Rice Moisture Detection Based on Oven Drying Technique Using Microstrip Ring Sensor

Sweety Jain, Pankaj Kumar Mishra and Vandana Vikas Thakare

Abstract A new microstrip ring moisture sensor is proposed for determining the moisture of rice grains using the oven drying method at multiple frequencies, i.e., 3.7, 5.8, 6.9, 8.4 GHz, with low insertion loss as well as good return loss −18, −17, −22, −27 dB. The proposed sensors parameters of ground length and width are 30 mm and 25 mm, as well as the outer and inner radii are 8 mm and 4 mm. The design is simulated by the CST software, fabricated on the FR4 substrate, which is cheaper and measured by the vector network analyzer (Model No. Field fox N9925A).

Keywords Microstrip ring sensor · Vector network analyzer · Oven drying technique · Rice moisture detection · Reflection coefficient

1 Introduction

Rice is the main source of nutrition for human beings. Moisture content inside rice grain is a crucial parameter for grain processing, i.e., harvesting storage, quality control, and transportation [1–4]. Mostly, rice grain is usually harvested between 19 and 25% MC for maximum grain yields and needs to be dried to 14% or less, depending on the season and the weather, for safe storage [5–7]. Also, the ideal moisture content for milling is 14% in order to maximize the head rice. So, moisture

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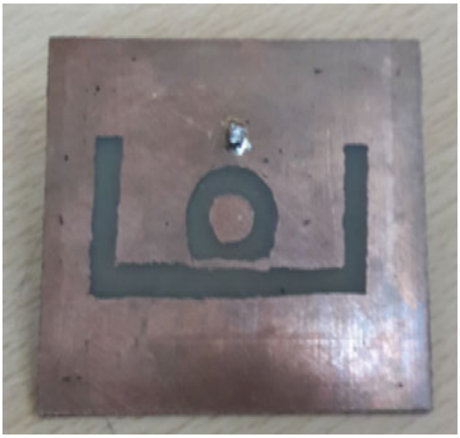

Fig. 1 Proposed microstrip ring sensor configuration

determination of rice is very important [8–11]. Water contained in rice is called rice moisture. The water is held within the rice pores. Rice water is the major component of the rice in relation to human beings growth [12, 13]. Hence, rice moisture content has a quite significant influence on engineering, industrial quality monitoring, and hydrological behavior [14–19] of the rice mass. Furthermore, it has a major role to play as far as the human being growth, the determination of rice water content is of the vital importance efforts to improve growth and water efficiency in agriculture.

In the agriculture sector, the application of adequate and timely moisture for irrigation, depending upon the rice moisture, storage place, and essential percentage of moisture in rice grains [20–22].

Earlier researchers have developed several techniques for measuring the rice moisture such as time-domain reflectometry, frequency-domain reflectometry, tensiometers, oven drying method, etc. Oven drying method is easy and cheaper method which is very helpful to measure the moisture of rice grains. Oven drying technique is cheap, less time-consuming, as well as accuracy [23, 24–26]. The proposed microstrip ring sensor configuration is shown in Fig. 1.

2 Sensor Configuration and Description

The proposed microstrip ring moisture sensor is designed at different frequencies simulating by CST Software and measuring by the vector network analyzer. The parameters of length and width of sensors are 30 and 25 mm as well as the outer radius and inner radius are 8 and 4 mm, and other parameters are shown in Table 1.

Table 1 Parameters and dimensions of microstrip ring sensor

Parameters	Dimensions
ε_r	4.4
h	0.038
tanδ	0.001

2.1 Simulation Results

The proposed microstrip ring moisture sensor is designed with the help of CST software and get the good return loss as at different frequencies as well as analyzed all the parameters which is useful for the microstrip ring sensor such as return loss, magnitude, phase, gain surface current, smith chart, axial ratio, etc., as shown in Figs. 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12.

