Microstrip Transmission Line Sensor for Rice Quality Detection: An Overview

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Abstract—: This paper describes the comparative analysis of different types of microstrip transmission sensor for rice quality detection. Basically the cylindrical slot antenna and microstrip line based structure have been discussed. This paper shows focus on the advantage and tremendous characteristics of microstrip couple line sensor over the other microwave sensors and the substantial amount of efficiency has been achieved by the use of Coupled line filter approach. The analysis on the basis of various parameters like, characteristics impedance, microstrip width and dielectric constant of the substrate, modes of reflection coefficient, insertion loss, radiation, moisture content in rice grain, and the frequency applied. By applying the different principles and methods and finally with Vector Network Analyzer the reflection coefficient measurement reading give us the measurement of broken rice.

Keywords-Coupled Line Filter, Microstrip, Moisture Content (m.c), Slot Antenna, Vector Network Analyzer

(VNA).

1. INTRODUCTION

Microstrip is a transmission medium used in printed circuit board over a ground plane, it is a printed circuit version of transmission wire. It is widely used in many applications as a planer transmission medium [1]. The microstrip transmission line sensor uses this basic array structure to design an application for rice quality detection. The rice quality detection contains two properties, moisture content and broken rice percent. The initial concept of microstrip based sensor came out near about 1970 which have given birth to so many ideas to make sensors. The first commercial sensor was for flesh meat processing [4], for ripeness for palm fruits for oil[5], for moisture content in green tea leaf[6] , to find out the moisture content in rice[3], and to find out the broken rice percentage[2]. In current the rice food consumption covers more than half of the world population [2] but there is problem in milling process which leaves large amount of rice either unused or as waste. There is another view about the rice characterization it is that most of the customer wants the best quality rice in the form of long grains.

The quality of the rice can be determined by moisture content, shape, chalkiness, whiteness and number of broken rice grains at less cost.The one of the most important criteria for determining the quality of the rice is head rice yield. Tan et.al [6] discussed about the appearance quality of rice, which represents a major problem of rice production in many of rice producing areas of the world, and this specially is a lot more significant in case of hybrid rice production. Currently, there is a strong emphasis to increase the total world rice production by improving the quality of hybrid rice. The most serious problems lie in eating quality,cooking quality and processing quality and to some extent, in milling quality. According to available knowledge, cooking and eating quality are mostly determined by amylose content, gelatinization temperature and gel consistency of the grain endosperm. The appearance of grain determines the quality of rice to huge extent. The parameters of visual inspection are grain length, grain width, the width length ratio and translucency of the endosperm. Quality is an important factor at the front and back end of rice production. If quality milled rice is expected at the end insurance of quality paddy is must at beginning of the process. According to the International Rice Research Institute (IRRI), measurement of quality provides data that can be used for decision making, optimization and the development of processes and technologies as well as for evaluating the properties, function, quality and reliability of the same. Several interrelated features determine the quality of paddy which includes moisture content, purity, varietal purity, cracked grains, immature grains, damaged grains and discolored/fermented grains. These characteristics are governed not only by the weather conditions during production, crop production practices, soil conditions and harvesting, but also by the post-harvest practices. Moisture content (MC) influences all aspects of paddy and rice quality, making it essential that rice be milled at the proper MC to obtain the highest head rice yield. IRRI said, Paddy is at its optimum milling potential at an MC of 14% wet weight basis. Higher moisture contents are too soft towithstand hulling pressure, which results in breakage and possible pulverization of the grain. Grain that is too dry is brittle and has greater breakage. MC and drying temperature is also critical, because it determines whether small fissures and/or full cracks can occur or not in the grain structure. Mixing paddy varieties can cause problems during milling, resulting in reduced capacity, excessive breakage, lower milled rice recovery and reduced head rice. Different sized and shaped grains makes it difficult to adjust equipment such as hullers, whiteners and polishers. This results in low initial husking efficiencies, a higher percentage ofre-circulatedpaddy,non-uniform whiteningand a lower quantity of milled rice. Grain size and shape, or the length-width ratio, is different for the varying paddy varieties. Long, slender grains typically have greater breakage than short, bold grains and therefore have a lower milled rice recovery. The dimensions to some degree dictate the type of milling equipment to be employed. Exposing mature paddy to fluctuating temperatures and moisture conditions can lead to the development of fissures and cracks in individual kernels. Cracks in the kernel are the most important factor contributing to rice breakage during milling [7]. This also results in reduced milled rice recovery and head rice yields. The amount of immature paddy grains in a sample greatly impacts the head rice yield and quality. The immature kernels are very slender and chalky, which results in excessive production of bran, broken grains and brewer's rice. Grain should be harvested at about 20% to 24% moisture or about 30 days after flowering. If the harvest is too late, grains are lost through shattering or dry out and are cracked during threshing, which causes grain breakage during milling. Milled rice is classified in groups based on the percentage of amylose:

