Bandpass Filter Design Using Microstrip Split-Ring Rectangular Resonator

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Abstract — **In this thesis, a multilayer bandpass filter using microstrip split-ring resonator has been proposed for frequency range of 1.452 GHz to 1.492 GHz. The filter was designed using Computer Simulation Technology (CST) software and implement on Rogers Duroid RO3003 substrate with dielectric constant, ε_r of 3 and tan δ of 0.0013 with thickness 0.75 mm. The insertion loss and return loss for this filter is -0.4539dB and -23.93 dB, respectively. The effect of coupling gap of the split-ring resonator and few other parameters was studied and the analysis has been included.**

***Index Terms*-split-ring resonator, multilayer structure, microstrip filter**

I. INTRODUCTION

Ring resonators have found many applications in microwave circuits. The microstrip ring resonators have been widely used to evaluate phase velocity, dispersion, and effective dielectric constant of microstrip lines. The main attractive features of the ring resonator are not only limited to its compact size, low cost, and easy fabrication but also present narrow passband bandwidth and low radiation loss. Many applications, such as bandpass filters, oscillators, mixers, and antennas using ring resonators have been reported [1].

A good filter has all the desired factors including low insertion loss, high return loss, and high rejection band. The split-ring resonators used to prevent signal propagation in a narrow band in the vicinity of their resonant frequency [6]. The size of the coupling gap between ring resonator and feed lines affect the strength of coupling and the resonant frequency. For instance, for a narrow coupling size gap, the ring resonator has a tight coupling and can provide a low insertion loss, but the resonant frequency will be influenced greatly and for a wide gap size, the resonator has a high insertion loss and the resonant frequency is slightly affected. In order to improve the insertion loss, some structures have been published to enhance the coupling strength of ring resonator.

II. FILTER DESIGN AND THEORY

This filter was designed based on the details that are shown below:

Table 1: Design specification

Parameters	Specification
Lower cutoff freq, f_L	1.452 GHz
Center freq, f_C	1.472 GHz
Upper cutoff freq, f_U	1.492 GHz
Bandwidth	40 MHz
Insertion loss, S_{21}	≤-3 dB
Return loss, S_{11}	≥-20 dB

Table 2 shows the properties of Rogers Duroid RO3003 material that is used to model the filter response.

Table 2: Substrate properties

Parameters	Values
Dielectric constant, ε_r	3
Substrate height, h	0.75 mm
Loss tangent, $\tan\delta$	0.0013

Figure below is the structure of the multilayer filter which consists of five layer structures and Table 3 shown the dimension of each layer.

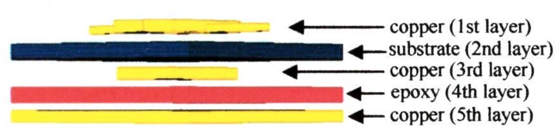

Figure 1: Filter Structure

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Table 3: Dimension of the filter

Layer	Properties	Thickness (mm)
1	top resonator with feed lines	0.035
2	substrate RO3003	0.75
3	inner resonator	0.035
4	epoxy	0.37
5	ground	0.035

The center frequency of the filter is at 1.472 GHz. Based on center frequency and dielectric constant, wavelength, λ calculated is 117.59 mm. At the first layer was the resonator on top of the dielectric substrate and the inner resonator was placed reversely to the face of the substrate. The thickness for both of the feeder are 1.74 mm x 16.4 mm to get the 50 Ω. The total size of this split-ring multilayer filter is 98 mm x 98 mm x 1.19 mm. The dimensions of the resonators are shown in Figure 2 (a) and Figure 2 (b).

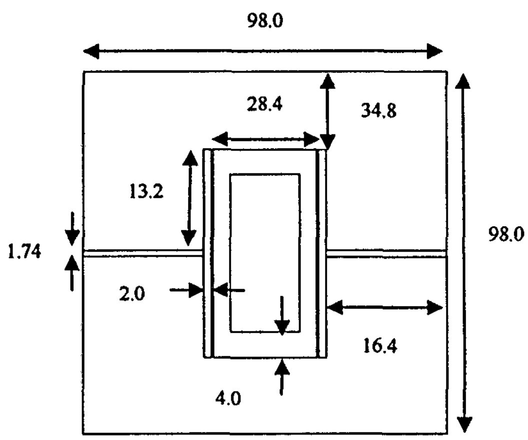
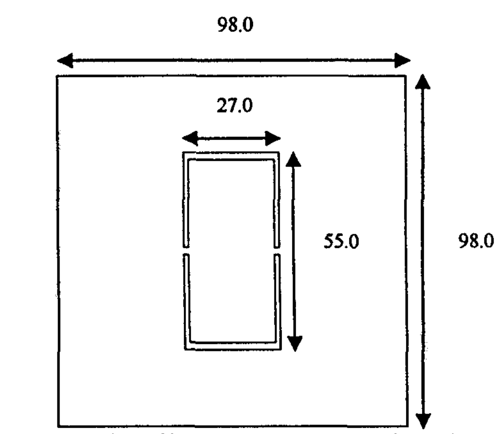


Figure 2: (a) Dimension of the upper layer resonator (unit: mm)



(b) Dimension of inner layer resonator (unit: mm)

Figure 3 summarize the methodology involved in designing the filter. All design and simulation process was carried out using CST Microwave Studio.

