Triple Band Bandpass Filter Design and Implementation Using SIRs

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Abstract: Microstrip triple band tri-section bandpass filter using stepped impedance resonators (SIRs) is designed, simulated, built for the first time using hair pin structure and tested. The coupling effect between each SIR is investigated and its effect on the filter characteristics including bandwidth, attenuation is given. The simulation results, and measured results are compared and found to be very close. It is shown that the coupling effect between SIRs can be used as a knob to obtain better performing bandpass filter for the desired frequency band. The results of this work can be used in RF transceivers where multiple frequency bands are needed.

Keywords: Bandpass, SIR, microstrip, filter, resonator.

1. **Introduction**

RF/microwave filter is one of the indispensable components in wireless communication systems. As the complexity of the communication systems increases, the demand for RF components operating in multiple bands becomes critically important. There has been numerous publications in the area of the filter technology. The development of microwave filter technology from an application perspective is given in detail in [1].

Conventional parallel coupled bandpass filters suffer drastically from the spurious harmonics. The stepped impedance resonator filters (SIRs) can be used to realize high performance bandpass filters by suppressing the spurious harmonics to overcome this problem [2]. One of the key features of an SIR is that its resonant frequencies can be tuned by adjusting the impedance ratios of the high-Z and low-Z sections. The dual band SIR bandpass filter design has been studied previously in [3,4]. The idea of a new coupling technique to improve the coupling degree and as a result performance of the SIR filter is discussed in [5]. The dual band tri-section folded SIR filter is described in [6]. The triple band bandpass filter using tri-section SIR filter which an improved performance over the dual band bandpass SIR filter discussed in [5] is given in [7]. SIR filter in [7] has resonators which have hairpin structures making the filter more compact. However, the filter design proposed in [7] lacks the important information on the coupling between each resonator and its effect on the filter performance. In addition, it has never been implemented.

In this paper, we use the method and design technique given in [7] to design and implement triple band bandpass filter. Triple band microstrip bandpass filter is designed and simulated using planar electromagnetic simulator, Sonnet V12. The filter is then implemented for the first time according to authors' knowledge on a low loss RF material RO 4003. The measured results and simulated are the compared and found to be in agreement. The coupling between SIRs and its effect on the filter performance for each band is studied using planar electromagnetic simulator. It is shown that the coupling between SIR can be as a knob to obtain the optimized triple bandpass filter for the proposed topology.

2. **Design of Triple Band Bandpass Filter**

The symmetrical tri-section SIR used in the bandpass filter desogn is shown in Fig.1.

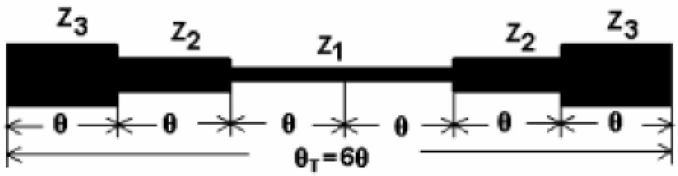


Fig.1**.** Three section SIR.

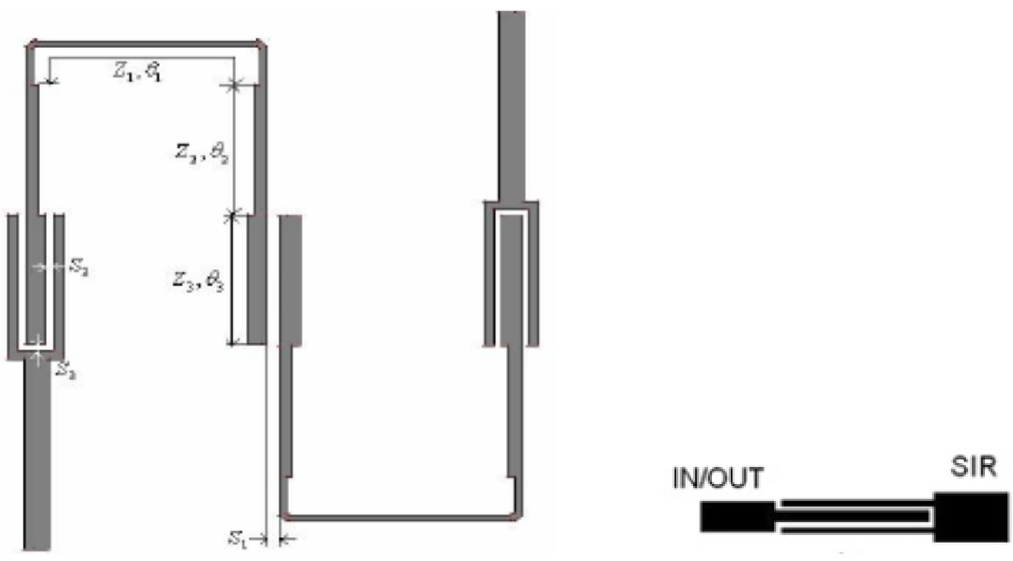
The total electrical length of the SIR is $\theta_T = 60^\circ$ with impedance ratios

