DESIGN OF SINGLE BAND NARROW BAND PASS FILTER USING OPEN LOOP STUB LOADED TRIANGULAR RING RESONATOR

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Abstract: The paper introduces a design of a single narrow band bandpass filter using an open loop folded triangular ring resonator. The open loop part of folded triangular resonator is embedded with back-to-back coupled E shape stubs to increase the inductive and capacitive effect in return to which an improved performance of s-parameter is achieved. The design is aimed at planar structure and ease of fabrication as no defected ground structure or via is used. The centre frequency of passband is 3.9 GHz with fractional bandwidth of 5.2%. The s-parameter performance characteristics also includes good rejection performance with skirt selectivity along passband. The proposed structure is designed and simulated using Keysight Advanced Design System. The simulated result is almost matched with measured result.

Keywords: Filters, Microstrip Filters, Stubs, Triangular Ring Resonators

INTRODUCTION

Numerous researches have taken place in wireless communication in recent years, filters play an important role in removing the unwanted frequencies in communication. Microstrip Resonators are key element required to create a filter and majority of filter consist of multiple resonators. Filters can be classified into lumped element d-element LC Filters, planar structure filters such as microstrip transmission line filters, coplanar waveguide filters, etc., and non-planar structure filters such as waveguide filters, resonant cavity filters, etc. On the basis of their attenuation, they can be classified into band-pass filters (BPF), band-stop filters (BSF), high pass filters (HPF) and low pass filters. [1]

Microstrip Resonators are formed using a patch of conductive material on top of dielectric substrate with grounded bottom layer and are used to transmit or attenuate energy at specific frequency bands [2]. They have low insertion loss and high-power handling capacity. Triangular Patch Resonator is a kind of it. But they can experience radiation losses, dispersion, unwanted coupling and discontinuity effect and to address these issues thinner substrates are often allowed at higher frequencies [3]. Later, Microstrip Ring Resonator showed support for dual Mode Operation. Dual Mode reduce the number of resonators needed by half and they enhance the compactness of filter to a great extent [4]. Another type of it is Microstrip Loop Resonator – they are known for their comparatively smaller size but they exhibit higher insertion losses. [5] To provide a greater flexibility in constructing various cross-coupled planar filters open-loop microstrip ring resonator were made with a gap in ring structure [6]. They exhibit both electric and magnetic coupling which results in better insertion loss and better coupling but they occupied space and to reduce the size Folded open-loop microstrip ring resonators were introduced and they were fruitful in operations of compact dual-band filters. In further developments, triangular ring structures were studied – they reduced the size but provided difficulty in fabrication and cost was also high. [7 – 11]. Filters with two passbands are used mainly in variable transmission of frequency but due to showing strong attenuation in practical examples, step impedance resonators parallel coupled lines and coupled serial shunted topology was used [12-14]. Recently, dual-band bandpass filters using transmission line coupled microstrip triangular open-loop ring resonator with stub was studied which showed low insertion loss and two transmission bands. [2].

In this paper, a compact single-band narrow bandpass filter using open loop stub loaded triangular ring resonator is presented. It shows low insertion loss. The dielectric material which is being used Rogers_RT_Duroid6010 with a thickness of 1.27 mm having dielectric constant 10.2.

The software used for simulation is Keysight Advanced Design System (ADS), 2021. It is used for high-speed and high-Frequency physical layer component simulation. It is used for electronic design automation (EDA). Its applications include Radio Frequency (Radio Frequency) components such as mobile phones, radar systems, satellite communications, high-speed data links, etc.

1. Triangular Dual Mode Resonator

Size along with number of patches in a circuit can be reduced by using various dual mode resonating symmetrical structures as they are equivalent to dual tunable resonators [8-10], thus miniaturization in scale of communication systems can be achieved. For achieving small size of triangular patch, circular and square patches are widely used for conventional patches.