•Waxy,1%to2%
•Verylowamylose,2%to9%
•Lowamylose,10%to20%
•Intermediateamylose,20%to25%
•High amylose,25% to 33%.

This paper gives an overview of different microstrip transmission line approaches being used describing the rice characteristic. One of the most famous of thecharacterizations is the moisture content characterization which has average threshold value of 12% [3] below which the rice grain will be considered as dried quality. This moisture content can be measured with the help of coupled microstrip line sensor. The coupled line application sensors are one of the most advance sensors in current sensing devices for rice moisture content.

2. DEVELOPMENTRELATED STUDIES OF MICROSTRIP TRANSMISSION LINE SENSORS

Microstrip Model

Microstrips are the printed circuit transmission medium, which are widely used in industrial electronics for PCB designing. As shown in figure 1 microstrip transmission line contains a substrate with dielectric material ε_r, conductor 1 with thickness t and width w. One of the most important properties of microstrip transmission line design is dielectric constant which is inversely proportional to the radiated power i.e. if we have to transfer maximum power to the load then the radiated power should be as less as possible. Microstrip transmission lines should be designed with a utmost care. The basic structure of microstrip transmission line is fabricated on PCB or its fabrication process is similar to the Printed Circuit Board (PCB).

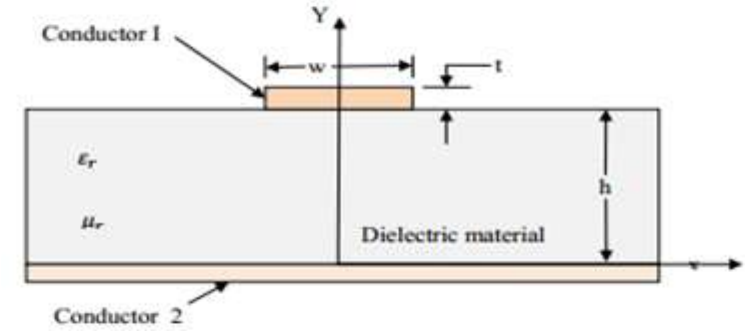


Fig: 1.Microstrip transmission line [1]

Parallel Edge Coupled Microstrip Line model

The parallel edge coupled line model consists of an array of microstrp transmission line in a manner for providing matching between the input impedance and the output impedance. In rice characterization the current approach is using resonator structure based filters to detect the moisture content and broken rice percent.A single band pass filter does not result in good filter performance with gradual pass band to stop band transitions, this gradual change can be overcome bycascading these building blocks which ultimately results in high performance filters [9]. The figure 2 shows the edge coupled filter.The filter structure consists of more than one pair of microstrip transmission line for matching input impedance to the output impedance.

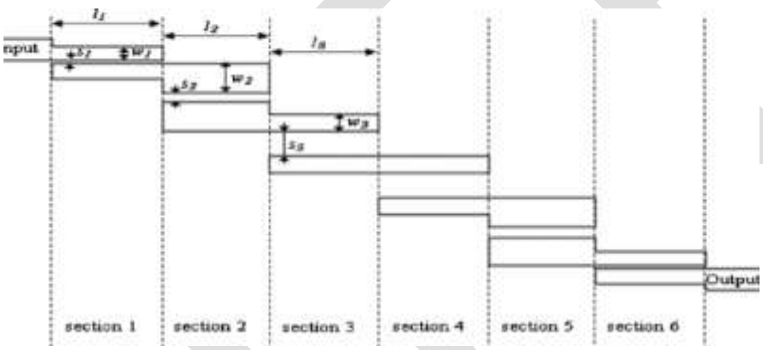


Fig 2. Edge couple microstrip transmission line filter. [10]