$$K_1 = \frac{Z_3}{Z_2}\ . \qquad (1a) \qquad\qquad K_2 = \frac{Z_2}{Z_1}\ . \qquad (1b)$$

Hence, the resonance occurs when the electrical length θ is equal to

$$\theta = \tan^{-1}\left(\sqrt{\frac{K_1 K_2}{K_1 + K_2 + 1}}\right). \qquad (2)$$

as given in [7]. The proposed triple band tri-section bandpass filter using SIR is shown in Fig. 2a below. The wideband characteristic in the passband is obtained by using coupling segments illustrated in Fig 2b. Each coupling segment in Fig. 2a is capable of producing additional reflection zero (pole) within the band. As a result, inter-coupled open end stub segments in Fig. 2b are used to improve the passband characteristics of the filter in Fig. 2a.



(a) (b)

Fig. 2. (a) Triple band bandpass filter using SIRs **(b)** Inter-coupled segments.

The filter has three center frequencies which are located at 1GHz, 2.4GHz, and 3.6GHz. The dielectric material is chose to be RO4003 which as a relative dielectric constant of 3.38 and loss tangent of 0.0021. The physical dimensions of the filter are found using the program written in Mathcad. The dimensions are then substituted into electromagnetic simulator Sonnet V12 and simulated. The layout of the structure simulated in Sonnet is illustrated in Fig. 3.

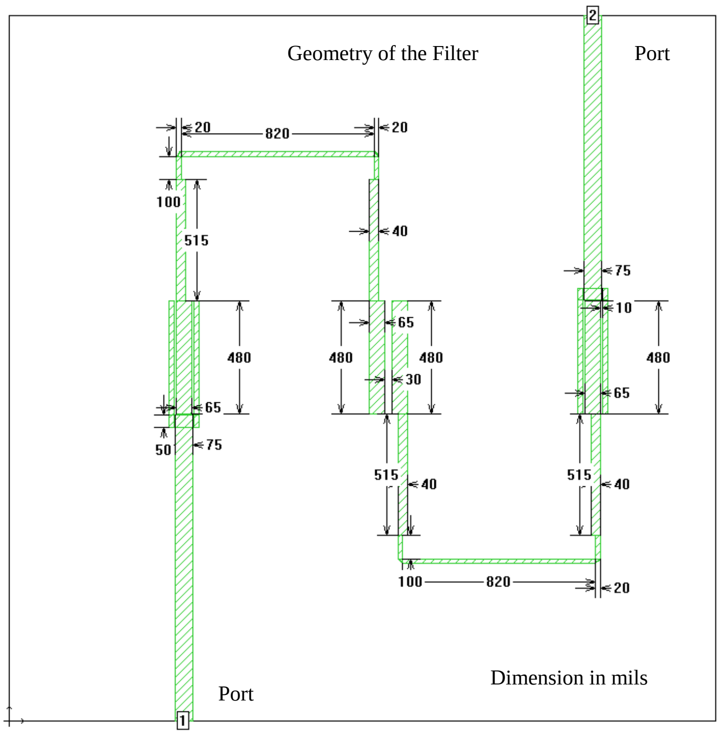


Fig. 3. Layout of the triple band bandpass filter simulated by Sonnet V12.

3. Measurement and Simulation Results

The simulation and measurement results for insertion loss, $|S_{21}|$, and return loss, $|S_{11}|$, for tri-section triple band bandpass filter are illustrated in Fig. 4 below.