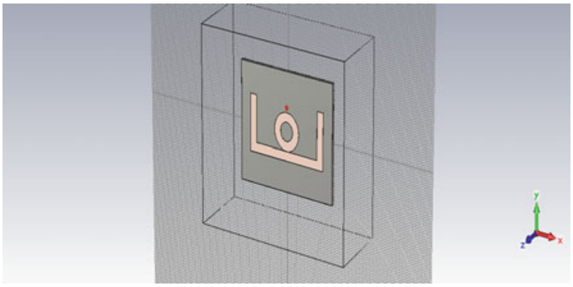

Fig. 2 Structure of microstrip ring sensor

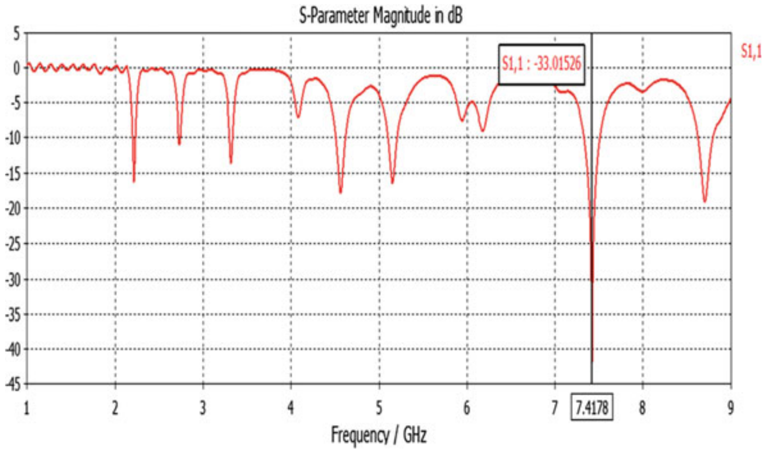

Fig. 3 Return loss of microstrip ring sensor

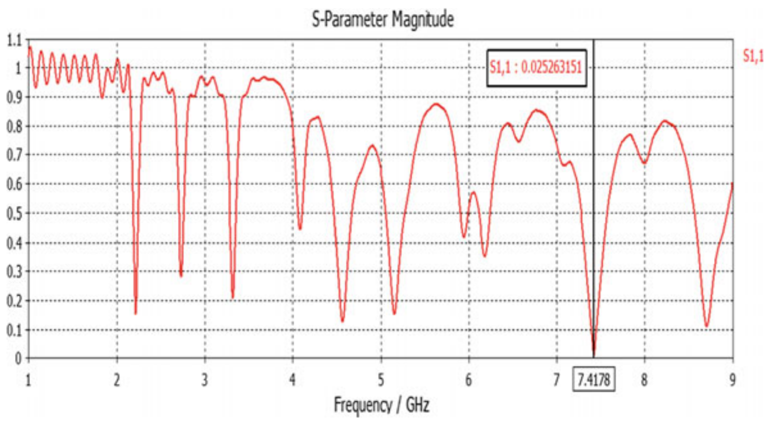

Fig. 4 Magnitude of microstrip ring sensor

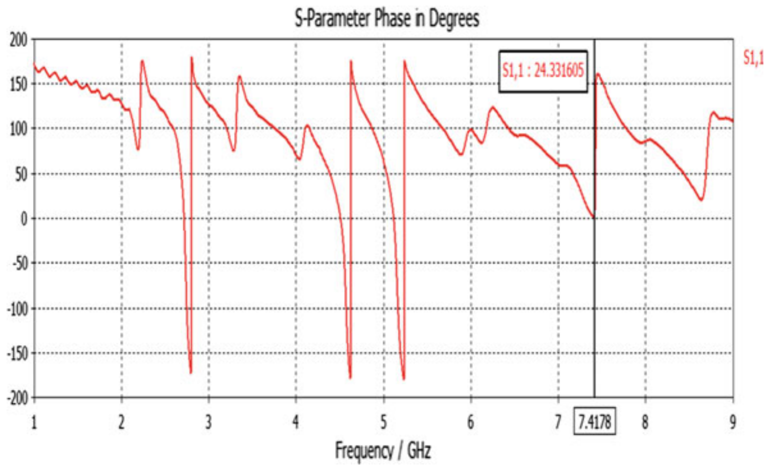

Fig. 5 Phase of microstrip ring sensor

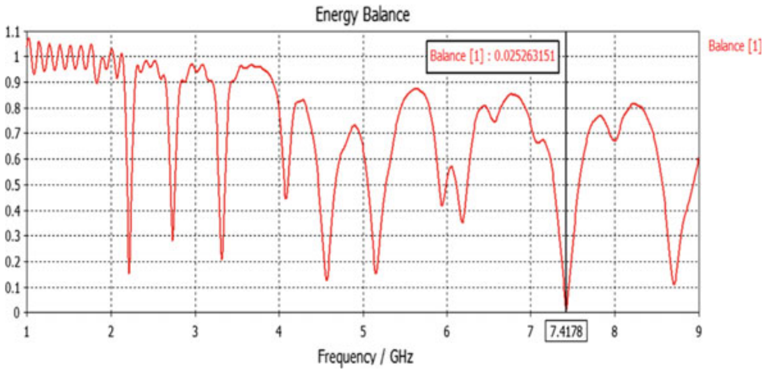

Fig. 6 Energy balance of microstrip ring sensor

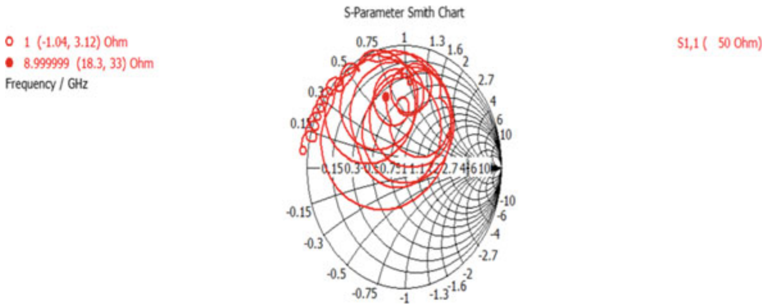

Fig. 7 Smith chart of microstrip ring sensor

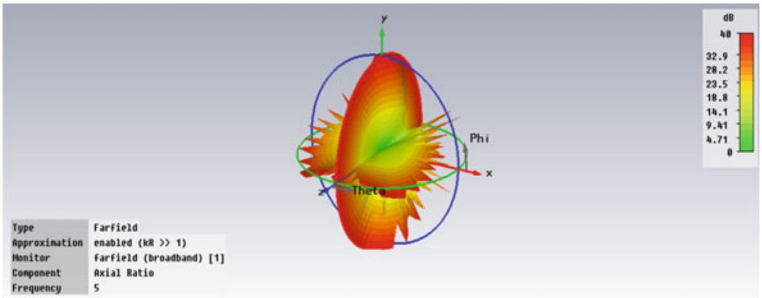

Fig. 8 Axial ratio of microstrip ring sensor

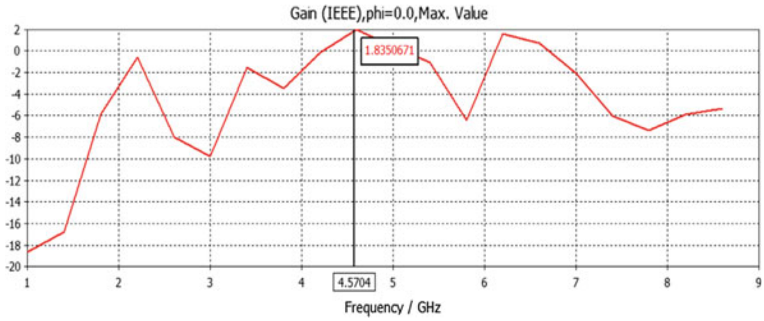