Edge coupled microstrip transmission line exhibits the properties of even and odd mode characteristic impedance according to which different pair have the different width, separation and length which is shown in the figure as $s_1, w_1, l_1, s_2, w_2, l_2, s_3, w_3, l_3$etc. There are three kind of impedances in transmission medium which affects the structure (i) Characteristic impedance (ii) even mode impedance(Z_{0e}) (iii) Odd mode impedance(Z_{0o}) [8,9]. Theeven and odd mode impedance of coupled microstrip line are determined by, using $J_{i,i+1}$ characteristic admittance of J-inverters is given as,

$$(Z_{0e})_{i,i+1}=Z_0[1+Z_0J_{i,i+1}+ (Z_0 J_{i,i+1})^2] \qquad (1)$$

$$(Z_{0o})_{i,i+1}=Z_0[1-Z_0J_{i,i+1}+ (Z_0J_{i,i+1})^2] \qquad (2)$$

In both the equations i ranges from 0 to n.

According to these even and odd mode impedance the width, space and physical length of the transmission line can be calculated. In the current scenario our main motto is to represent microwave methods which are used in rice characteristic detection so further detail of designing coupled microstrip transmission line filter is discussed in [8] and [9].

Microstrip Ring Resonator Sensor

According to Semouchkina et.al [11] microstrip ring resonators are widely used in many microwave devices, particularly in filters, mixers, oscillators, and couplers. The interest of researchers and communication industry engineers to these structures has recently increased due to the application of ferroelectric thin-film substrates and high-temperature superconducting microstrip lines in ring resonator fabrication [12, 13].The efficient design of microwave structure usually depends on size, weight and quality factor.The current designs of microstrip ring resonator are small in size, light in weight and are of high quality because of the superconductivity in microstrips. Due to the sensitivity of the substrate to changes in dc electric fields these are also easily tunable. In order to successfully integrate new microstrip ring components into communication systems, it is very important to have a clear understanding of the resonance processes in ring resonators, and to model their responses adequately. This ring resonator approach is limited; as it cannot be used either for arbitrary microstrip geometries or for a large dielectric constant of the substrate, and is not appropriate for high frequencies. The geometrical view of microstrip ring resonator is shown in figure 3, in which the feed port, coupling port and resonator are shown with tags.

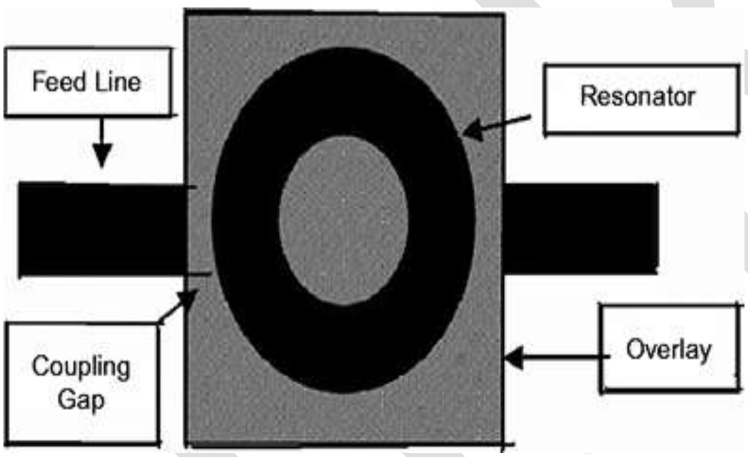


Fig 3. Microstrip Ring Resonator [14]

3.Comparative Study of Microwave Approaches For Rice Charecterization

In this section we have studied and compared three well known rice quality detection microwave approaches.

