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Early Detection of Salt and Sugar by Microstrip Moisture Sensor Based on Direct Transmission Method

Sweety Jain[1]

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Abstract
Microstrip Moisture Sensor is designed for detection of dissolved salt and sugar in liquid medium. Sensor size is, determined by CST software analysis, 50 mm × 50 mm fabricated on FR 4 substrate which is low cost and easily available. Sensor is designed for four frequency, 3.4 GHz, 5.8 GHz, 6.2 GHz and 8.9 GHz, selected between the range of 3 GHz to 9 GHz. These four frequency is selected because of having lowest reflection coefficient between 3 to 9 GHz. To check the accuracy of sensor, whether it is eligible to work, gain and efficiency is determined for ideal (simulated, calculated from CST software) and actual (measured, determined by VNA). Simulated gain and efficiency are found to be approximately equal to measured gain and efficiency. Hence, it can be conclude that sensor is applicable for detection of salt and sugar. Now, sensor is tested for salt and sugar solution, each having four samples. This microstrip moisture sensor is work on the principle of direct transmission method which is based upon the amount of absorption of radiation in the solution. Amount of absorption of radiation by the solution is given by VNA, termed as reflection coefficient. Higher the salt or sugar, absorption will be more and results in increase of reflection coefficient. It means design sensor is accurate. Hence, it can be say that sensor is now available for detection of salt and sugar, having applications in various field such as food industry, construction industry for water supply engineering.

Keywords CST · Microstrip sensor · Salt · Sensor · Sugar · VNA

1 Introduction

Being a daily essential requirement of human life, salt and sugar can prove to be a responsible for good health. If salt is taken as per requirement then it can play important role in nerve conduction, flood balance and kidney functioning. While limited intake of sugar, it made better liver functioning and even provides energy to the body. But, with the frequently changes in food habits of population such as intake of processed food, cold drinks etc. it has become necessary to early detection of salt and sugar in these food items so that

✉ Sweety Jain
1502sweety@gmail.com

[1] Department of Electronics and Communication Engineering, Samrat Ashok Technological Institute (Govt. Aided Institution), Vidisha, Madhya Pradesh, India

people would not eat excess amount of salt and sugar. Because it may lead to various diseases such as diabetes, chronic diseases. As per WHO recommendation salt intake should not be in excess of 5 g per day [1] while as per ICMR recommendation sugar intake should be 30 g per day [2].

Apart from health sector, construction sector also not far behind in terms of salt criteria. During curing or concrete making process, water required should not contain excess amount of salt. IS 456:2000 [Plain and Reinforced Concrete] recommended for not using sea water for curing. But, in spite of this, water used for curing and other purposes should be tested for such impurities, otherwise excess amount of such impurities may lead to shrinkage and efflorescence in concrete. Similar phenomenon is also true for bricks.

Aiming for detection of salt and sugar, microstrip sensor is designed having for four frequency in the range of 3 to 9 GHz and working performance of sensor is determined with the help of gain and efficiency factor. This sensor will proved to be low cost, quick and accurate than previously fabricated sensors such as antenna was designed as a sensor for detecting the salt and sugar (24 mm × 18 mm) with tuning fork shape patch slotted on ground plane, fabricated on RT/duroid 5880 substrate at 9.70 GHz [3], psi shaped patch (24 mm × 18 mm) with slotted on ground plane at 16 GHz [4], crescent shaped patch (32 mm × 22 mm) slotted partial ground at 3.2 GHz, 8.7 GHz, 11.6 GHz and 14.5 GHz [5]. Microstrip patch antennas as a sensor play a very important role many fields such as medical, agricultural, communication etc. [6–9], discussed the enhancement of reflection coefficient for circular ring microstrip moisture sensor [10], design and analysed the microstrip moisture sensor for wheat grains [11], hevea latex rubber [12]. Microstrip patch antenna as a sensor is very beneficial in every fields whether communication, agriculture or biomedical with the different bands such as dual or triple as well as focused the size of antenna [13–20].

2 Working Pricinciple of Microstrip Patch Antenna as a Sensor

The concept of microstrip patch antenna (MPA) was first introduced in 1953 by G.A. Deschamps. MPA as a sensor designed, fabricated on the printed circuit board (PCB) in 1970. Further it has also been used to detect the ripe fruits. Microwave sensors (MS) utilize electromagnetic field (EMF) and devices internally at operating frequencies starting from ~ 300 mega hertz (MHz) up to tera hertz (THz) ranges. Although, MS are widely used in various fields such as, agriculture, industrial, food products, medicals, communication etc.

