



Research Article

Band-stop filter design based on split ring resonators loaded on the microstrip transmission line for GSM-900 and 2.4 GHz ISM band

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ABSTRACT

Split-ring resonator is a popular research topic in literature. As known, it may be used in the design of electromagnetic metamaterials. Additionally, these structures can be preferred in microwave filter devices. In this study, a band-stop filter was designed for GSM-900 and 2.4 GHz ISM band by using split-ring resonators. Two split-ring arrays (sizes of one of these arrays were larger than the other) were loaded on the transmission line and each array consisted of four identical rings. Thus, a dual-band pass filter was obtained and this filter covered the frequency of 0.91 (GSM) and 2.43 (ISM) GHz. Then, this proposed design was fabricated and measured. According to the measurement results, the fabricated structure operated at 0.93 GHz and 2.47 GHz. The experimental results were consistent with the simulation results. As a result, thanks to the proposed structure, two frequencies can be stopped at the same time. There is no need to design a different filter structure for each frequency.

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1. Introduction

Metamaterials are artificial materials and in desired frequency, they may exhibit extraordinary electromagnetic properties (e.g., negative permeability, negative permittivity, reverse Doppler Effect and negative refractive) [1, 2]. Due to these features, it takes place in many applications such as filters [3-22], antenna [23, 24], absorbers [25, 26] and sensors [4, 5, 13, 14, 16, 18, 21, 22, 27, 28]. Split ring resonators (SRR) are one of the most preferred structures for electromagnetic metamaterials design [2-5, 8, 14, 18].

One of the applications in which metamaterials are widely used is filters [3-22]. In this study, it was aimed to design a band-stop filter for GSM-900 and 2.4 GHz ISM band. A lot of SRR-based dual/multi-band stop filter designs are available in the literature [4-10,14,17]. According to some of these studies, dual/multi-band filters can be obtained when two or more SRR structures with different resonance frequencies load the microstrip transmission line [4-6]. Also, resonance magnitude can be increased by increasing the number of rings having the same resonance frequency [6,12].

In this study, two resonator arrays were placed on the transmission line. Each array consisted of four identical rings and sizes of one of these arrays were smaller than the other. To enhance the transmission coefficients $|S_{21}|$ magnitude of the filter structure in operation frequency, the number of resonators was increased without changing their size. Thus, a dual band stop filter was achieved that operated at frequencies of 0.91/2.43 GHz and 0.93/2.47 GHz in simulation and measurement, respectively.

In the context of this study, a filter that stopped two different frequency bands was designed, fabricated and measured. Thus, thanks to this design, there is no need to design two-filter structures for two different frequencies. In addition, frequency tuning can also be made by changing the dimensions of the split ring resonators.

2. Simulation and Measurement

A 50 Ω microstrip transmission line was designed. Schematic view of the proposed transmission line with its design parameters is given in Figure 1. The structure consists of a line at the top, dielectric layer in the middle and ground plane at the bottom. FR4, which had thickness

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of 1.6 mm, permittivity (ϵ_r) of 4.3, and loss tangent ($\tan\delta$) of 0.025, was used as the dielectric substrate layer. Line and ground plane were built using copper having a conductivity of 5.8×10^7 S/m and thickness of 0.035 mm. Design and analysis of the microstrip transmission line were performed using the CST microwave studio based on frequency domain solver. The proposed structure was excited by using a waveguide port. In addition, boundaries were selected as open for x , y and z axes. S-parameter results of the transmission line obtained from simulation were plotted in Figure 2.

Firstly, 1 SRR was loaded on the proposed transmission line in order for that the structure would behave like a band stop filter in 2.43 GHz. However, $|S_{21}|$ magnitude of the filter was not satisfactory in resonance frequency. Therefore, one more from the same SRR was placed again on this structure. Since it was observed that this was useful, the SRR placement process continued until the number of SRR was 4. The design parameters and schematic views of these structures (design 1 — design 4) are given in Figure 3. The transmission coefficients $|S_{21}|$ obtained from the simulation software are shown in Figure 4.