Cylindrical Slot Antenna Sensor

You et al. [15] have discussed that cylindrical slot antenna approach to detect the quality of milled rice.They have used this approach to determine the quality on the basis of percentage of moisture content present in rice grain and the percentage of the broken rice. The methodology to detect the rice quality is to use the reflection coefficient of one or two slot antenna sensors of infinite ground plane in the frequency range from DC to 6 GHZ Vector Network Analyzer (VNA).Then the calibration equations have been generated to relate the reflection coefficient to the moisture content and broken rice percentage. Figure 4 shows this approach for single slot and couple slot antenna,

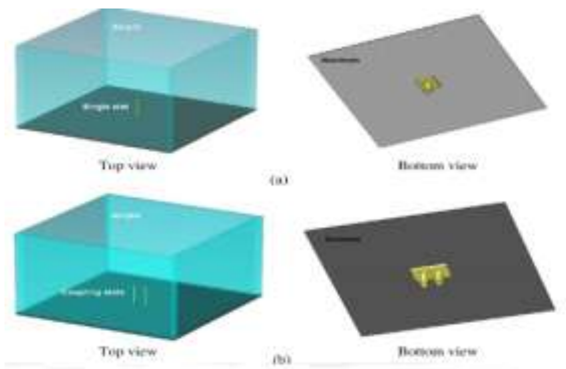


Fig 4. (a) Single slot sensor (b) Coupling slot cylindrical antenna sensor [15]

Initially the radiated wave from slot antenna spread around the mixture sample of rice and air. The low frequency, long wavelength signal is required to reduce the sensitivity of wave to the air gap between the rice grains. Thus shorter the wavelength tends to high frequency and tries to increase theair gap in the rice grain because the broken rice have high density and low air gap compared to the unbroken rice grain. Hence the different moisture quality depends on the air gap in rice grain and shows a different reflection coefficient with Vector Network Analyzer. In methodology they have used frequency range from 1 GHz to 13.5 GHz and rice sample were placed over the acrylic holder with a height of 30 mm for 6 hours at 130^{o}C, then the moisture content can be calculated by following equation using the weighs of rice grain before dry and after dry m_{Before_Dry} and m_{After_Dry} [16],

$$m.c=\frac{m_{Before\_Dry}-m_{After\_Dry}}{m_{Before\_Dry}}\times 100\% \qquad (3)$$

so five varieties of rice contents have been measured in this DCto 6 GHz frequency range [15]. The moisture content is measured between 12- 16%.

Wide Ring Sensor

Mun et.al [2] have discussed that conventional microstrip ring with loose coupling exhibits a high insertion loss of about 10 dB at the resonant frequency [Chang and Hsieh, [16]). When a signal is transmitted through the microstrip ring with high insertion loss, the transmitted signal will become very low. Because of this drawback the transmission quality of signal becomes very weak and low quality or low cost signal usually not detects these signals. Figure 6 shows the microstrip wide ring structure with SMA connector for providing feed through coaxial transmission lines with width of the ring W_r, width of the feed line W_f, length of the feed line l, inner radius of the ring R_i& outer radius of the ring R_o.

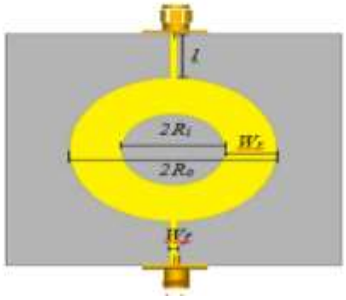


Fig 6. Wide-ring sensor [2].

Hence the new microstrip ring sensor designed by the researchers has low insertion loss and high reflection coefficient. It is designed to operate within a frequency range from 1 GHz to 3 GHz and exhibit low insertion loss for the percentage of broken rice grain determination. Both sensors operate at a relatively low frequency, within 1 GHz to 3 GHz, which can reduce the cost when compared with other devices that operate at a higher frequency. The microstrip ring is designed to have a wide ring in order to provide a relatively large contact area with the rice grains. Also, the 50 Ω feed lines are directly coupled with the ring to realize low insertion loss at the resonant frequency. Moreover, calibration equations for both sensors at selected frequencies are developed based on the relationship between the percentage of BR with corresponding measured magnitude and phase of transmission coefficient. The minimum insertion loss for wide-ring sensor is close to 0.67 dB or |T| equal to 0.93, while the minimum insertion loss for a couple-line sensor is close to 1.81 dB or |T| equal to 0.81.the experimental result for wide ring microstrip sensor shows that |T| magnitude of transmission coefficient increases gradually as the BR percentage increases within the frequency range from 1.80 GHz to 2.28 GHz but reverses from 2.38 GHz to 2.52 GHz, while ϕ decreases with the increase in percentage of BR in the frequency range of 1.80 GHz to 2.60 GHz. The selection of frequency was determined by the largest changing rate of the |T| and ϕ with respect to frequency within the sensitive frequency range. The sensitive frequency range for a wide-ring sensor is within 1.80 GHz to 2.28 GHz and 2.38 GHz to 2.52 GHz. Also, the sensitive frequency range for a coupled-line sensor is within 1.80 GHz to 2.10 GHz and 2.20 GHz to 2.42 GHz. Calibration equation relates the percentage of broken rice with the magnitude and phase of transmission coefficient for the wide-ring sensor at different frequencies. The calculation of broken rice percentage is shown in the following table1 as,

