Field is the orthogonal direction of propagation in a plane wave. It is determined the direction of maximum radiation. The current density is 118A/m^2 and the axial ratio is 40dB as shown in figure 6 and 7. The proposed design parameters satisfied the all condition, it is used to determine the losses of the antennas as well as it will be worked proper, maximum radiation is transmitting and reflecting. The maximum current distribution is 73.4A/m, it shows the maximum current in an antenna as shown in figure 8. The proposed microstrip patch antenna (MPA) as a sensor after satisfying all the parameters, it can be determined the mean relative error (MRE) between the predicted moisture content (PMC) and actual moisture content (AMC).

The predicted moisture content (PMC) can be determined at selected frequencies with the help of vector network analyzer (VNA).

The different techniques have been used to determine the moisture content but due to time consuming and low accuracy, then introduced the standard oven drying technique this technique is useful to determine the moisture content as well as no time consuming and accuracy.

The standard oven drying technique will be used to determined the actual moisture content-

$$\text{Moisture Content (\%)} = \frac{m_{wet}-m_{dry}}{m_{wet}} \times 100 \quad (3)$$

Where, m_{wet} and m_{dry} are the initial and final mass before and after drying.

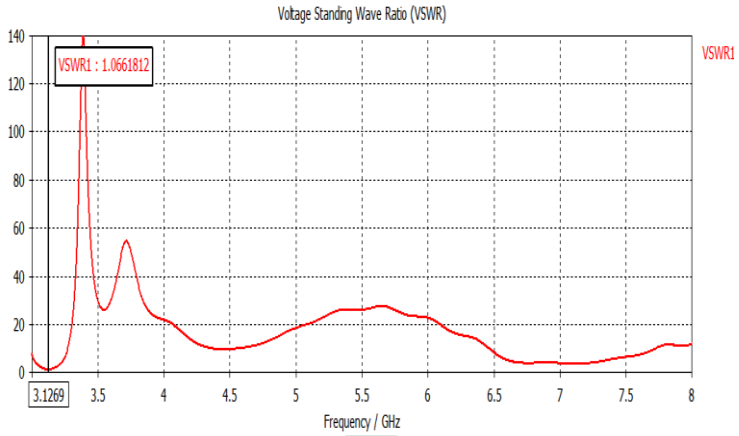


Figure 3. VSWR of proposed sensor

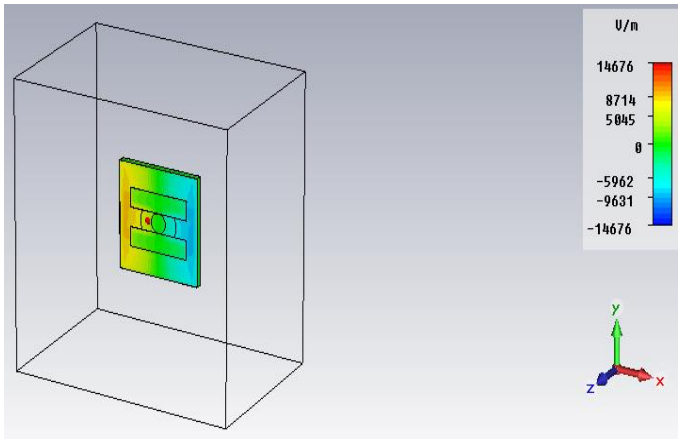


Figure 4. E-Field of proposed sensor

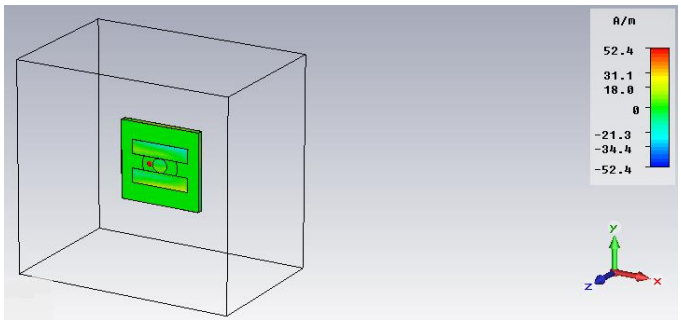


Figure 5. H-Field of proposed sensor

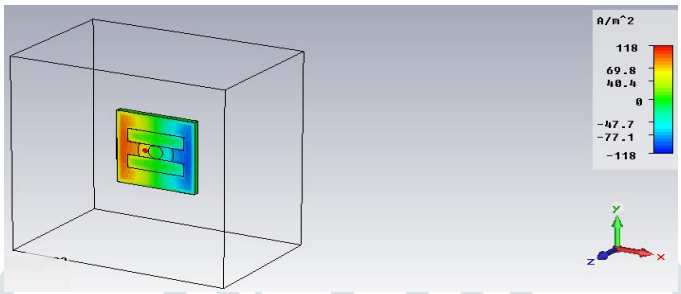


Figure 6. Current Density of proposed sensor

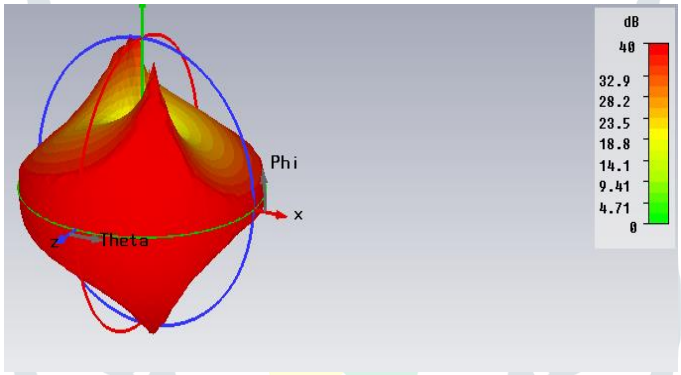


Figure 7. Axial Ratio of proposed sensor

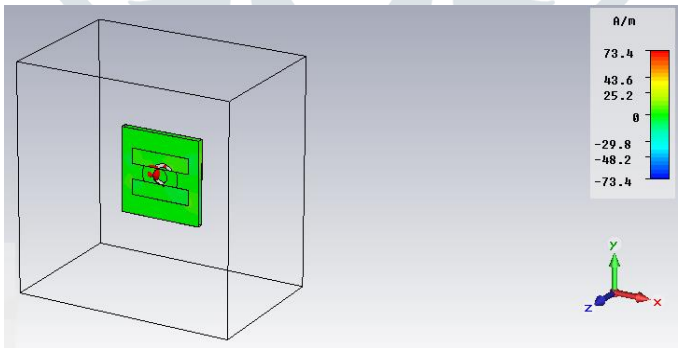


Figure 8. Surface Current Distribution of proposed sensor

IV. CONCLUSION

The proposed microstrip moisture sensor was designed and analyzed with the help of CST software and satisfied all the parameters such as VSWR, E-Field, H-Field, current density, axial ratio, and surface current distribution at 3.1GHz. It can be fabricated for detecting the moisture content of grains. The proposed design wass compact size $11\times11mm^2$. It will be fabricated on FR-4 PCB substrate. The actual moisture content and predicted moisture content can be determined by the calibration equation and standard oven drying technique. The microstrip patch antenna can be used to determine the moisture content in wheat as well as useful in agricultural applications.

