Design of Triple Band Bandpass Filter using Two Coupled Open Loop Triangular Ring Resonators Loaded with Stub

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Abstract. This paper presents a triple band bandpass filter using two coupled open loop triangular ring resonator loaded with stub operating at frequencies 5.7 GHz, 6.8 GHz and 12.85 GHz. The coupled open loop triangular ring resonator is based on the coupled resonator theory to improve the stopband performance of the proposed filter. Transmission zeros (TZs) are generated at edges of passbands to obtain good selectivity. Stubs are loaded to improve the passband performance of the filter. The proposed filter is design and simulated using Agilent Advanced Design System (ADS). The simulated and measured results are in good agreement and show good in band performance.

Keywords: Triple band bandpass filter, open loop triangular ring resonator, stubs, selectivity

1. Introduction

During last few year multi-band bandpass filters had shown a rapid progress in the area of multi-services in various communication systems such as WLAN, RFID, PCS, and WIMAX. Triple-band filter is the essential building blocks of multiband transceiver systems [1, 2]. Initially, triple band filters are developed by using a combination of stubs with step impedance resonator or with different sets of resonators giving good selectivity but with the drawback of increased size [3, 4]. To minimize the size of the triple band filter, use of single resonator with loaded open and short stubs came into existence, but this design lacks behind with sharp selectivity [5–8]. Still, researches are conducted to meet the sharp selectivity and miniaturization.

In this paper, a triple band bandpass filter is proposed with two coupled open loop triangular ring resonator loaded with the stub. The dielectric material used in designing is Rogers RT Duroid 6010 with thickness 1.27 mm having dielectric constant 10.2.

2. Design of triple band bandpass filter

Open loop triangular ring resonator is mostly used for designing filters is due to its smaller size as compared to conventional resonators used for designing. Open loop resonator encounters both electric coupling and magnetic coupling. Coupling strength is determined by the nature and extent of the field along the resonator which further depends upon the length, width and dielectric constant of the filter. For a single passband, an open loop triangular ring resonator is coupled in series with the transmission line, see Figure 1.

Resonant frequency of single passband of open loop triangular ring resonator is coupled with transmission line is given by

$$f_o = \frac{c}{2L\sqrt{\varepsilon_{eff}}}$$

where, c is the Speed of light, f_o is the fundamental resonant frequency, L is the length of microstrip line and ε_{eff} is the effective dielectric constant.

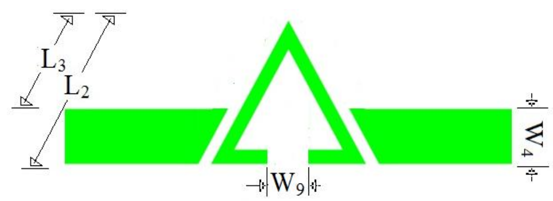

Fig.1. Structure of open loop triangular ring resonator coupled in series with the transmission line.

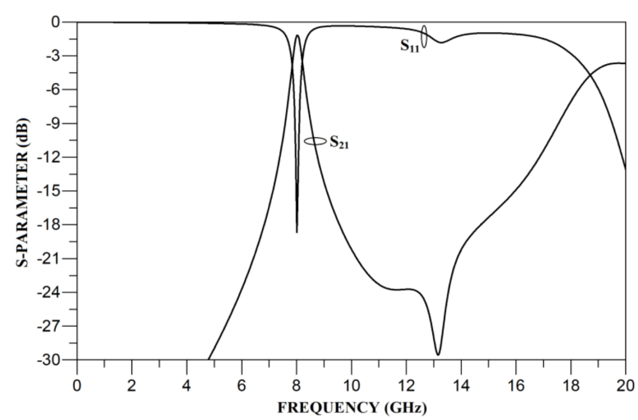

Fig.2. Frequency response of open loop triangular ring resonator coupled in series with transmission line.

The frequency response of the open loop triangular ring resonator is shown in Figure 2. The resonant frequency is found to be centered at 8 GHz with insertion loss as 1.1 dB and return loss as 18.7 dB. A wide stopband is achieved on both sides of the passband.

An upper stopband extends from 18.2 GHz to 18 GHz with return loss less than 3 dB and a maximum value of insertion loss as 29 dB.