Table 1. Calibration equations for broken rice calculation using wide ring sensor [2]

Measured Parameter |T|	Frequency(GHz)	Calibration Equations	R^2
|T|	1.93	$BR=119781.53452\|T\|^2-75620.06268\|T\|+11911.59888$	0.8288
	2.50	$BR=14451.77159\|T\|^2-24678.18077\|T\|+10283.96782$	0.7400
ϕ	1.93	$BR=7873.94165\phi^2-29444.11854\phi+27510.22726$	0.8028
	2.50	$BR=5479.77309\phi^2+7234.81986\phi+2382.18976$	0.8740

The principle of wide ring sensor says that in free space the particular frequency of microstrip depends mainly on the effective permittivity $\varepsilon_{eff}$and the mean circumference of the conductor ring. The resonant frequency of the ring sensor can be approximated by using the mean radius of ring r, with n number of modes and where speed of light is c,

$$f_r = \frac{nc}{2\pi r\sqrt{\varepsilon eff}} \quad (4)$$

The ε_{eff} is affected by the parameters like dielectric constant of substrate $\varepsilon_{r,sub}$,width of the ring Wr, thickness of substrate h, and dielectric constant of the material that covers the ring sensor ε_r`.

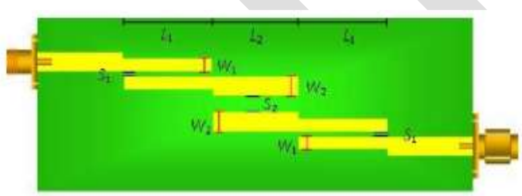
$$\varepsilon_{eff} = \frac{\varepsilon r,sub + \varepsilon r`}{2} + \frac{\varepsilon r,sub - \varepsilon r`}{2}\left(1+12\frac{h}{Wr}\right)^{-0.5} \quad (5)$$

When the ring sensor is fully filled with air, then ε_r' is equal to 1. Whereas, if the ring sensor is overlaid with rice grain, the ring sensor will produce a resonant frequency shift and a broadening of the resonance curve (a change in the transmission coefficient) when compared to free space. The ε_r' relates with the capability of energy storage in the electric field in the material (Nelson and Trabelsi, [17]).

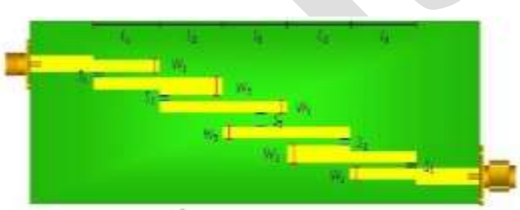
Coupled Line Sensor

A microstrip coupled-line has been widely used in the filter application. It can be employed as a band pass filter with low insertion loss and can be easily designed at any desired centre frequency. Besides this, it offers an attractive physical dimension that is small in size, light in weight and easy to fabricate. Although a microstrip coupled-line exhibits many advantages, it has not been applied to the determination of the percentage of broken rice [2, 3]. The measurement parameter for the study of these sensors is reflection/transmission method.

