A New Compact and Miniature Coplanar Band-stop Filter Based on Modified Rectangular Split Ring Resonator

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ABSTRACT

This paper proposes a new compact and miniature coplanar band-stop by using modified Rectangular Split-Ring Resonator. The simulation Results of the proposed BSF demonstrates a good characteristic rejected band with stopband fractional bandwidth of 60% at center frequency of f_0= 2.25GHz. A good attenuation is obtained and low return loss is remarked, that is less than 0.2 dB in the rejected band f_0. The designed filter has a good electrical performance of transmission in the first and second bandpass. The proposed circuit is designed, simulated and optimized by CST microwave studio. It is a good choice for various applications and systems.

KEYWORDS

Coplanar, band-stop filter, SRR, Metamaterials

1 INTRODUCTION

Newly, the coplanar filters have been receiving a great interest in microwave and wireless systems due to their ease of fabrication, and their compatibility with Monolithic Microwave Integrated Circuit MMIC and several planar components in those systems. Moreover, the CPW technology has excellent characteristics at high frequencies and it is widely used in the design of various devices in order to reduce the radiation losses. [1-8]

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One of the recent techniques that is used to design coplanar or microstrip band-stop filter is based by using novel engineered materials which are known under the name of metamaterials. The research area in materials with novel electromagnetic properties has achieved remarkable development since 2002. these artificial materials which have unusual electrical and magnetic properties have become the interest of many scientists and researchers in various fields such as aerospace, telecommunications, and biomedical engineering. These special materials show a negative effective permittivity or/and negative permeability near their resonant frequencies and they are characterized by phase and group velocity having opposite sign and provide a negative refractive index around of their practical frequencies. Consequently, these characteristics make the metamaterials good choice to design the miniature radio frequency devices and to achieve certain desired features. [9-13]

This work describes a novel coplanar band-stop filter based on modified rectangular split ring resonator unit cell. This designed filter has an excellent transmission in the first and second pass-band and it is characterized by two transmission zero in the stop-band. Furthermore, it has small circuit size.

2 DESIGN PROCEDURES

2.1 Proposed metamaterial unit cell

The idea of metamaterial was first introduced by Victor Georgievich Veselago at the end of 1967. After thirty years, Pendry et al are succeeded to suggest a medium with negative permittivity and negative permeability. In 2002 David R. Smith was the first researcher who could realize and create a medium media of metamaterial based on split ring resonators and metallic wires. Afterwards, various kinds of these composite materials have been appeared and developed. they have then extensively used and implemented in the microwave components such as filters, antennas, and couplers, in order to attain some purposes in term of size and electrical responses of these devices.

in the beginning, the proposed modified split-ring resonator is designed on Flame Resistant 4 substrate and its dimensions are chosen after several series of optimization and analysis so as to achieve and obtain a desired resonant frequency around 1.5 GHz. Its configuration geometry is presented in Fig. 1, and its simulated scattering parameters are shown in Fig. 2

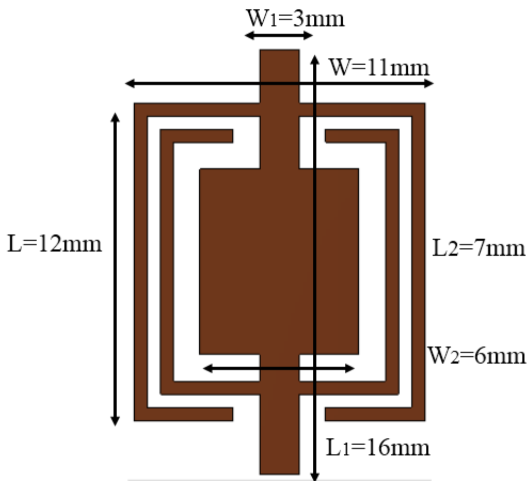

Figure 1: Layout of the Proposed metamaterial unit cell.

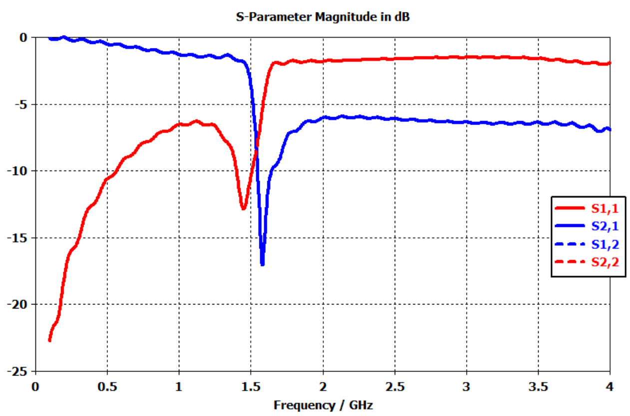

Figure 2: The scattering parameters of the Proposed metamaterial unit cell.