The three important parts to design the microstrip patch sensor are: ground plane, dielectric substrate and radiation patch. In microstrip sensor the upper surface of the dielectric substrate supports the printed conducting strip which is suitably contoured while the lower surface of the substrate is backed by a conducting ground plane. The patch is generally made of conducting material such as copper and structure can be design in various shapes.

Electromagnetic radiation originates from fringing ground which is generated by patch and directs to substrate. Hence, the performance of microstrip patch sensor affected from the permittivity of substrate and patch size directly. While signal sources to the patch originated from coaxial or probe feeding mechanism. This feeding mechanism is directly attached to the patch and this results in minimize of fraudulent radiation. Hence, the antenna able to operate at large bandwidth. Patch size affects the performance of antenna in such a way that with change in patch size, it will change resonance frequency of antenna. In this paper discusses the microstrip patch antenna as sensor for measurement of reflection

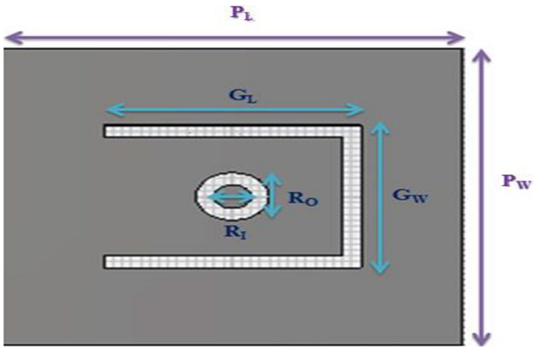

Fig. 1 Schematic view of microstrip sensor

Fig. 2 Fabricated of microstrip sensor

coefficient of sensing antenna in salt and sugar solution. According to Ref. [21], dielectric constant affected by the increment or decrement of samples salt and sugar solution. In Ref. [22], when the salt is added in water, the dielectric properties change due to the bond of dissolved ions and water molecules. This results in minimization of polarization of water and reduction of dielectric constant. Similarly, In Ref. [23], for sugar, when sugar added to water the molecules of sugar bonded with molecules of water and results in minimization of polarization of water molecules and reduction in dielectric constant. Hence, with the reduction in dielectric constant the load impedance increases while reflection coefficient decreases.

3 Design and Fabrication of Microstrip Sensor

The layout and prototype of designed microstrip sensor shown in Figs. 1 and 2. The CST optimized microstrip sensor parameters as shown in Table 1. The size of the sensor is 50×50 mm^2. The FR-4 material sheet is used to fabricate the sensor and energized using 50 Ω SMA connector. The parameters of the sensor are: $P_L = 50$ mm, $P_W = 50$ mm $G_L = 28$ mm, $G_W = 10$ mm, $R_O = 4$ mm, $R_I = 2$ mm.

The sensor is designed for four frequency, 3.4 GHz, 5.8 GHz, 6.2 GHz and 8.9 GHz, having lowest reflection coefficient in both simulated and measured, in the range of 3 to 9 GHz as shown in Fig. 3. Simulated reflection coefficient found to be −26.12 dB, −21.62 dB, −33.76 dB, and −15.88 dB while measured reflection coefficient of −24.73 dB, −20.

Table 1 CST optimized microstrip sensor parameters

Parameter	Value
Length of the ground (L)	50 mm
Width of the ground (W)	50 mm
Length of the substrate	50 mm
Width of the substrate	50 mm
Relative Permittivity (εr)	4.4
Loss Tangent (tanδ)	0.001
Thickness (h)	1.676 mm

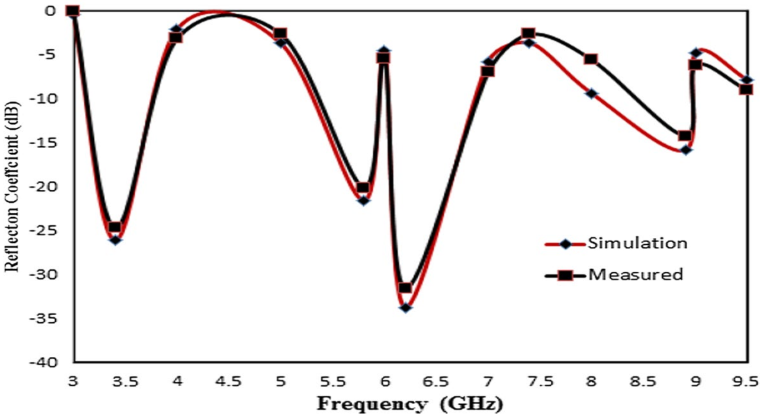

Fig. 3 Variation between reflection coefficient and frequency

15 dB, − 31.62 dB and − 14.62 dB respectively for frequency 3.4 GHz, 5.8 GHz, 6.2 GHz and 8.9 GHz.