The method contains different order or we can say the higher order coupled transmission line design. Yeow et.al [3] has given the comparative design of 2nd order and 4th order microstrip couple transmission line band pass filter.As discussed in coupled line filter sensitivity is greater than wide ring microstrip filter. The 2nd order couple line filter has less sensitivity compared to the 4th order filter. The 2nd order filter have less number of coupled microstrip transmission line compared to 4th order filter hence it will provide less area for rice grain sensing whereas 4th order filter provides large area for rice grain sensitivity. The 2nd and 4th order filter structure design have been shown in figure 7 using [2, 3] as



(a)



(b)

Fig 7. (a) 2nd order BPF (b) 4th order BPF with dimensions widthW, lengthL, size coupling gap S. [3]

The measurement techniques for rice moisture content uses an E5071C Network Analyzer at frequency range 1.5 GHz to 3GHz.Before measurements, the two port calibration of both the ends of the coaxial cable have been done using calibration kits. So finally to measure the quality of the milled powder rice sample placed in acrylic holder sensor with 15mm height.Experimental setup for both wide ring and microstrip sensor has been shown in following figure 8.

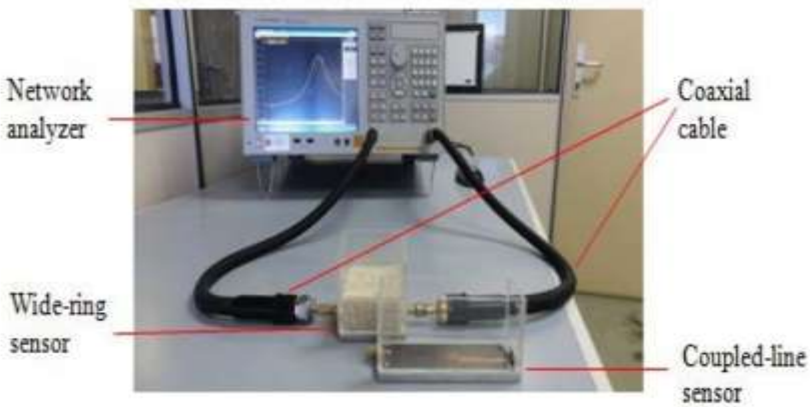


Fig8. Experimental setup for wide ring and coupled microstrip line resonator [2]

The part of the experiments shows that the 4^{th} order filters have higher sensitivity than 2^{nd} order. The following conclusion have been found in [3]

Higher order filter have higher density compared to the lower order filter.

The reflection coefficient Γ and transmission coefficient T depends on the order of the filter deign.

Different substrate properties are used for PCB based microstrip filter design. Each substrate shows different properties of transmission and reflection coefficient.

Rice powder should be use for measuring the moisture content in the place of rice grain.

So we have studied the different approaches microwave sensor design for rice quality detection. There comparison given in following table 2.

Table 2. Microwave Sensor Model Comparison

Microwave Parameters	**Cylindrical slot antenna model**	**Wide Ring microstrip model**	**Couple microstrip line**
Reflection coefficient	It measures reflection coefficient for coupleslot antenna	Its reflection coefficient based on the reflection ring reflection from rice grain	Reflection coefficient is high among three.
Frequency Range	1 GHz to 13.5 GHz	1GHz to 3 GHz	1.5 GHz to 3 GHz
Sensitivity	Less sensitivity	Higher than slot antenna	Higher among three
Cost	High	Less	Less
Broken Rice(%)	0-100	0-20,0-40,0-100	0-20,0-40,0-100
Average Error (%)	Unknown	2.32,3.79,8.97	9.57,9.59.9.88

Complexity	Simple	Simple	Simple
Speed	Fast	Fast	Fast

Above table gives an overview of different microwave sensor approach for rice quality detection and concludes thatmicrostrip transmission line approach is better to design sensor devices for rice quality detection.

4. Conclusion

The increasing technologies to measure the quality of food are making the human work easier and faster. The rice quality measurement is a big question in current industry, because conventional methods are not so fast and not easy to implement. The slot antenna pair is was probably the first microwave broken rice detection techniques which works for both moisture content and broken rice measurement. But the drawback is in the frequency range as it works on higher frequency which makes it less suitable for rice detection. The other approach is microstrip approach in which there are two approaches one is wide ring sensor and other one coupled line transmission approach. Both are good in their mechanism. But couple line approach is more sensitive than the wide ring microstrip. These microstrip line approach use average frequency 1- 3 GHz which makes it less expensive. Hence, finally we can conclude that the microstrip line approach should be used to make more and more sensors. In futurewe can design 5th order edge coupled transmission line for finding out the moisture content using a rice powder sample because it will result in an increased reflection coefficient .

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