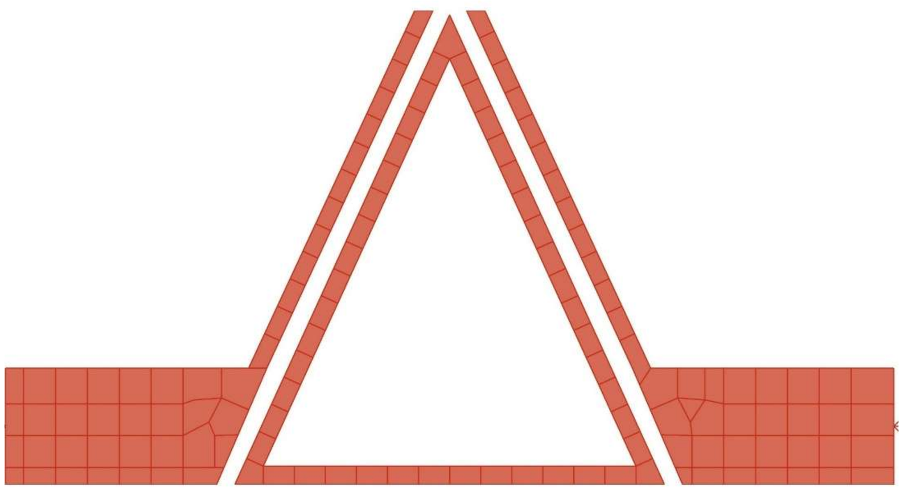

Figure 1: Configuration of Conventional Triangular Dual-Mode Filter

Figure 1 shows the conventional design of triangular ring patch resonator as dual-mode bandpass filter, different responses with different size combinations can be obtained [5]. On the basis of resonant mode theory and slow-wave effect triangular part structure is equal to a cut a part of the structure that is introducing a change in field distribution and inspires the degenerating modes, which generates the attenuation poles due to cross coupling of it with a shift of resonant frequency of higher harmonic wave thus achieving miniaturization technique to design the filter [2].

Fundamental resonance occurs when λ_g is perimeter of outer isosceles triangle where λ_g is the guided wavelength,

$$\lambda g = \frac{c}{f\sqrt{\varepsilon_{eff}}}$$

Where c is the velocity of light in free space and ε_{eff} is the effective dielectric constant of substrate. While a resonant frequency is fixed, λ_g is decreased to realize size reduction ε_{eff} is increased.

2.Design of Triangular Dual Bandpass Filter

As compared to conventional dual mode filters, triangular open loop resonators have a small size [11]. Open loop resonators have a valuable role in loading stubs in proposed structure and coupling with transmission lines. Open loop resonator encounters both electric coupling and magnetic coupling, giving better coupling and insertion loss. Apart from size of resonator, other parameters are also responsible for coupling such as length and width of side of triangular ring resonator. For a particular substrate with a relative dielectric constant ε and a thickness h, the coupling coefficients can be characterized by the dimensions of the open-loop resonator.

When an open loop triangular ring resonator is coupled in series with transmission line, then a passband is seen in the s-parameter characteristics (Figure 3), whose resonant frequency is given by,

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

where,
c = speed of light
f_o = fundamental resonant frequency
L = Length of Microstrip Line
ε_{eff} = effective dielectric constant

Figure 2 shows the structure of open loop triangular ring resonator coupled with transmission line in series.

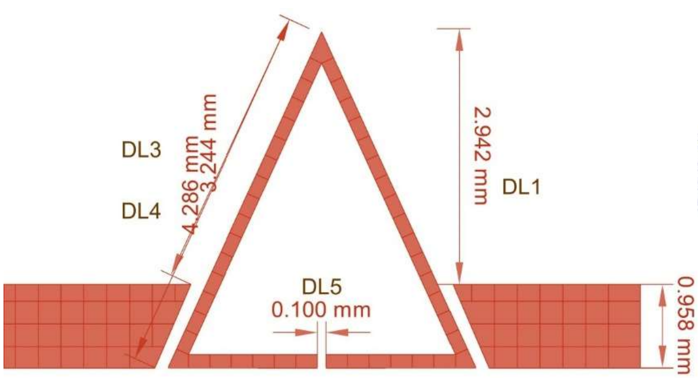

Figure 2: Structure of Open-Loop Triangular Ring Resonator Coupled in series with Transmission Line