Various checks applied for sensor accuracy analysis such as gain and efficiency as shown in Figs. 4 and 5. Simulated gain found to be 5.3 dBi, 4.6 dBi, 5.9 dBi, and 3.9 dBi while measured gain of 4.9dBi, 4.2dBi, 5.7 dBi and 3.5dBi respectively for frequency 3.4 GHz, 5.8 GHz, 6.2 GHz and 8.9 GHz. Similarly simulated efficiency found to be 78%, 88.68%, 95%, 71% while measured efficiency 75.44%, 85%, 90% and 69% respectively. Hence, it can be concluded that measured gain and efficiency is approximately equal to simulated gain and efficiency. Therefore sensor is adoptable.

4 Results and Discussion

4.1 Method of Working

Sensor works on direct transmission method for the detection of dissolved salt and sugar. In this method, sensor is dipped in a transparent glass having dissolved salt or sugar. Sensor's port connected to the vector network analyser (VNA). When experiment gets started, radiation emitted from the sensor in the solution. Amount of absorption of radiation by the

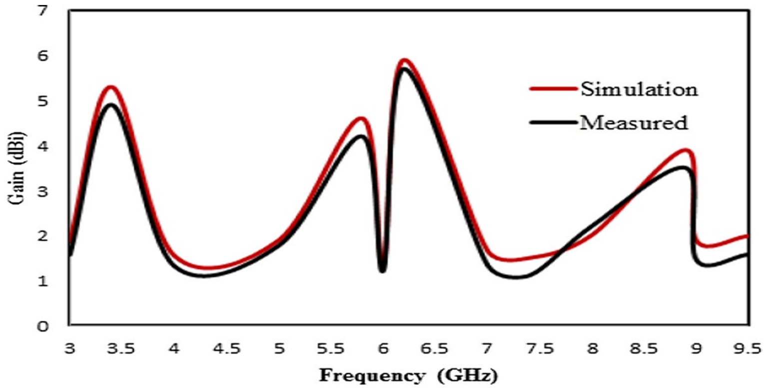

Fig. 4 Variation between gain and frequency

Fig. 5 Variation between efficiency and frequency

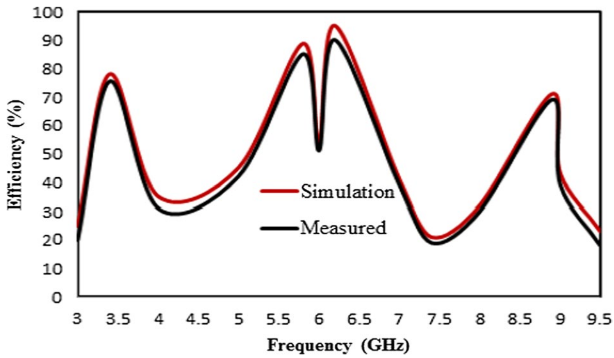

Fig. 6 Measurement setup

solution is given by VNA, termed as reflection coefficient as shown in figure 6. Higher the salt or sugar, absorption will be more and results in increase of reflection coefficient.

4.2 Performance of Sensor

Experiments conducted for 8 samples ,4 each for salt and sugar, in 250ml of water for each case. Beginning with salt solution is made for 20 gram, 30 gram, 40gram and 50 gram separately. By considering direct transmission method, reflection coefficient is achieved for each case of solution at 3.4 GHz, 5.8 GHz, 6.2 GHz and 8.9 GHz as shown in table 2.

Figure 7 also clarifies that sensor is accurate because reflection coefficient obtained for four samples of salt is increasing with increase in quantity of salt at 3.4 GHz, 5.8 GHz, 6.2 GHz and 8.9 GHz. Hence, satisfying the criteria of direct transmission method.

Similarly, in second part of study, sugar is taken as sample whose solution is also made in 250 ml of water for 20 g, 30 g, 40 g and 50 g. With the help of direct transmission method, reflection coefficient obtained is shown in Table 3.

Like as salt, for sugar sensor proved has proved accurate as shown in Fig. 8. Here also it is found that with the increase of sugar reflection coefficient also increased. Hence direct transmission method has satisfied. So, it can be concluded that sensor is able to detect salt and sugar.

