Design and Analysis of Slotted Ring Wideband Bandpass Filter for Microwave Sensor

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***Abstract*—Aiming to operate in wideband frequency range as a microwave sensor to measure the rice quality, two new design of slotted ring wideband bandpass filter design are presented in this paper. Broadside-coupled microstrip-slot technique has been implied into both designs to produce tight coupling filter with a wideband frequency range performance. Rogers RO4003C substrate with a thickness of 0.508 mm is used for the designs to maintain the low manufacturing cost. Both designs have different slotted ring widths. Therefore, investigations on the effect of difference slotted ring's widths towards the scattering parameter performance will also be presented in this paper. The simulation results show that the slotted ring wideband bandpass filter with thicker width shows better results compare to the one with thinner width. The overall results show that the designed wideband BPF possess good performance and suitable to be used as a microwave sensor to measure the rice quality.**

***Index Terms*—Bandpass Filter; Broadside Coupling; Microstrip-Slot; Wideband**

I. INTRODUCTION

The applications of microwave sensors are wide. Microwave sensors, or known as radar or radio frequency (RF) operate at frequencies ranging from 300 MHz to terahertz. They are commonly used in industry due to their effectiveness in sensing and not sensitive to the environment. One of their great advantages is their ability in sensing task in wide capacity [1]. This great advantage leads the communication between the sensor and the Material Under Test (MUT) to become non-invasive, non-ionizing and contact-less manner, which by then allows the information of the MUT to be extracted further [1]. Thus, the test subject information could be extracted without affecting the quality and material's condition of the test subject. Microwave sensors can be divided into several types such as radiometer sensors, transmission sensors and last but not least the most popular among all, resonator sensor. The easiest way to develop the resonator sensors is by applying the principle of microstrip filter. The microstrip filter response greatly on the frequency shift and broaden the curve compared to free space when filled with a test subject.

Microstrip wideband bandpass filter (BPF) is one of the most used devices as the microwave sensors. In recent years, the development of the wideband BPF has shown rapid increment and variety of different wideband BPF has been reported in the literature [2-11,14-15]. As reported in [4], cascading both low pass filters and high pass filter in one circuitry will produce the wideband bandpass filter. By using this technique, very simple BPF can be produced. However, it leads to large size of BPF, which is not suitable for current trends. Other techniques that have been proposed to produce wideband bandpass filter is by using short-circuited stubs, stub-loaded ring resonators, multi-mode stepped-impedance resonators (SIRs) and other multi-mode resonators [4].

Therefore, in this paper, two slotted ring wideband bandpass filter design with difference ring's width will be presented. Broadside-coupled microstrip-slot technique has been implied into both designs. This technique can produce tight coupling filter with a wideband frequency range performance where the slotline in the bottom layer will be coupled to the two open-circuited stubs on the upper layer of the patch. Meanwhile, Rogers RO4003C substrate with thickness of 0.508 mm is used for the designs to maintain the low manufacturing cost. The investigations on the effect of difference slotted ring's widths will also be presented. The results show that the designed wideband BPF possess good performance and suitable to be used as a microwave sensor to measure the rice quality.

II. DESIGN THEORIES AND ANALYSIS

Figure 1 through Figure 4 shows the configurations of the two slotted ring wideband bandpass filter designs (Type 1 and Type 2) with different ring's width. Both designs consist of top patch and ground. For Type 1 slotted ring wideband bandpass filter design, both top patch and ground are shown in Figure 1 and Figure 2, respectively. Meanwhile, for Type 2 slotted ring wideband bandpass filter design, both top patch and ground are shown in Figure 3 and Figure 4, respectively. Both Port 1 and Port 2 are located on the top patch.

As seen in Figure 1 to Figure 4, the top patch and the ground of both slotted ring wideband bandpass filter consists of elliptical ring broadside design and radial slot, respectively. The width of the elliptical ring have different dimension from each other.

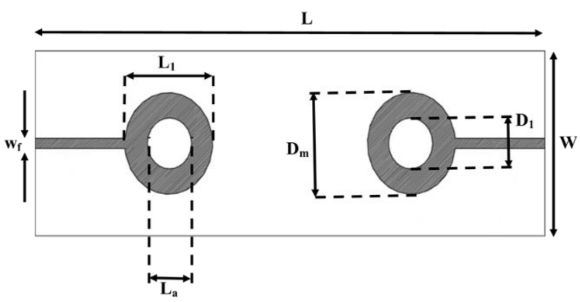

Figure 1: Type 1 slotted ring wideband bandpass filter design (top patch)