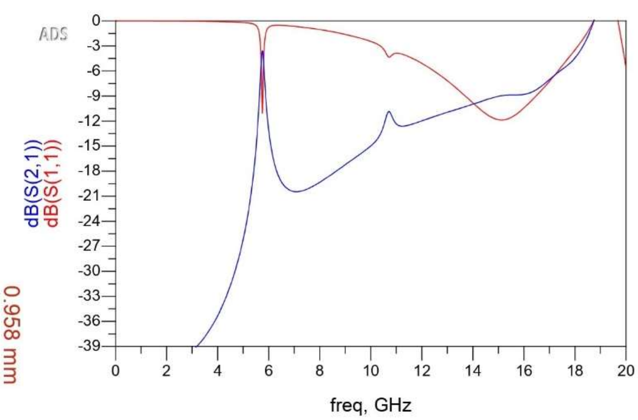

Figure 3: Frequency response of Open-Loop Triangular Ring Resonator Coupled in series with

The resonant frequency is centred at 5.7GHz for C-band applications such as 5G Networks and wireless networks. Stopband is achieved on both the sides of passband and their s-parameter characteristics are shown in Table 1.

S.No	Centre frequency of Passband (GHz)	Insertion Loss (dB)	Return Loss (dB)
1.	5.74	3.5	11.08

Table 1: Simulated Frequency Response Shown in Figure 3

The open-loop triangular ring resonator coupled in series with transmission line with extended stubs **(stub thickness 0.15 mm)** is shown in figure 4 and a two resonant frequency is obtained as shown in figure 5. The two stubs on both the sides are kept of variable length to obtain a resonant frequency in Unlicenced National Information Infrastructure (UNII) and two passbands are separated by a stopband. Table 2 shows the two resonant frequencies and their s-parameter characteristics.

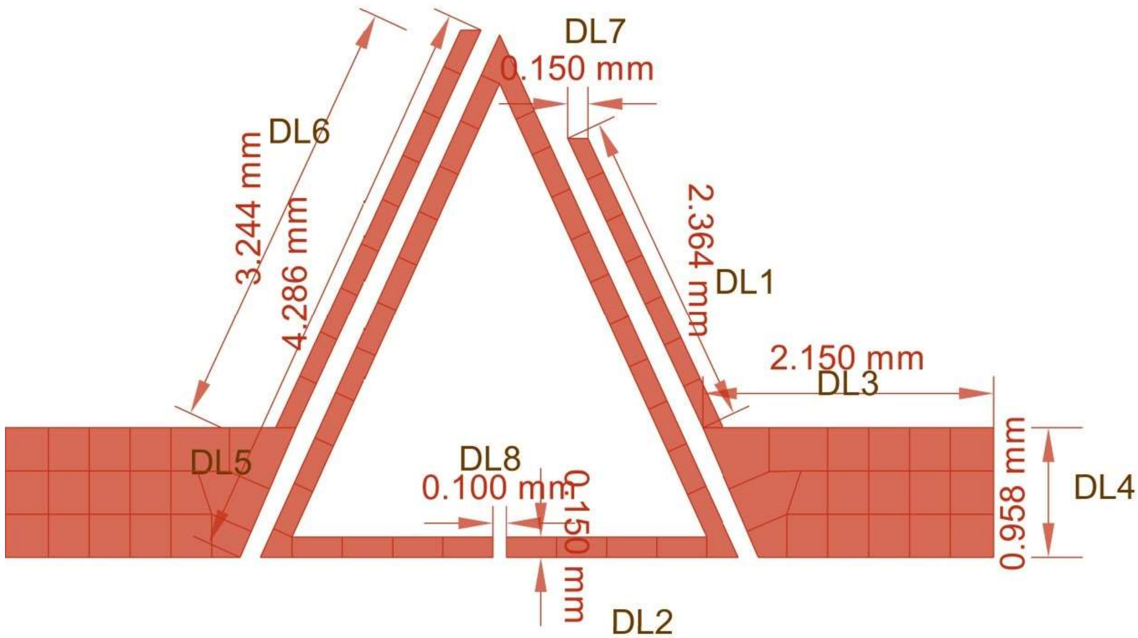

Figure 4: Structure of Open Loop Triangular Ring Resonator Coupled in Series with transmission line extended stub at ports.