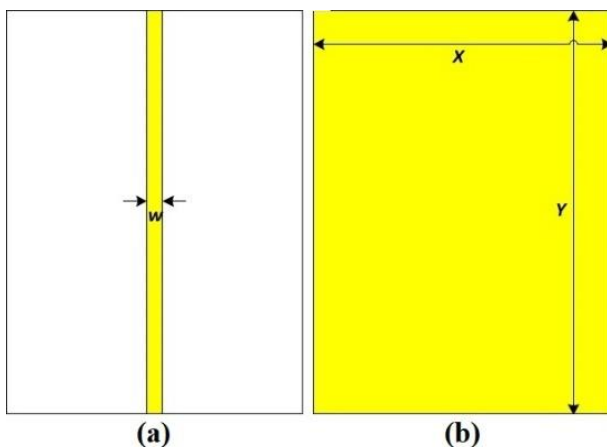


Figure 1. Schematic views of the transmission line a) front, b) back; $w = 2.87$, $X = 80$ and $Y = 110$ (all in mm)

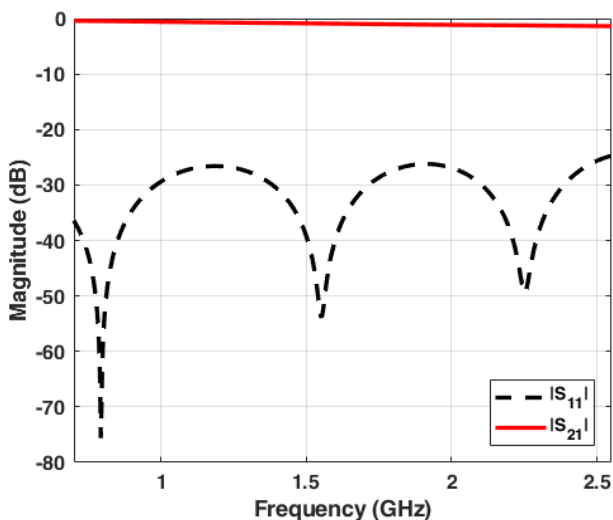


Figure 2. S-parameter simulation results of the transmission line

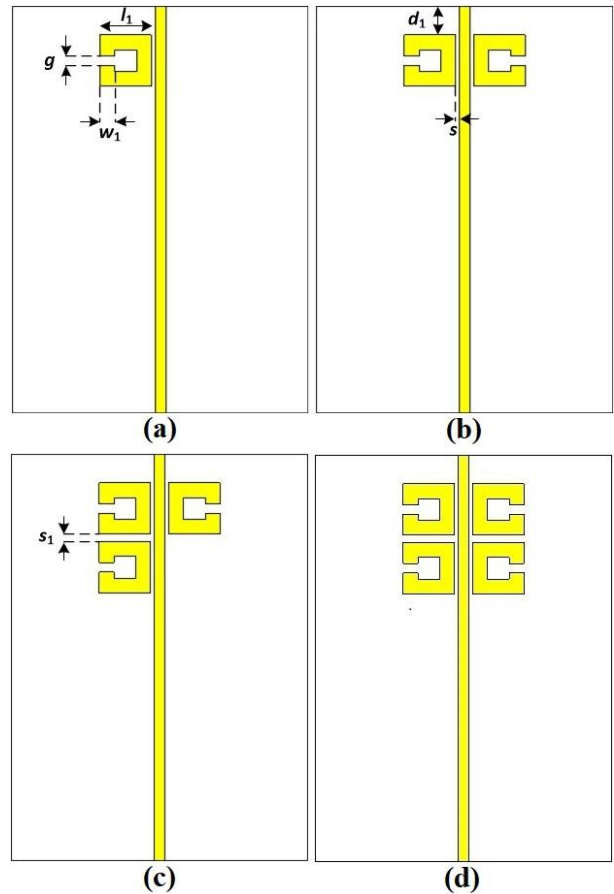


Figure 3. SRR loaded transmission line a) design 1, b) design 2, c) design 3, d) design 4; $l_1 = 13.9$, $w_1 = 4$, $g = 2.5$, $d_1 = 7.7$, $s = 1$ and $s_1 = 2$ (all in mm)