An open loop triangular ring resonator will work as dual band filter when its coupling with the transmission line is increased that is increase in electrical coupling will increase the resonant frequency. To increase the resonant frequency a stub is added to the transmission line which is electrically coupled to the side of open loop triangular ring resonator, see Figure 3. Considering resonant mode theory and slow-wave effect, change in field distribution of open loop triangular ring resonator inspires the degenerate modes, which in return generates attenuation poles due to cross coupling of it with a shift of resonant frequency of higher harmonic wave. A two resonant frequency is obtained with centre frequency as 7.5 GHz and 13.7 GHz, the insertion loss and return loss at first passband is 0.38 dB and 35 dB whereas the second passband has 2.6 dB and 13.6 dB, see Figure 4. The two resonant frequencies are separated by stopband. A good upper stopband is also achieved extending from 15.05 GHz to 20 GHz with return loss less than 3 dB and maximum value of insertion loss as 23 dB.

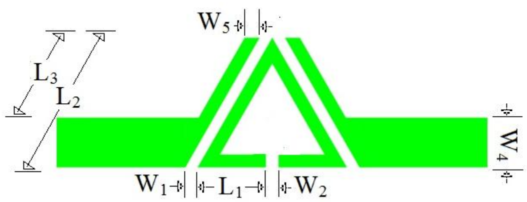

Fig.3. Structure of open loop triangular ring resonator coupled in series with transmission line with loaded stub.

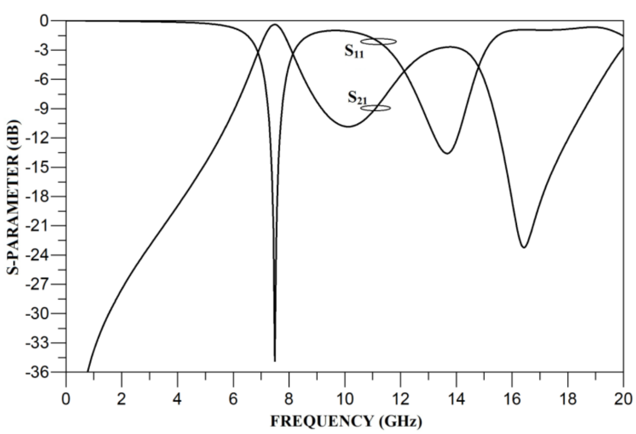

Fig.4. Frequency response of open loop triangular ring resonator coupled in series with transmission line loaded with stubs.

To improve the stop band that is one separating the passband and the other is the upper stop band, Stubs are loaded to open loop triangular ring resonator for coupling degenerating modes to obtain the work condition of dual mode resonator, see Figure 5. The structure of the resonator is shown in Figure 5, can be modeled as a combination of open loop triangular ring resonator and parallel coupled lines, see Figure 6. L_R in the equivalent circuit represents the inductance due to length of the open loop triangular ring resonator; C_P is the capacitance formed due to parallel combination of the C_{P1} and C_{P2} where C_{P1} and C_{P2} are the parasitic capacitance due to the dielectric used. C is the capacitance formed due to the parallel combination of the C_1 and C_2 where C_1 represents the capacitance due to the open loop triangular area and C_2 represents the capacitance due to coupled lines at open loop triangular ring area. When the distance between coupled stubs is increased then the resonant frequency shifts towards the higher frequency side since capacitance C decreases and when it is decreased then the resonant frequency shifts towards the lower frequency side since capacitance C increases, see Figure 7. Figure 8 shows the comparative study of open loop triangular ring resonator loaded with and without coupled stubs. It is found that both the passband degrades with the shift of centre frequency towards lower frequency side while the stop band improves. The two passbands centre frequencies are 6 GHz and 11.64 GHz. The insertion loss and return loss at first passband are 0.65 dB and 24.62 dB while the second passband has 4.3 dB and 8 dB. Stop band separating the two passbands extends from 6.285 GHz to 11.05 GHz with minimum return loss as 0.275 dB and maximum insertion loss as 47 dB. The upper stop band extends from 12.33 GHz with return loss less than 3 dB and maximum insertion loss as 37.66 dB.