After the validation of the resonator by the obtainment of the wanted particular frequency and optimized geometry dimensions. The verification of unusual characteristics of this proposed resonator was achieved by using The S-parameter Retrieval Method that is very useful and has been largely used for distinct and many kinds of metamaterials to extract the effective parameters linked to the studied medium using the S_{11} and S_{12}. The frequency responses are related to effective permittivity and permeability by the equations below.

$$n = \frac{1}{k_0}\cos^{-1}\left[\frac{1}{2S_{21}}\left(1 - S_{11}^2 + S_{21}^2\right)\right] \quad (1)$$

$$z = \pm\sqrt{\frac{(1+S_{11})^2+S_{21}^2}{(1-S_{11})^2+S_{21}^2}} \quad (2)$$

$$\varepsilon_{eff} = \frac{n}{z} \quad (3)$$

$$\mu_{eff} = nz \quad (4)$$

The Fig. 3 illustrates the effective permeability of the proposed metamaterial unit cell. As we can see this resonator provide a negative real permeability near to its resonant frequency.

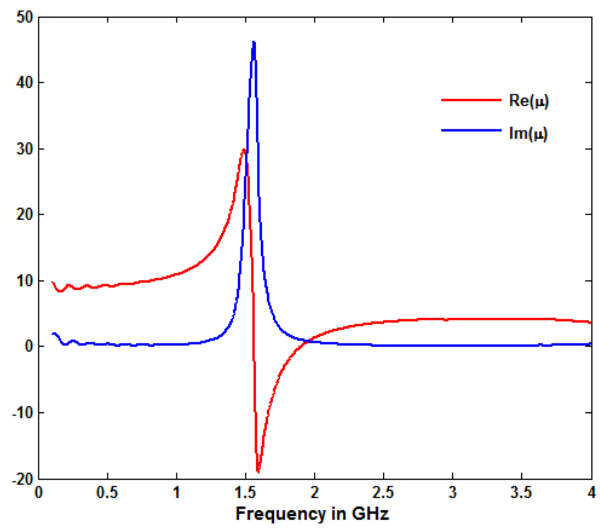

Figure 3: Real and imaginary of the effective permeability.

2.2 Proposed band-stop filter

The aim of this work is to design and develop a novel coplanar band-stop filter has good electrical characteristics in the rejected-band and high quality of transmission in both pass-bands. As well as it has a small circuit area.

The proposed circuit is designed on Flame Resistant 4 epoxy substrate which is characterized by a relative permittivity of 4.4, a loss tangent of 0.025 and a thickness h= 1.6 mm. The modified R-SRR is located and added on the center of the top layer Fig.4 and present the geometry of the proposed filter

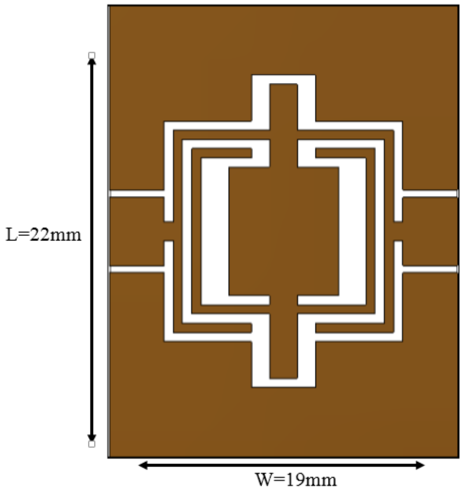

Figure 4: Geometry of the proposed BSF

To explain the effects of the modified R-SRR dimensions on the filter responses, several resonator parameters are varied.

Firstly the influence of the resonator length is investigated and studied by varying the Lr from 9 mm to 12 mm and keeping the all other parameters fixed. The transmission and reflection coefficients are illustrated respectively in Fig. 5.a and Fig. 5.b.