Fig. 9 Gain of microstrip ring sensor

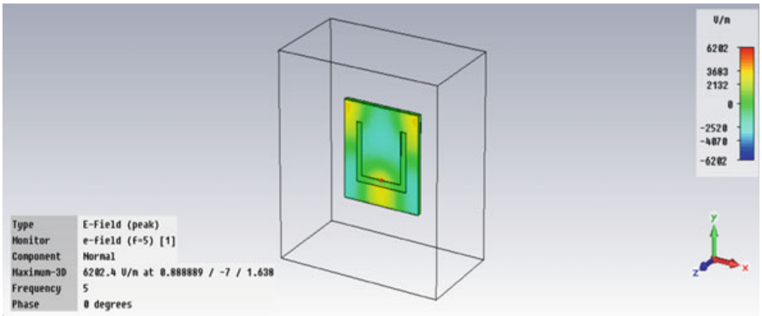

Fig. 10 E-field of microstrip ring sensor

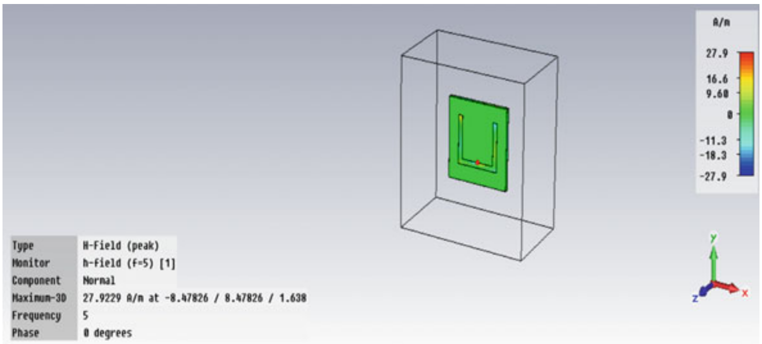

Fig. 11 H-field of microstrip ring sensor

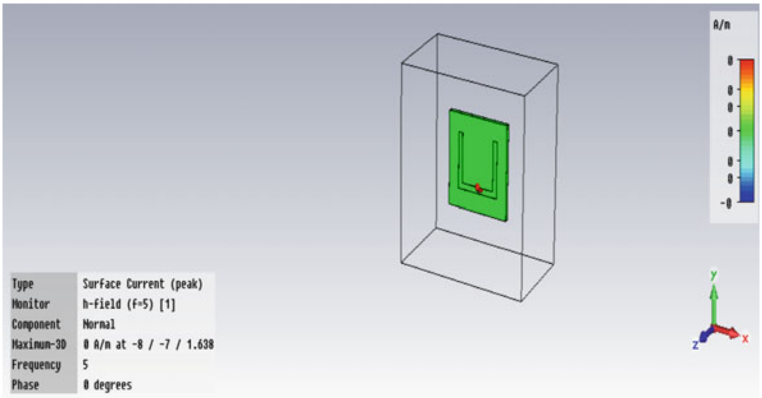

Fig. 12 Surface current of microstrip ring sensor

2.2 Experimental Results

The proposed microstrip ring moisture sensor is measured with the help of vector network analyzer at different frequencies. The dry rice measured the moisture at 3.7, 5.8, 6.9, and 8.4 GHz with return loss −18, −17, −22, −27 dB, after measure the moisture of wet rice at same frequencies 3.7, 5.8, 6.9, and 8.4 GHz with return loss −17, −16, −16, −24 dB as shown in Table 2. The comparison of the measured moisture content at different frequencies, the dry rice increased the return loss but when measured the wet rice of moisture then return loss id decreased after calibration of dry and wet rice then the percentage of moisture can be determined by this formula

Table 2 Summary of dry and wet rice measured the moisture content by vector network analyzer

Frequency	Dry rice	Wet rice
1	−0.66	−0.77
2	−1.65	−3.17
3	−11	−4.6
3.7	−18	−17
4	−3.2	−3.5
5	−2.7	−3.2
5.8	−17	−16
6	−5.5	−6.03
6.9	−22	−16
7	−10	−8
8.4	−27	−24
9	−7	−9.8