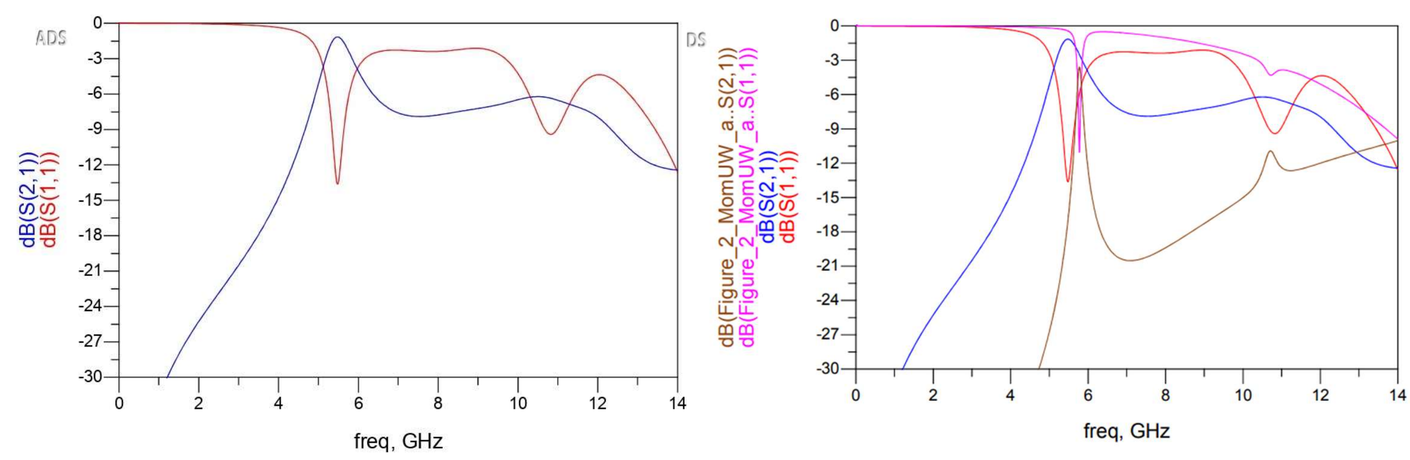

Figure 5(a & b): Frequency response of Open Loop Triangular Ring Resonator Coupled in Series with Transmission Line with extended stub at ports: (a) Without comparison; (b) Comparison with Figure 2

S.No	Centre frequency of Passband (GHz)	Insertion Loss (dB)	Return Loss (dB)
1.	5.48	1.1	13.6
2.	10.82	6.2	9.4

Table 2: Simulated Frequency Response Shown in Figure 5(a)

Further, to improve the coupling and s-parameter performance of triangular ring resonator, a stub is inserted at the mid of open loop triangular ring resonator such that both the stubs are coupled to each other as shown in figure 6. The dimensions of all other parameters are same as shown in figure 4, only the dimensions of loaded stubs are shown in figure 6.