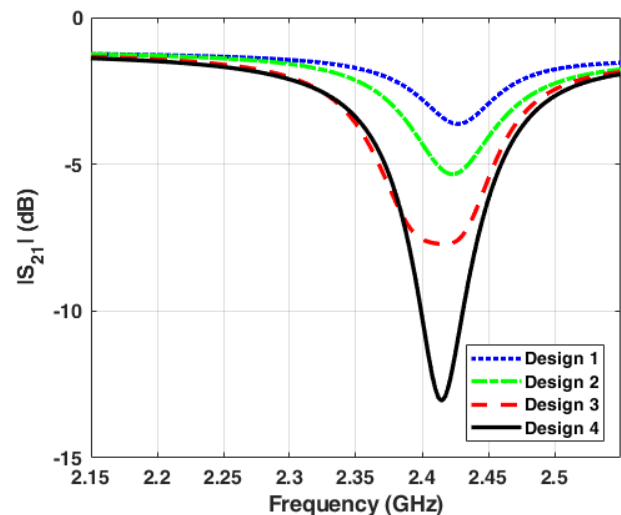


Figure 4. Simulation results of the transmission coefficients $|S_{21}|$ for design 1, design 2, design 3 and design 4

Secondly, 1 SRR was added again to the transmission line shown in Figure 1. However, size of this newly added ring was larger than the SRRs shown in Figure 3. The operation frequency decreases as the size of the resonator length increases. This structure behaves as a band stop filter and operates at 0.91 GHz. In order to enhance $|S_{21}|$ magnitude of the filter, SRR loading continued until the number of the SRR was 4. Schematic view of these

structures are given in Figure 5. The transmission coefficients $|S_{21}|$ of the designed structures (design 5 — design 8) are shown in the figure 6.

Finally, design 4 and design 8 were combined; thus, two resonator arrays were loaded on the microstrip transmission line. Although each array consisted of 4 SRRs, the sizes of one of these arrays were larger than the other. In this way, a dual-band operation was achieved at 0.91 GHz and 2.43. Then, the proposed structure was fabricated and the ends of the transmission line were terminated with 50 Ω SMAs. Schematic and fabricated views of the proposed dual band stop filter are shown in Figure 7. The transmission coefficient $|S_{21}|$ of the fabricated filter was measured using the Anritsu MS4624B vector network analyzer operating in the frequency range of 10 MHz — 9 GHz. The fabricated structure operates at 0.93 GHz and 2.47. As seen in Figure 8, the experimental results are consistent with the simulation results.

Surface current distributions obtained from the simulation are demonstrated in Figure 9. As seen, the surface current behaviors are circular at resonance frequencies. In addition, it is seen that whereas the low frequency (0.91 GHz) is caused by large rings, the high frequency (2.43 GHz) is caused by small rings.