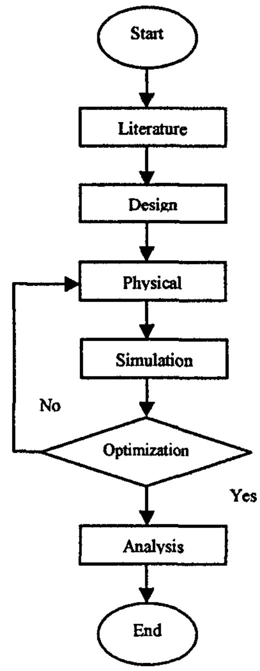


Figure 3: Flowchart of multilayer design

III. Results And Discussion

Figure 4 shows the frequency response of split-ring resonator bandpass filter, centre frequency of 1.47 GHz was obtained, the insertion loss, S_{21} is -0.4539 dB and the return loss, S_{11} is -23.93 dB. The expected result is respective frequency at 1.472 GHz. According to the theoretical result, return loss, $S_{11} \leq -20$ dB while insertion loss, $S_{21} \geq -3$ dB must be satisfied. So, the return loss and the insertion meet the theoretical result.

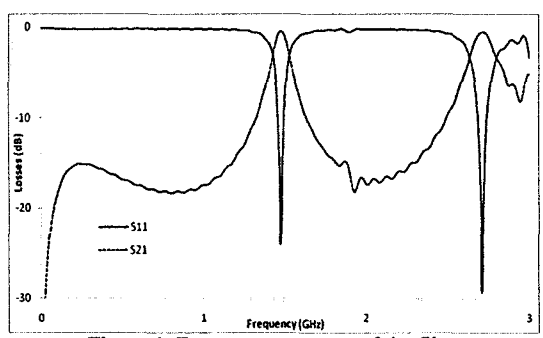


Figure 4: Frequency response of the filter

A number of parameters affect the response of a filter based on multilayer ring resonator. These are the length of the resonators, position of the feed, gap between adjacent resonators on top layer and inner layer which has a large influence on the performance related to insertion loss, S_{21} and return loss, S_{11}. These parameters are optimized in order to achieve a response. The dielectric constant and the thickness control the capacitive/inductive coupling between the neighboring resonators which can be used to achieve various desirable bandwidths. In order to enhance the filter, appropriate substrate thickness, dielectric constant and gap size have to be chosen.

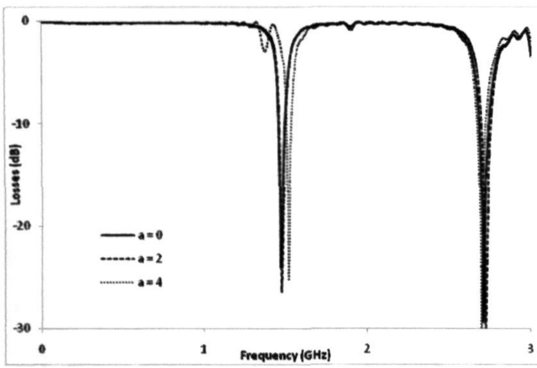


Figure 5: Parameter sweep of S_{11} on variation of inner resonator size

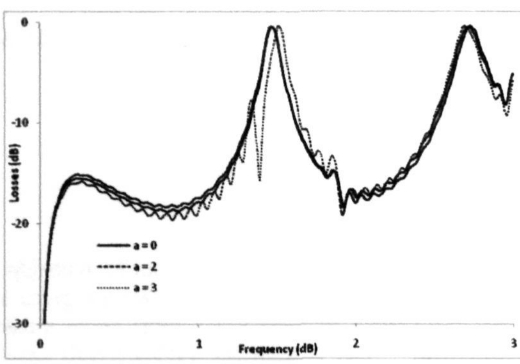


Figure 6: Parameter sweep of S_{21} on variation of inner resonator size

From the analysis, the response is affected by the size of inner layer resonator as shown in Figure 5 and Figure 6. "a" is a value to be added to the inner layer resonator width simulated design proposed earlier. From the graph, the response is having a slightly shifted to the right when the size of inner resonator is being increased.

Figure 7 and Figure 8 shows the response that shifted when added "b" as the constant. "b" is the value added to the proposed design for width of top layer resonator. By increasing the size of resonator structure, the response will shifted to the lower frequencies and vice versa, as it fulfill the theory of $\lambda = c/f$. The wavelength is inversely proportional to the frequencies.