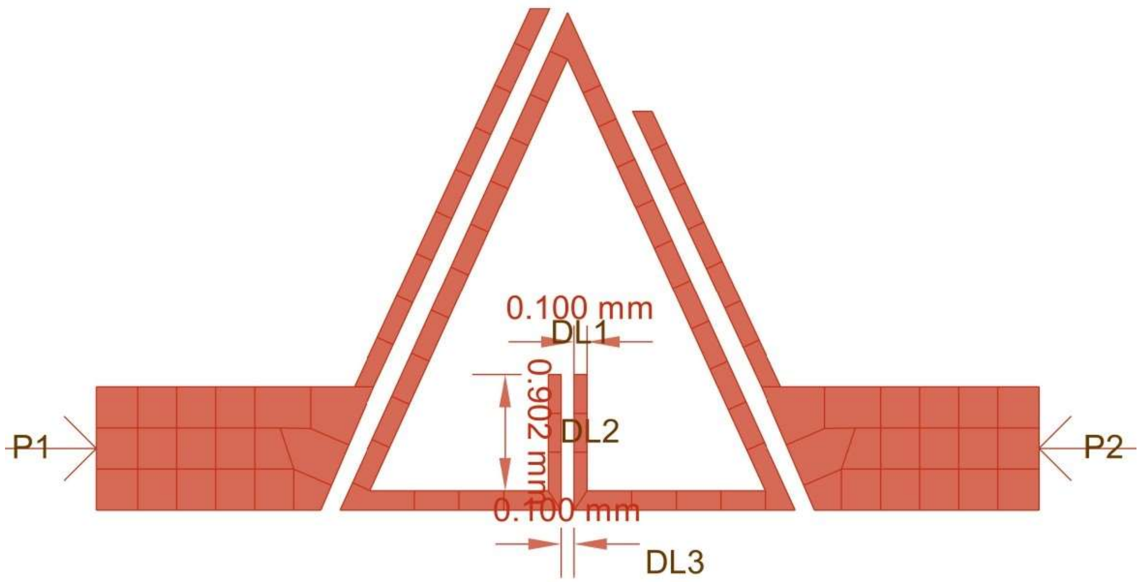

Figure 6: Structure of Open Loop Triangular Ring Resonator Loaded with Stub coupled in series with transmission lines with extended variable length stub at ports

Two resonant frequencies are again obtained as shown in figure 7(a) and A comparative study with and without coupled stub is done by using s-parameters performance as shown in figure 7(b); the comparison shows that there is a shift in both resonant frequencies towards lower frequency side by 0.9 GHz and 0.4 GHz respectively, losses are also improved – the return loss stood less than 3dB.

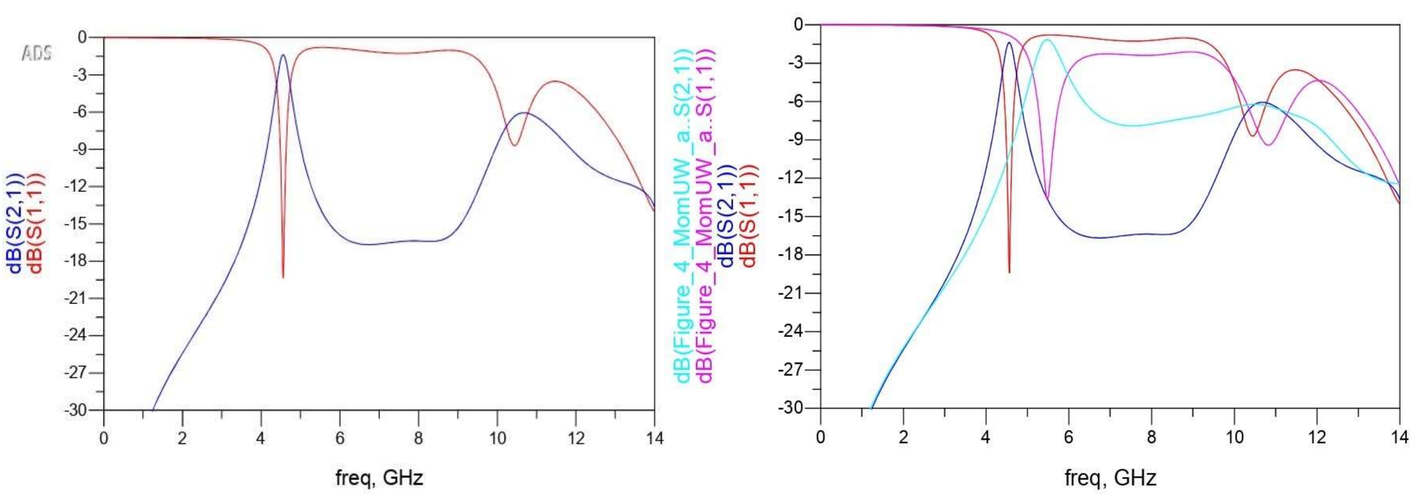

Figure 7(a & b): Frequency Response of Open Loop Triangular Ring Resonator Loaded with Stub coupled in series with transmission lines with extended variable length stub at ports
(a) Without Comparison; (b) Comparison with figure 5(a)

The changes in s-parameter are also observed if anything among the length of coupled stub or the coupling distance between the stub are varied [2].