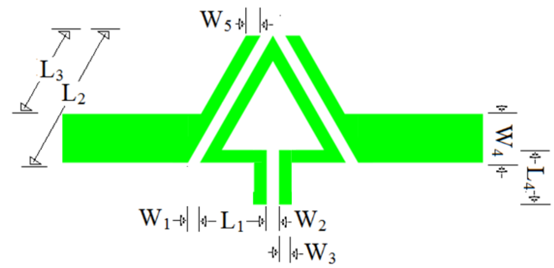

Fig.5. Structure of open loop triangular ring resonator loaded with coupled stub.

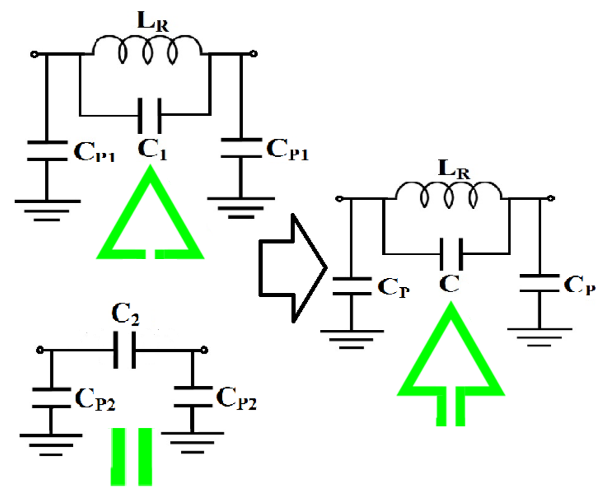

Fig.6. Equivalent circuit of resonator of structure shown in Fig. 5.

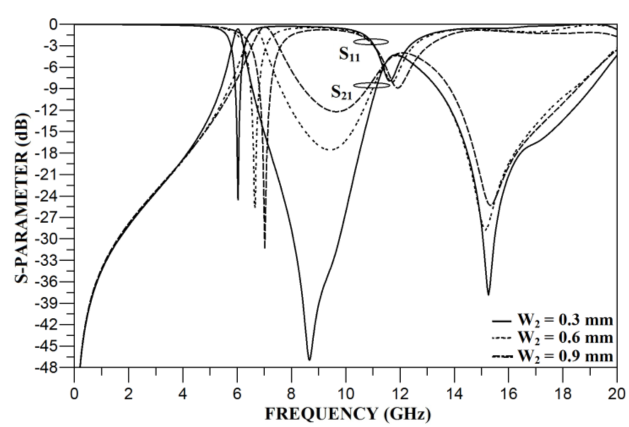

Fig.7. Comparative Frequency response of open loop triangular ring resonator loaded with coupled stubs with varying coupled distance.

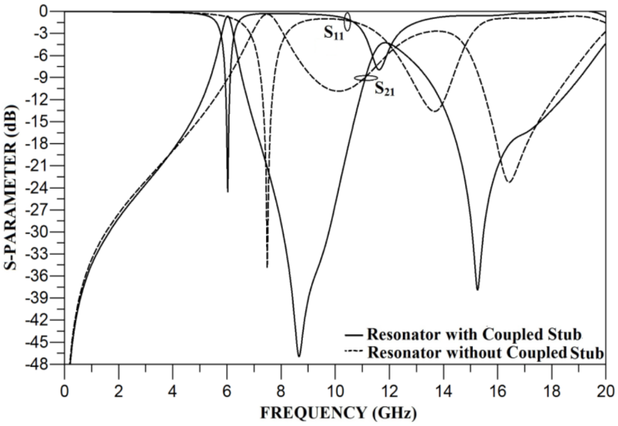

Fig.8. Comparative Frequency response of open loop triangular ring resonator with and without coupled stubs.

For work condition of filter as triple band, a resonant frequency is to be increased. Considering coupled resonator theory [9], two open loop triangular ring resonators loaded with stubs are coupled in parallel resonating at different frequencies, see Figure 9. The insertion loss and return loss is improved in the third passband due to the improvement in electrical and magnetic coupling at the open loop triangular area of both the triangles, see Figure 10. The first and second resonating frequencies are due to the difference in the distance between the coupled stubs of the two resonating structures. The third band is the harmonic of higher frequency. The three passbands have centre frequency as 5.7 GHz, 6.8 GHz and 12.85 GHz each separated by wide stop band. The first stopband is separating first and second passband extends from 5.9 GHz to 6.7 GHz has minimum return loss as 0.34 dB and maximum insertion loss as 30.5 dB. The second stop band separating second and third passband extends from 7 GHz to 12.5 GHz has return loss less than 0.6 dB and insertion loss more than 11 dB, The upper stop band extends from 13.44 GHz with maximum insertion loss as 37.2 dB and return loss less than 3 dB, see Figure 11.