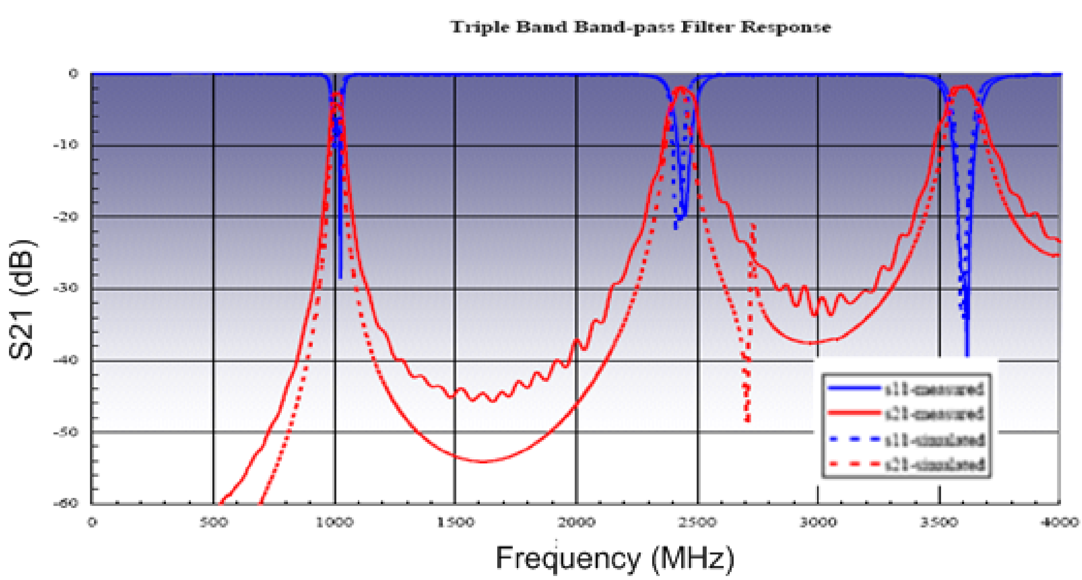


Fig . 4. Measured and simulation results for insertion loss and return loss up to 4GHz.

The simulation and measured results are found to be closely in agreement as seen in Fig. 4. The effect of coupling between each resonator is studied using planar electromagnetic simulator for three different cases in each frequency band. The simulation results are shown in Fig .5.

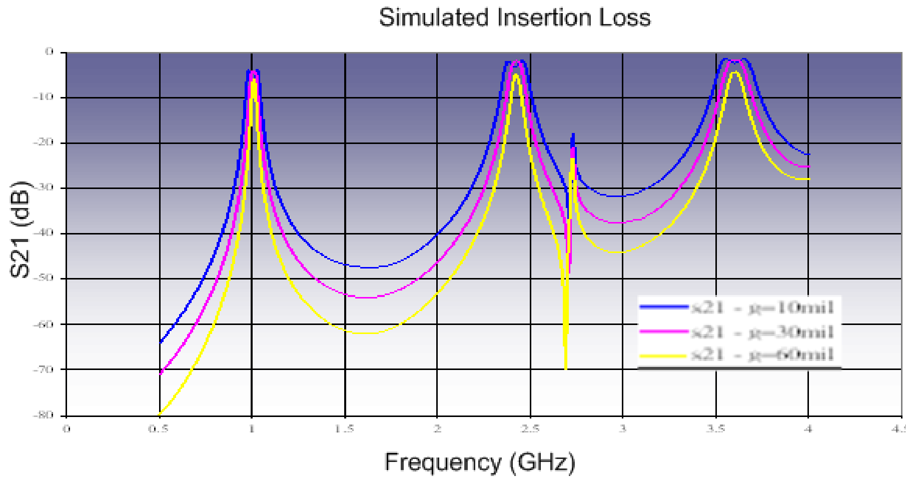


Fig . 5. Effect of coupling in each frequency band for tri section triple band bandpass filter.

As seen in Fig. 5, the amount of attenuation in the stopband and the desired bandwidth in the passband can be adjusted using this unique feature of the proposed filter.

4. Conclusions

Tri-section, triple band microstrip bandpass filter using SIRs is designed, simulated, built and tested. The measured and simulation results are compared and found to be very close. The coupling between each resonator is studied to observe its effect on the filter performance. It has been shown that the coupling between the resonators can be used to adjust the amount of attenuation in the stopband and the desired bandwidth in the passband. This type of filter can be used in wireless communication systems where multiple frequency bands are required.

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