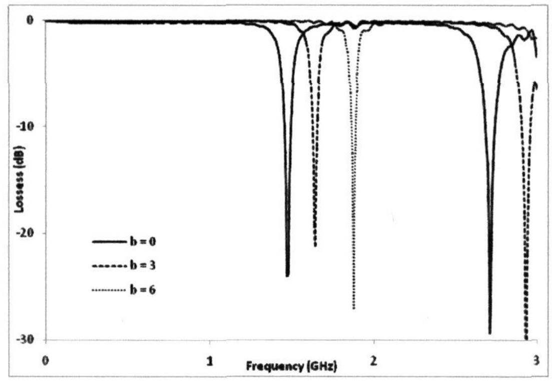


Figure 7: Parameter sweep of S_{11} on variation of top resonator size

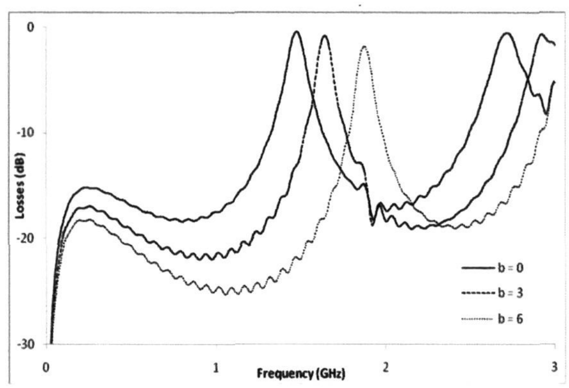


Figure 8: Parameter sweep of S_{21} on variation of top resonator

The suitable size of split-ring resonator is needed in order to make a stronger coupling effect and at the same time the losses due to parasitic and fringing effect if the resonator to be located nearer other adjacent. Figure 9 and Figure 10 shows the variation of gap size of the adjacent resonator. Let take "c" as the constant to be added to the proposed design. The response will be shifted to the right as the gap size is become larger between the resonators. This is due to the weaker coupling effects that arise to the design. Without coupling gaps between feed lines and ring, there are mismatch and radiation losses between them. Thus the filter can obtain a low insertion loss and the major losses of the filter are contributed by conductor and dielectric losses.

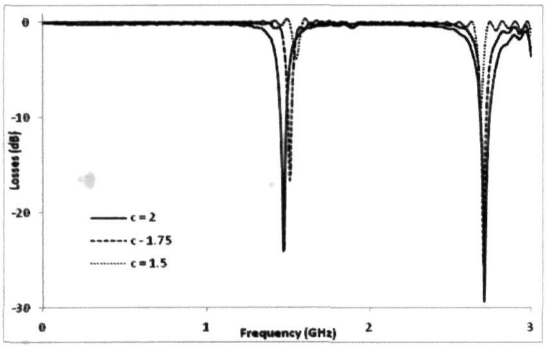


Figure 9: Parameter sweep of S_{11} on variation of gap size between adjacent resonators on top layer

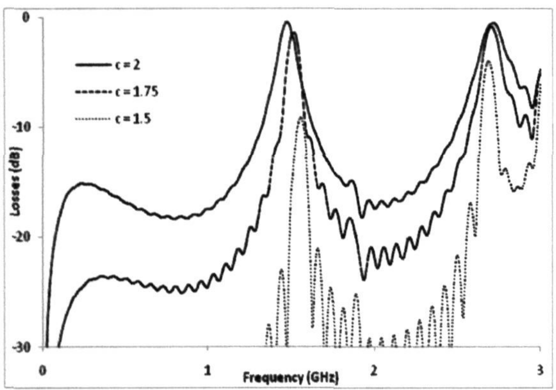


Figure 10: Parameter sweep of S_{21} on variation of gap size between adjacent resonators on top layer

IV. CONCLUSSION

The objective of the project to design a multilayer bandpass filter using microstrip split-ring rectangular resonator with operating range from 1.472 GHz to 1.492 GHz has been achieved through CST software. The designed filter was simulated for its input return loss and insertion loss responses. There are some analysis has been conducted for the selected parameters such as gap size of the upper layer resonator, width and length of the resonator. However, the simulated results did not agree well with the desired specification. Although the designed filter did not meet the specification perfectly therefore there are rooms for further improvement.

This design can be modified and constructed in many ways to suit the applications and operating range in the future. By creating any slits, adding a notch, cascading two or more rings, implementing using high relative permittivity substrate, and so on. It is believed that the variations and applications of ring circuits have not been discovers yet and many new circuits will certainly out in the future.

Multilayer structure is known to be one of the methods to reducing the size of circuit. In order to improve the filter performance, filter can be designed using more than one type of substrates and by adding the number of stacked structure, can be conducted and analyzed. By choosing the substrate with lower loss tangent can improve the performance of the filter.

The analysis on the design parameters that have effect the frequency response on filter performance should carry out. It can be related to microwave theory. Hopefully, this designed filter can be realized in the future.

V. ACKNOWLEDGEMENT

The authors would like to thank all the supervisors, MOSTI for funding this project and Microwave Technology Centre (MTC) for supporting all the activities.

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