S.No	Centre frequency of Passband (GHz)	Insertion Loss (dB)	Return Loss (dB)
1.	4.5	1.3	19.3
2.	10.44	6.1	8.7

Table 3: Simulated Frequency Response Shown in Figure 7(a)

The obtained resonant frequency has wide use applications in the field of wireless local area networks (WLANs), specifically in 5GHz band which is employed generally in high-speed data transmission in Wi-Fi systems, they are also resourceful in radar system and 5G network applications.

Proposed Design Structure

The introduction of coupled stubs in open loop triangular ring resonator showed progressive results in obtaining improved s-parameter results and shifting the resonant frequency towards lower frequency side. To further improve the obtained resonant frequency results and improve s-parameters, a planar open loop stub loaded triangular ring resonator (with E-shaped stubs) is proposed. The E-shaped stub is coupled at the mid of open loop triangular ring resonator such that both the stubs are coupled to each other to produce capacitive effect. The proposed structure is shown in figure 8. The dimensions of all other parameters are same as shown in figure 4 and figure 6. Only the dimensions of E-shaped stub are shown in Figure 8.

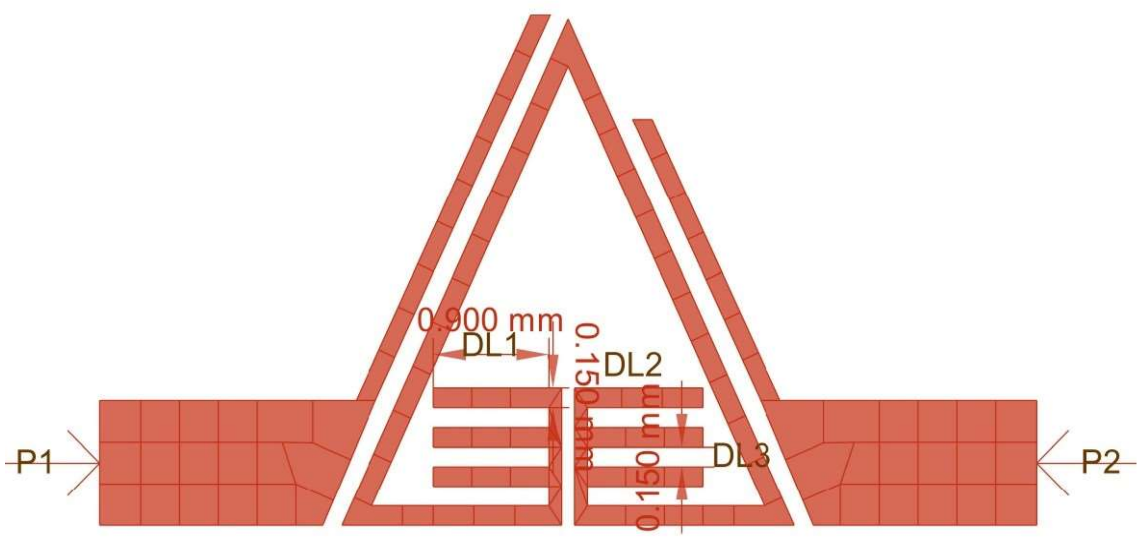

Figure 8: Structure of planar open loop E-shaped stub loaded triangular ring resonator

On simulation, the proposed structure shows promising results. Resonant frequency obtained is 3.9 GHz and 12.8 GHz with a maximum loss of 33.8 dB and an insertion loss of 1.8 dB. The introduction of E-shaped stubs shifted the resonant frequency more towards lower frequency side and also improved the obtained losses. The fractional bandwidth obtained from the simulated results is 5.2% (calculated using formula). The simulated results are shown in Figure 9 (a). A comparative study is conducted between the results obtained of the proposed design structure and structure without E-shaped stubs (structure as shown in Figure 6) and it was observed that the new resonant frequency obtained in proposed structure is more shifted towards lower frequency side and obtained value of insertion and return losses are also improved. Figure 9(a) shows the frequency response of figure 8 and figure 9(b) shows the comparative analysis.