Form the first figure, it is clearly observed that both transmission zeros which exist in the rejected band can be easily shifted and controlled by modifying the value of the metamaterial length. Furthermore, if we increase the value of LR we notice that the transmission zeros shift toward lower frequencies

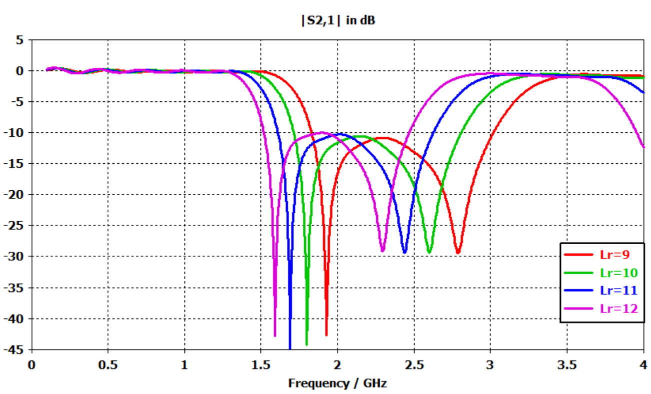

Figure 5.a: The transmission coefficient of the proposed BSF with variation of L_r

The Fig. 5.b shows that the first reflection zero might be shifted from 1.2 GHz to 1.4 GHz and the second one can be shifted from 3 GHz to 3.6 GHz. These confirm that the SRR-length has significant effect on the frequency responses of the proposed filter

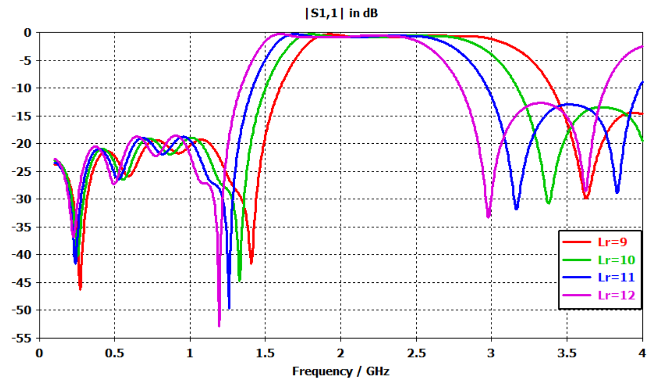

Figure 5.b: The reflection coefficient of the proposed BSF with variation of L_r

Secondly, the width of the resonator is varied from 10 mm to 13 mm in order to verify its effect on the scattering parameters of the proposed circuit. As we can see, the transmission and reflection zeros can be shifted toward lower frequency side by increasing the width of the metamaterial unit cell this short investigation proves again that the resonator dimensions control the stop-band and pass-band characteristics of the filter.

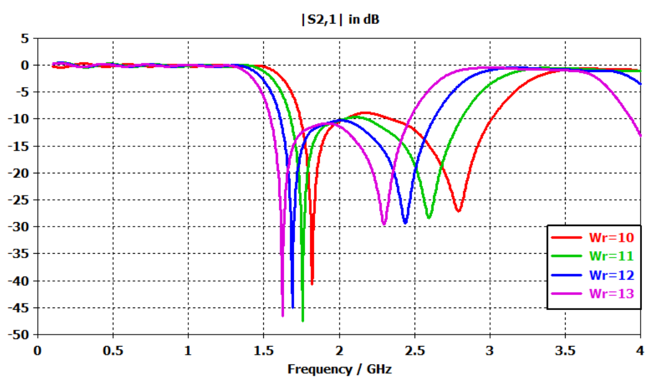

Figure 6.a: The transmission coefficient of the proposed BSF with variation of W_r

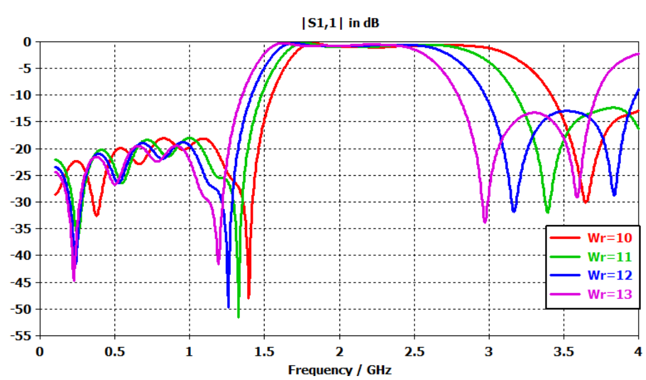

Figure 6.b: The reflection coefficient of the proposed BSF with variation of W_r

The Fig. 7 presents the simulated results of the final proposed band-stop filter. It is plain to see that the circuit show an excellent attenuation in the stop-band with insertion loss which is lower than 0.3 dB and return loss can reach more than 25 dB. Moreover, two attenuation poles might be noticed in this rejected band and it has a fractional bandwidth FWB=61.1% at the center frequency of 2.1 GHz which allows us to say that this circuit has a good stop-band characteristics.

$$FBW = \frac{(f_2 - f_1)}{f_0} \times 100\% \tag{5}$$

This filter has an excellent transmission in two pass-bands as demonstrated in fig 7, the proposed design has a low insertion loss in both pass-bands and good return loss can attain more than 20 dB. On the other hand, three reflection zeros can be remarked in the desired range of frequencies which mean that this circuit has high electrical performances in the first and second pass-band.