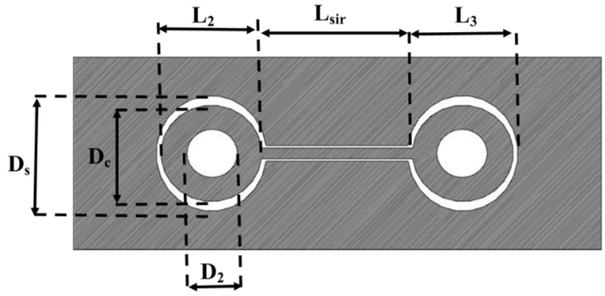

Figure 2: Type 1 slotted ring wideband bandpass filter design (ground)

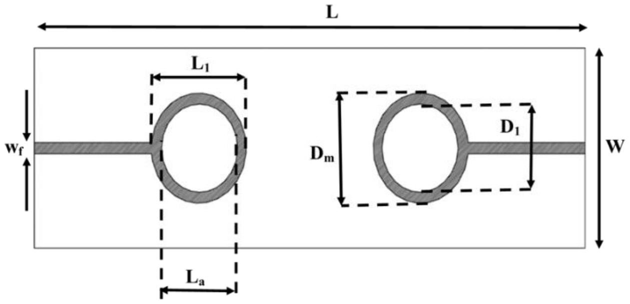

Figure 3: Type 2 slotted ring wideband bandpass filter design (top patch)

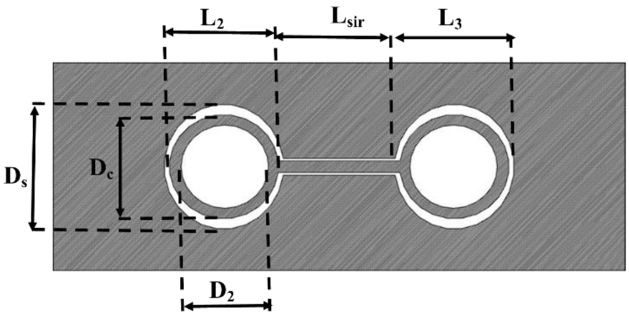

Figure 4: Type 2 slotted ring wideband bandpass filter design (ground)

Initially, the dimension of the slotted ring wideband bandpass filter is based from [12] where the insertion loss for the bandpass filter is chosen to be less than -0.5 dB. From the obtained value, the value of the outer elliptical shaped is attained. Once the outer shaped is attained, the ring slotted is made based on the width of the transmission line. Type 2's width for the slotted ring is similar to the transmission line, meanwhile for Type 1 the width is bigger compared to the transmission line by 33%. The reason of having different width is to analyze which width giving best performance and to understand the effect of the different widths towards the performance of the bandpass filter.

Meanwhile, the dimension of the stepped impedance resonator, L_{sir} at the ground patch is calculated by using (1) [13].

$$L_{\text{sir}} = 2\,\lambda_e \tan^{-1} \sqrt{Zr/\pi} \tag{1}$$

where, Z_r is the ratio of the impedance of the two ends of the SIR to impedance of the middle section of the stepped-impedance resonator (SIR) and λe is calculated by using (2):

$$\lambda_e = c/f\sqrt{\varepsilon_e} \tag{2}$$

where ε_e, the effective dielectric constant of a microstrip line is defined by (3):

$$\varepsilon_e = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(\frac{1}{\sqrt{1+12\frac{h}{W}}}\right) \tag{3}$$

Once the initial dimension is determined, the optimization is made to achieve the best performance for the bandpass filter. Therefore, Table 1 presents the bandpass filter optimized values.

Table 1
Type 1 And Type 2 Slotted Ring Wideband Bandpass Filter Designs Optimized Values

Parameter	Dimension of the Slotted Ring Bandpass Filters (mm)	
	Type 1	Type 2
D_c	10.0	10.0
D_m	11.0	11.0
D_S	12.0	12.0
D_1	5.5	8.8
D_2	5.25	8.4
L_1	9.5	9.5
L_2	10.5	10.5
L_3	11.5	11.5
L_a	4.75	7.6
L_{sir}	25.0	25.0
W_f	1.128	1.128
L	55.0	55.0
W	20.0	20.0

III. RESULT AND DISCUSSION

Both slotted ring wideband bandpass filter designs are simulated using ADS software and the comparison for both Type 1 and Type 2 scattering parameter results are shown in Figure 5 and Figure 6. Figure 5 shows the return loss, S_{11} parameter while Figure 6 shows the insertion loss, S_{21} parameter.

From the result of the return loss shown in Figure 5, it can be seen that Type 1 slotted ring wideband bandpass filter design is having better performance compare to Type 2. For Type 1, good return loss result, which is less than -10 dB, is covering from 1.13 GHz to 5.62 GHz meanwhile for Type 2, the good return loss result is only covering from 1.53 GHz to 5.12 GHz. In addition, for the insertion loss, the minimal insertion loss is at -0.15 dB and -0.20 dB for both Type 1 and Type 2, respectively along the same designated band as the return loss performance. Table 2 indicates the summary of the results' comparison for both bandpass filter.