3. Fabrication and Measurement

The optimized dimensions of the proposed filter are as follows: L_1 = 1.6 mm, L_2 = 3.5 mm, L_3 = 2.16 mm, L_4 = 1.3 mm, W_1 = 0.3 mm, W_2 = 0.2 mm, W_3 = 0.3mm, W_4 = 1.16 mm, W_5 = 0.35 mm, W_6 = 0.3 mm, W_7 = 0.3 mm, W_8 = 0.3 and W_9 = 0.9 mm. The proposed structure is a triple band bandpass filter.

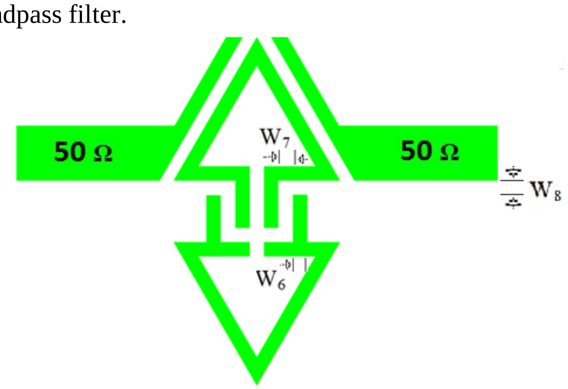

Fig.9. Structure of proposed filter.

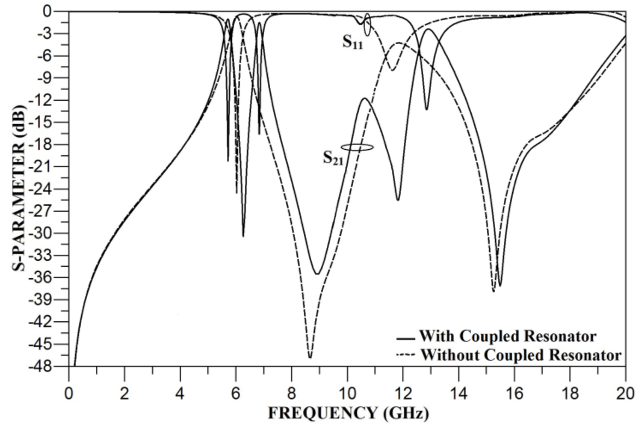

Fig.10. Comparative frequency response of filter with and without coupled open loop triangular ring resonator.

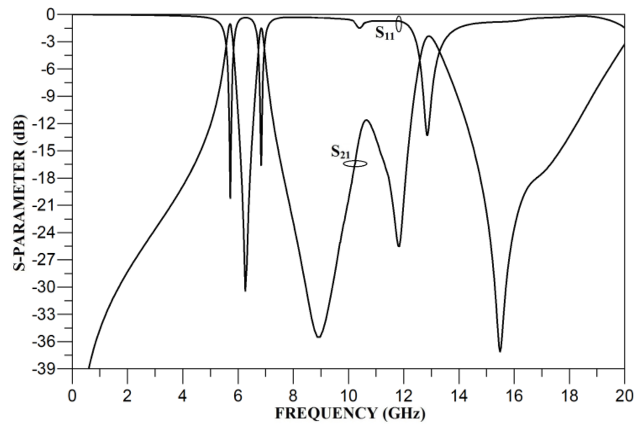

Fig.11. Frequency response of proposed filter.

The photograph of the fabricated filter is shown in Figure 12. Figure 13 shows the simulated and measured frequency response of the proposed filter.