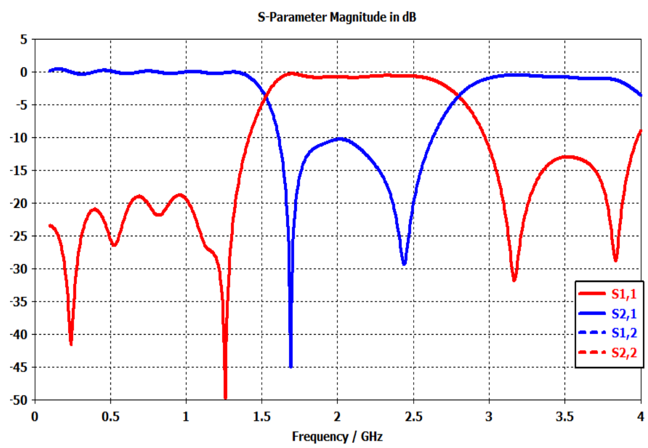

Figure 7: Frequency responses of the proposed BSF

Fig. 8.a and Fig. 8.b present respectively the current density distributions of the first pass-band at 1.2 GHz and at 2.4 GHz in the rejected-band. As we can easily observe that the radio frequency power is transmitted from the input port to the output port which implies a good transmission level in this pass-band. Whereas, the second figure shows that the RF power is blocked and no current density around the output port which means that there is not a propagation of the signal in this circuit

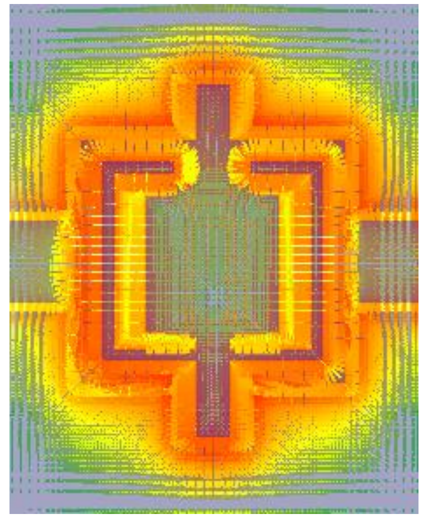

Figure 8.a: Simulated surface current density at the frequency 1.2GHz

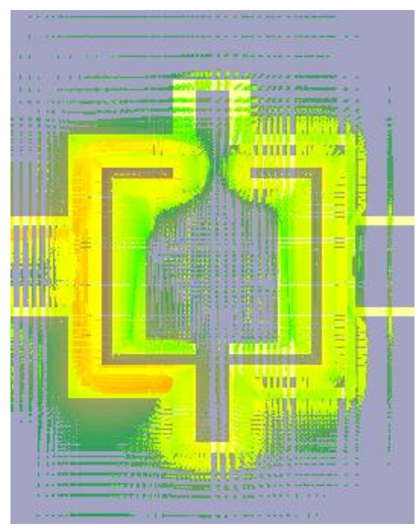

Figure 8.b: Simulated surface current density at the frequency 2.5GHz

The designed circuit performances are compared with other published work in term of size and stop-band characteristics. As we can conclude from the Table.1, that this proposed band-stop filter has good features make it a suitable for many applications and systems.

Table 1: Performance comparisons among published band-stop filters and this work

Parameters /Ref	Rejected Band(GHz)	FBW	S21 Deep	Size mm^2
[3]	[4.6-4.8]	4%	45dB	1200
[4]	[6-11]	58%	40dB	1100
This Work	[1.5-2.8]	60%	30dB	418

3 CONCLUSION

In this study, a new compact and miniature coplanar band-stop filter based on modified rectangular split ring resonator was designed and optimized. The proposed BSF characterized by rejected-band between 1.5GHz and 2.8 GHz and it has excellent electrical characteristics such as high return loss and insertion loss is less than 0.2dB in the passband. Moreover, it shows a good attenuation level in the stopband with FBW of 60% and it can be considered as a good solution for various applications and wireless systems.

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