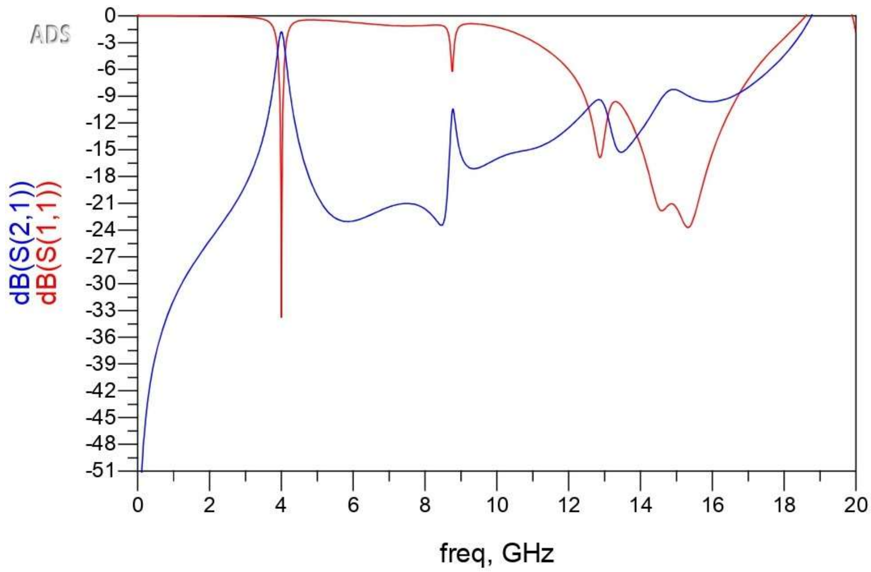

Figure 9(a): Frequency response of open loop E-Shaped stub loaded triangular ring resonator

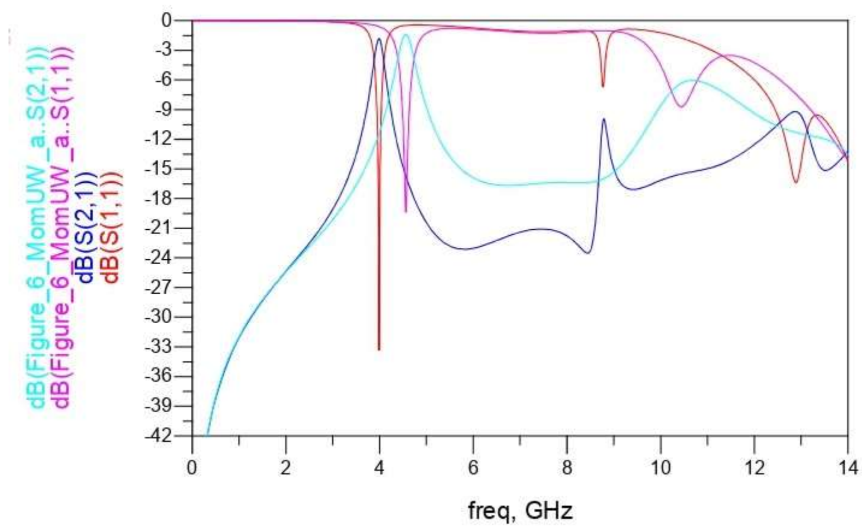

Figure 9(b): Comparison of Frequency response of open loop E-Shaped stub loaded triangular ring resonator with result obtained in figure 7(a)

The obtained value of fractional bandwidth emphasizes that the proposed filter structure so designed is a narrowband bandpass filter and the resonant frequency obtained of 3.9 GHz have wide range application in the field of wireless communication and satellite communication systems

CONCLUSION

A novel planar compact narrow-band bandpass filter using open-loop E-shaped stubs loaded triangular ring resonator is proposed and the proposed design structure generates a passband at 3.9 GHz and 12.86 GHz with a fractional bandwidth of 5.2%. The introduction of E-shaped not only shifted the resonant frequency more towards lower frequency side but also helped in induction of capacitive effect in the filter. Moreover, the size of proposed structure is also compact and provides a good selection and better insertion loss from previous works. The proposed design has wide range of applications in various fields such as Satellite Communication Systems (transmission and reception both), Wireless Communication Devices (such as smartphones and routers), radar systems (in filtering and isolation of signals), 5G Mobile base stations (filtering of 5G bands from other frequency bands), various filter technologies. Further works can be concluded in obtaining multiple bands and obtaining other frequencies for transmission.

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