The simulated and measured center frequencies of the three passbands are 5.7 GHz, 6.8 GHz and 12.85 GHz, respectively. The value of insertion loss and return loss in the first passband are 1.0 dB and 18.5 dB, respectively whereas its counterpart is 0.78 dB and 20.3 dB. The simulated second passband insertion loss and return loss are 1.4 dB and 16.6 dB respectively whereas its counterpart is 0.6 dB and 19.6 dB. The simulated third passband insertion loss and return loss are 2.3 dB and 13.3 dB respectively where as its counterpart is 2.4 dB and 14.3 dB. The first stop band separating first two passbands has simulated maximum insertion loss and minimum return loss as 30.5dB and 0.34 dB whereas its measured result is 28.75dB

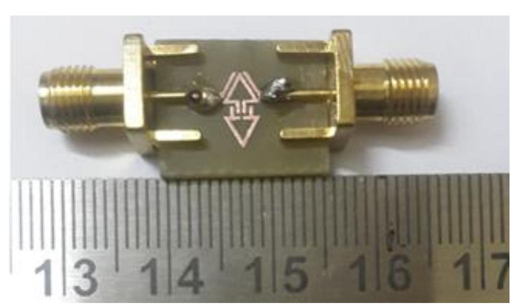

Fig.12. Photograph of the proposed filter.

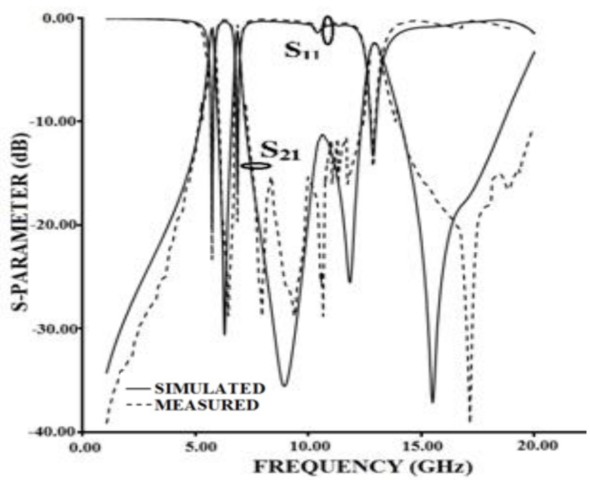

Fig.13. Simulated and measured frequency response of proposed filter.

and 0.14 dB. The second stop band has simulated maximum insertion loss and minimum return loss is more than 11 dB and 0.6 dB whereas its measured results are more than 11.4 dB and 0.11 dB. Upper stop band extends from 13.44 GHz while measured is 13.3 GHz. The upper stopband has return loss less than 3 dB and maximum insertion loss as 37.2 dB while its measured values are less than 3 dB and more than 15 dB. The size of the proposed filter is 3.5 mm x 7.36 mm.

4. Conclusions

This paper investigates a compact and planar triple-band bandpass filter using two coupled open loop triangular ring resonator loaded with stubs. The 3-dB fractional bandwidth of the three narrow passbands centered at 5.7 GHz, 6.8 GHz and 12.85 GHz are 4.03%, 2.7% and 3.1%. The proposed filter shows good selectivity at the edges of passbands. The three passbands are separated by wide stopband. The overall size of the proposed filter makes it suitable for various multiband applications in microwave communication systems. Numerical simulations using ADS shows the feasibility of triple-band bandpass filter.

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Yatindra Gaurav received a Bachelor of Technology degree in Electronics and Communication Engineering from Uttar Pradesh Technical University of Uttar Pradesh, India in 2006 and received his Master of Technology in Electronics Design and Technology from Uttar Pradesh Technical University of Uttar Pradesh, India in 2010. He now holds a research scholars chair at the Madan Mohan Malaviya Institute of Technology, Gorakhpur, Uttar Pradesh, India. His main research interests are Design and Optimization of Microwave Bandpass Filter using Resonators.

Rajeev Kumar Chauhan received the Ph.D degree in Electronics Engineering from IIT (BHU), Varanasi in 2002 and ME from MNNIT – Allahabad in 1993 and B.Tech from G.B.P.U.A.T, Pantnagar in 1989. He has joined erstwhile Madan Mohan Malaviya Engineering College, Gorakhpur in 1993 as a Lecturer, as Assistant Professor from 2002 and Associate Professor since 2006. The college has been reconstituted as Madan Mohan Malaviya University of Technology by U.P. State Government in 2013. He also worked as Professor in Department of ECE, Faculty of Technology, Addis Ababa University, Ethiopia between 2003 to 2005. He is author of more than 100 research papers published in Journals and Conferences. His current research interests include emerging nanoscale devices and issues in in VLSI as well as circuits and systems. He is also involved in exploring the microstrip based antenna and metamaterials based filter design. He has just completed one AICTE sponsored Research Project on “Design and Development of SRAMs”.