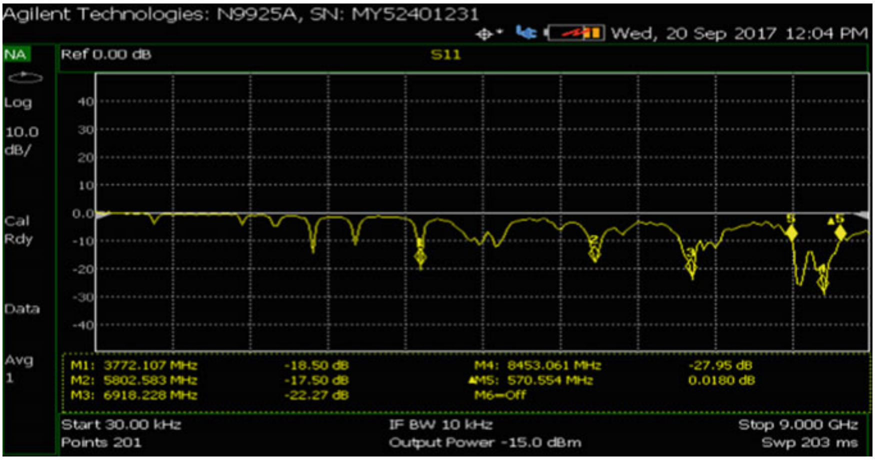

Fig. 13 Measured moisture of dry rice with microstrip ring sensor

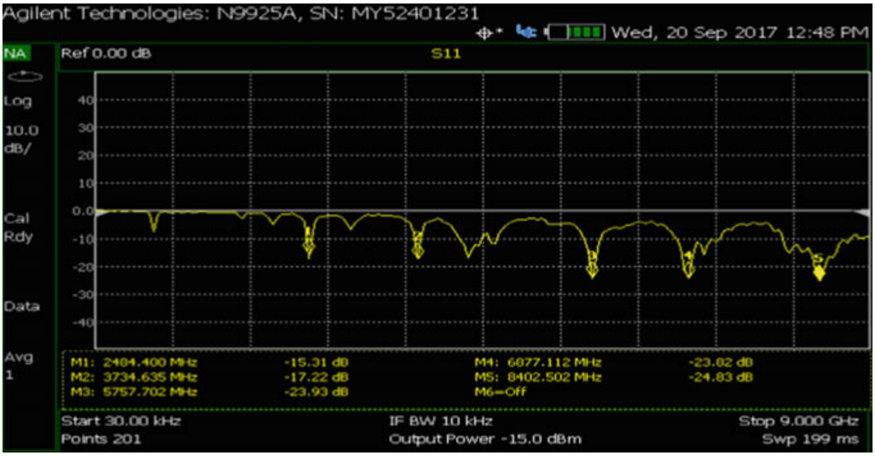

Fig. 14 Measured moisture of wet rice with microstrip ring sensor

as given below. The experimental results of dry and wet rice are shown in Figs. 10 and 11.

The actual moisture content is determined using the standard oven drying technique.

Moisture content (%) = (mass of water/dry mass of sample) * 100
Mass of water = wet of mass – dry of mass

where

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

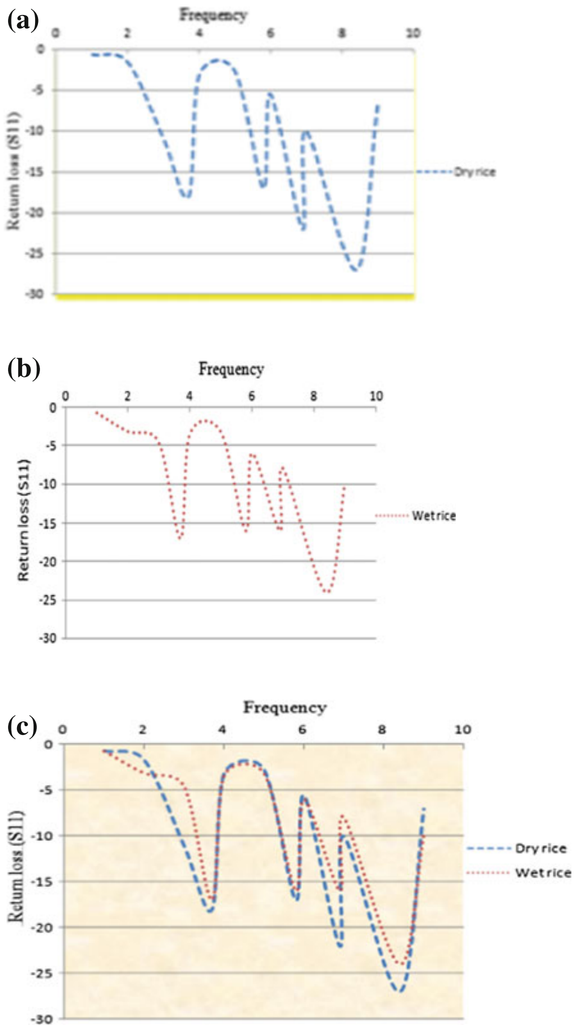

Fig. 15 **a** Measured dry rice with microstrip ring sensor. **b** Measured wet rice with microstrip ring sensor. **c** Comparison of dry rice and wet rice measured moisture by microstrip ring sensor

The experimental results of dry and wet rice measured the moisture content are shown in Figs. 13 and 14.

The comparison of moisture content of dry and wet rice with different frequencies is shown in Fig. 12.

3 Conclusion

A fast and accurate method of measurement of moisture content of rice grains using a microstrip ring sensor and a new microstrip ring moisture sensor is proposed using the oven drying method at multiple frequencies, i.e., 3.7, 5.8, 6.9, 8.4 GHz, with low insertion loss as well as good return loss −18, −17, −22, −27 dB simulated using the CST software and measured by the vector network analyzer (Model No. Field fox N9925A). The proposed design is very cheap, versatile, small size, accuracy, reliability, sensitivity, time nonconsuming, as well as determination of moisture at dual and triple frequencies (Figs. 13, 14 and 15).

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