REFERENCE

[1] A.F. Ahmad, Z. Abbas, Suzan J. Obaiys, M.A. Jusoh and Z.A. Talib. 2012. Analysis and optimal design of a microstrip sensor for moisture content in rubber latex measurement: Adv. Studies theory Physics, 6(2): 49-62.

[2] K. K. Joshi, Mahesh Abegaonkar, R. N. Karekar and R. C. Aiyer. 1997. Microstrip ring resonator as a moisture sensor for wheat grains: IEEE, 1679-1682.

[3] Haiying Huang. 2013. Flexible wireless antenna sensor: A Review: IEEE Sensors journal, 13(10): 3865-3872.

[4] Sweety Jain, Pankaj Kumar Mishra, Vandana Vikas Thakare. 2016. Analysis of moisture sensor based on microstrip patch antenna: A review: International conference on futuristic trends in engineering science, humanities and technology (FTESHT-16), 3(1): 64-67.

[5] Wentworth M. Stuart. 2005. Fundamentals of Electromagnetic with Engineering Applications: John Wiley & Sons, NJ, USA: 442- 445.

[6] P. Bhartia, I. Bahl, R. Garg, and A. Ittipiboon. 2000. Microstrip Antenna Design Handbook: Artech House, Norwood, Mass, USA.

[7] Sweety Jain, Pankaj Kumar Mishra, Vandana Vikas Thakare. 2016. Design and analysis of dual-frequency microwave moisture sensor based on rectangular microstrip antenna: 4th International workshop/conference on computational condensed matter physics and materials science (IWCCMP-2016), 18-20 November, at IIITM, Madhya Pradesh.

[8] J. R. James, P. S. Hall, and C. Wood. 1986. Microstrip Antenna Theory and Design: Peter Peregrinus, London, UK.

[9] R. F. Harrington and J. Mautz. 1971. Theory of characteristic modes for conducting bodies: IEEE Transactions on Antennas and Propagation, 19(5): 622–628.

[10] Sweety Jain, Pankaj Kumar Mishra, Vandana Vikas Thakare. 2016. The analysis and design of circular microstrip moisture sensor for rice grain: 4th International workshop/conference on computational condensed matter physics and materials science (IWCCMP-2016), 18-20 November at IIITM, Madhya Pradesh.