Based from the summary in Table 2, it can be concluded that Type 1 slotted ring wideband bandpass filter gives better performance compare to Type 2 slotted ring wideband bandpass filter. The thicker or wider width of the slotted ring produce better results compare to the one with thin slotted ring is due to the reason of the number of signal power that can transfer from input port to output port.

The thicker width provides more signal power that leads to better S_{11} and S_{21} performance as seen in Figure 5 and Figure 6. From these figures and table, it can be concluded that the proposed wideband bandpass filter exhibits good performance and can be used in as a microwave resonator.

Compared to the filters proposed in [2,14-15], both of the insertion loss, return loss and bandwidth coverage of the Type 1 slotted ring wideband bandpass filter proposed in this paper also perform better as shown in Table 3.

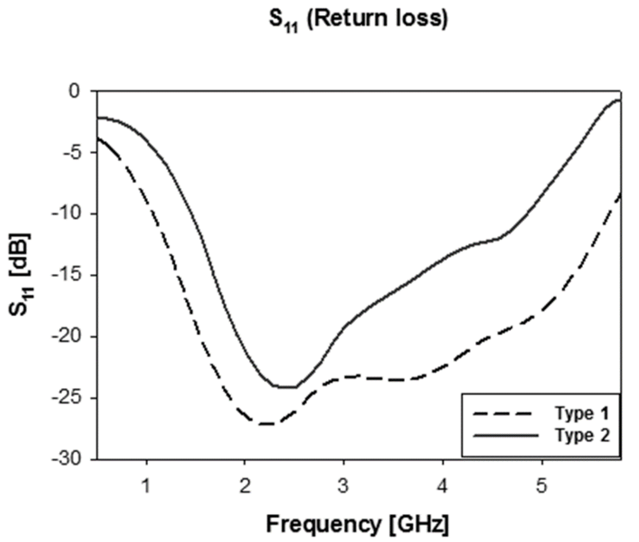

Figure 5: Comparison for return loss (S_{11}) simulation results between Type 1 and Type 2 slotted ring wideband bandpass filter design Type 2 slotted ring wideband bandpass filter design (ground)

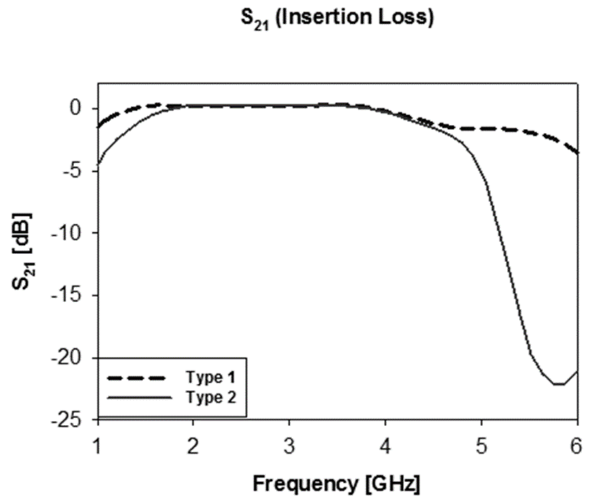

Figure 6: Comparison for insertion loss (S_{21}) simulation results between Type 1 and Type 2 slotted ring wideband bandpass filter design

Table 2
Summary of the Comparison of Return Loss and Insertion Loss Results for both Type 1 and Type 2 Slotted Ring Wideband Bandpass Filter

Parameter	Results for Slotted Ring Wideband Bandpass Filter	
	Type 1	Type 2
Return Loss, S_{11} (dB)	-25.32	-25.08
Insertion Loss, S_{21} (dB)	-0.15	-0.20
Operating Frequency (GHz)	1.13 to 5.62	1.53 to 5.12
Bandwidth (GHz)	4.49	3.59

Table 3
Summary of the Comparison with Previous Works [2,14-15]

Parameter	BPF ref [2]	BPF ref [14]	BPF ref [15]	Proposed Design
Return Loss, S_{11} (dB)	-10	-11.7	-7	-25.32
Insertion Loss, S_{21} (dB)	1.03	1.62	1.55	-0.15
Bandwidth (GHz)	1	0.272	2.03	4.49

IV. CONCLUSION

Two designs of slotted ring wideband bandpass filter design with difference ring's width are presented. Broadside-coupled microstrip-slot technique has been implied into both designs to produce tight coupling filter with a wideband frequency range performance. The results show that the slotted ring wideband bandpass filter with thicker width shows better results where it is capable to operate at wideband operating frequency range covering from 1.13 GHz to 5.62 GHz. The thicker width of the slotted ring produces better results compared to the one with thin slotted ring as the number of signal power that can transfer from input port to output port for thicker width will be more compare to the thinner width. Both return loss (S_{11}) and insertion loss (S_{21}) of the filter show that the proposed wideband bandpass filter exhibits good performance and can be used in as a microwave resonator to measure the quality of rice when be filled with the rice on top of the proposed filter.

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