Table 2 Reflection coefficient for the different concentrated salt in water in different frequencies

Frequency (GHz)	20 g (dB)	30 g (dB)	40 g (dB)	50 g (dB)
3.4 GHz	− 22.16	− 18.63	− 12.42	− 9.63
5.8 GHz	− 19.72	− 14.63	− 8.24	− 6.42
6.2 GHz	− 27.43	− 21.62	− 13.43	− 7.68
8.9 GHz	− 12.99	− 9.43	− 8.27	− 5.43

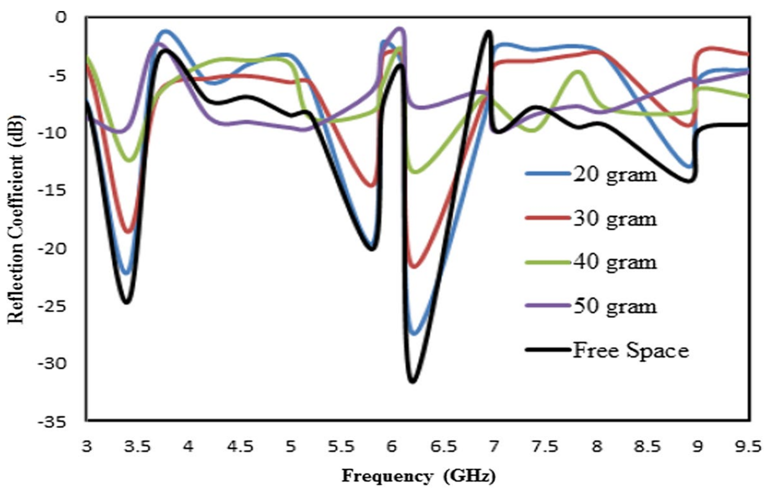

Fig. 7 Reflection coefficient variation with the different quantity (gram) of salt in water

Table 3 Reflection coefficient for the different concentrated salt in water in different frequencies

Frequency (GHz)	20 g (dB)	30 g (dB)	40 g (dB)	50 g (dB)
3.4	− 21.73	− 17.66	− 12.66	− 9.22
5.8	− 18.62	− 14.55	− 7.16	− 7.88
6.2	− 27.22	− 20.15	− 11.46	− 9.16
8.9	− 11.68	− 9.12	− 7.24	− 6.22

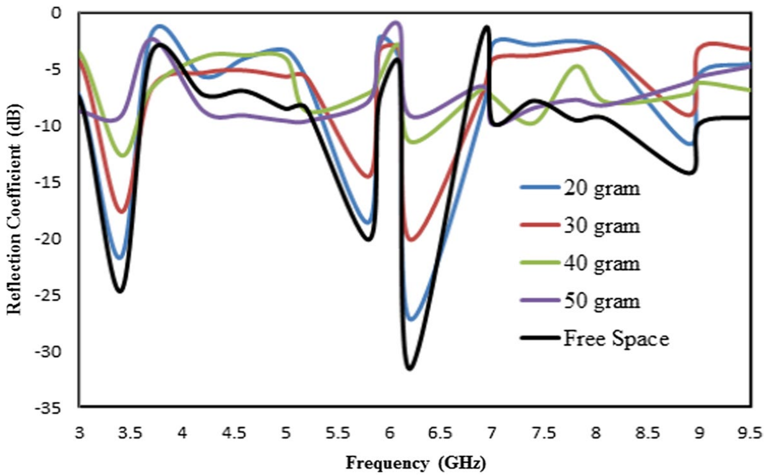

Fig. 8 Reflection coefficient variation with the different quantity (gram) of sugar in water

5 Conclusion

Aiming for public beneficial, sensor is designed to detect salt and sugar. By complete analysis, sensor is found to be accurate in every aspect such as efficiency, gain, satisfying direct transmission method criteria. Sensor is designed having low cost and easily fabricated. Sensor has applications not only in food industry but also in construction sector. If it is taken in use then early detection of salt and sugar in food items will help people from causing any disease due to intake of excess salt and sugar. With respect to construction sector, it will be very helpful in detection of water quality during preparation of cement concrete and curing because excess amount of salt in cement concrete to a shrinkage problem. Hence, it is advisable to adopt microstrip moisture sensor for detection of salt and sugar.

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Sweety Jain received her B.E. degree in Electronics and Communication Engineering, from Maharana Pratap College of Technology, Gwalior, Madhya Pradesh, India, in 2009, M.E. degree in Communication Control and Networking, from Maharana Pratap College of Technology , Gwalior Madhya Pradesh, India, in 2012, Ph.D. degree in Electronics and Communication from Amity University, Madhya Pradesh, India. She has Five Years Teaching Experience and Five Years Eight Months Research Experience. Her area of interest is Sensing Technology – Low Frequency, RF and Microwave Engineering. Her PhD Thesis selected by Bhabha Atomic Research Centre (BARC), Mumbai and presented in Indian Institute of Technology (IIT) Jodhpur. She has a Patent on "A Microstrip Moisture Sensor". She has published over 20 research papers in International and National Journals and 15 papers presented International and National Conference. She is an Editorial Board Member in International and National Journal.