[11] Abegaonkar, M.P., R.N. Karekar and R.C. Aiyer. 1999. A microwave microstrip ring resonator as a moisture sensor for biomaterials: Application to wheat grains. Meas. Sci. Technol., 10: 195-200. DOI: 10.1088/0957-0233/10/3/014

[12] Hamza, Z. P., K. F. Anna Dilfi, M. N. Muralidharan, and K. Thomas. 2008. Microwave oven for the rapid determination of total solids content of natural rubber latex: International Journal of Polymeric Materials, 57(9): 918–923.

[13] Sweety Jain, Pankaj Kumar Mishra, Vandana Vikas Thakare. 2016. Design and Analysis of microstrip moisture sensor for the determination of moisture content in soil: Indian journal of science and technology, 9(43):1-6, DOI: 10.17485/ijst/2016/v9i43/101065.

[14] Sweety Jain, Pankaj Kumar Mishra, Vandana Vikas Thakare. 2017. A Rectangular microstrip moisture sensor based on microwave measurement technique: SKIT Research Journal, 7(1):30-33.

[15] M.Kent. 1973. The use of stripline configuration in microwave moisture measurements: Journal of microwave power, 8(2):189-194.

[16] K. B. Khalid, T. S. M. Maclean, M. Razaz, P. W. WEBB. 1988. Analysis and optimal design of microstrip sensor: IEE proceedings, 135(3):187-195.

[17] Sweety Jain, Pankaj Kumar Mishra, Vandana Vikas Thakare. 2017. Bandwidth and Gain enhancement in microstrip moisture sensor for agricultural applications: Indian journal of science and engineering research 1(1), 37-40.

[18] Sweety Jain, Pankaj Kumar Mishra, Vandana Vikas Thakare. 2017. Design and development of microstrip sensor with triple frequency for determination of rice grains moisture content: International journal of mechanical and production engineering research and development (IJMPERD), 7(5): 375-380.

[19] I.Gagnadre, C.Gagnadre, J.P. Fenelon. 1995. Circular patch antenna sensor for moisture content measurement on dielectric material: Electronic Letters, 31(14):1167-1168.

[20] K. Sarabandi, E.S. Li. 1997. A microstrip ring resonator for soil moisture measurements: IEEE Transaction on Geosciences and Remote Sensing, 35: 1223–1231.

[21] Trabelsi S., Kraszewski A.W., Nelson S.O. 1997. A new density independent function for microwave moisture content determination in particulate materials: Proc. IEEE Instrumentation & Measurement Technology Conference sensing, processing, networking, 1: 648-652.

[22] Sweety Jain, Pankaj Kumar Mishra, Vandana Vikas Thakare. 2018. Determination of moisture content in soil based on oven drying method using a microstrip patch sensor: International journal of engineering technologies and management research (CINSP-2018), 5(2): 233-239, DOI: 10.5281/zenodo.1202501.

[23] Sweety Jain, Pankaj Kumar Mishra, Vandana Vikas Thakare. 2019. Rice Moisture Detection Based on Oven Drying Technique using microstrip ring sensor: Engineering Vibration, Communication and Information Processing Lexture notes in electrical engineering, 99-109.

[24] Sweety Jain, Pankaj Kumar Mishra, Vandana Vikas Thakare. 2018. Analysis and Optimal design of moisture sensor for rice grain moisture measurement: American Institute of physics, doi: 10.1063/1.5028775, 060005 (1-3).

[25] Elen Semouchkina,Wenwu Cao,Raj Mittra, and Wenhua Yu. 2001. Analysis of Resonance Processes in Microstrip ring Resonators by the FDTD Method: Microwave and optical technology letters, 28(5): 312-321.

[26] J.O. Curtis. 2001. Moisture effects on the dielectric properties of soil: IEEE Transaction on Geosciences and Remote Sensing, 39(1):125–128.

[27] Thomas J. Jacson, Albin. J. Gasiewski, Anna Oldak, Marian Klein, Eni G. N joku, Aleksander Yevgrafov, Sven Christiani and Rajat Bindlish. 2002. Soil moisture retrieval using the C-Band polarimetric scanning radiometer during the southern great plains 1999 experiments: IEEE Transactions on geosciences and remote sensing, 40(10):2151-2161.

[28] G. Biffi Gentili, G. Avitabile, C. Riminesi, N. Sottani, V. Tesi. 2002. Microwave system for moisture mapping by a linear array of slot sensors: Sensors for industry conference houtan texas: 32-34.

[29] S.Trabelsi, and S.O. Nelson. 2003. Free-space measurement of dielectric properties of cereal grain and oilseed at microwave frequencies: Measurement Science and Technology, 14(5):589-600.