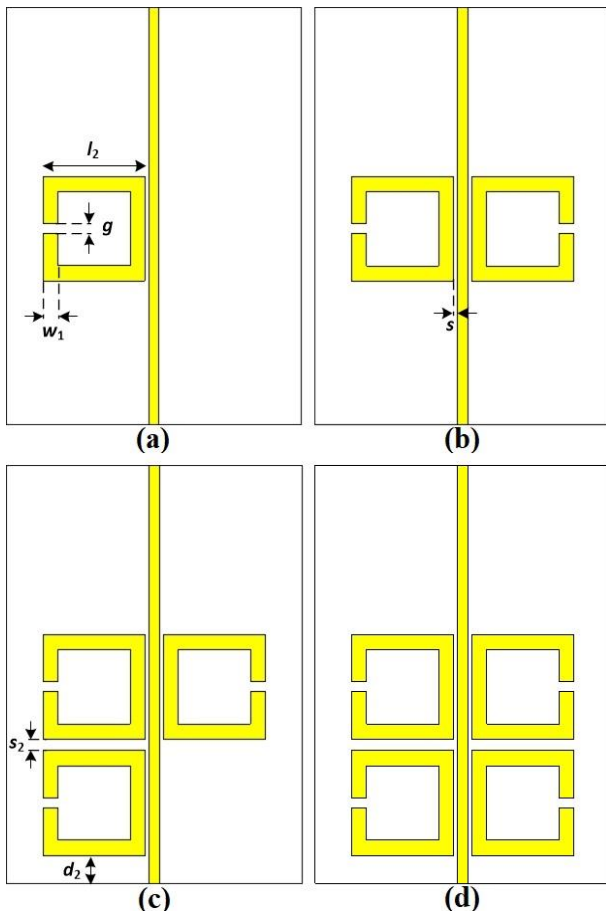


Figure 5. SRR loaded transmission line a) design 5, b) design 6, c) design 7, d) design 8; $l_2 = 27.6$, $w_1 = 4$, $g = 2.5$, $d_2 = 7.7$, $s = 1$ and $s_2 = 3$ (all in mm)

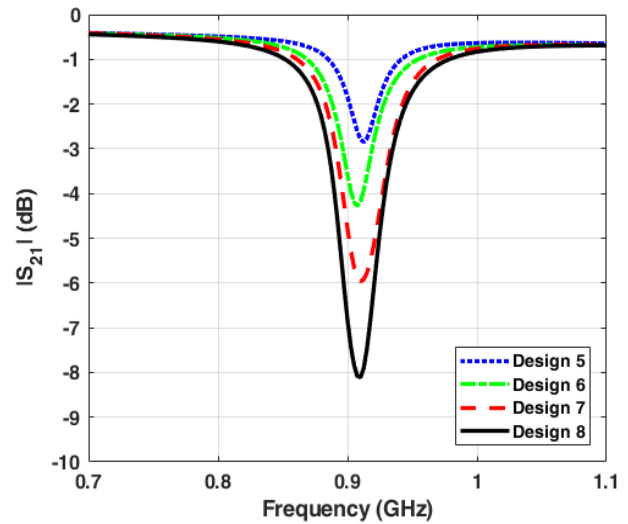


Figure 6. Simulation results of the transmission coefficients $|S_{21}|$ for design 5, design 6, design 7, and design 8

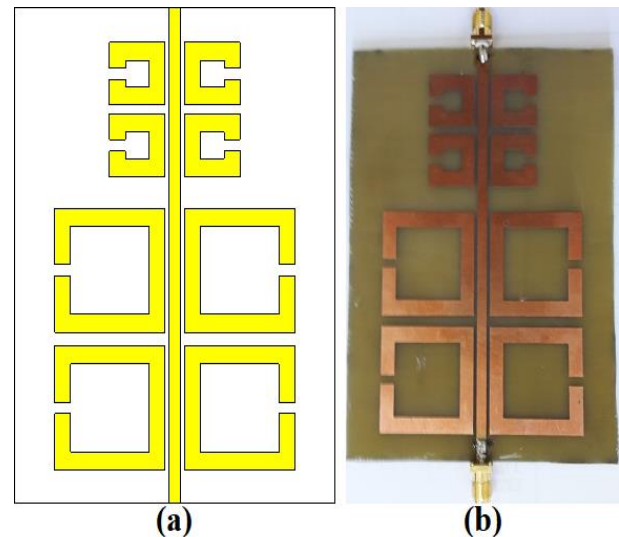


Figure 7. Views of the proposed dual band stop filter a) schematic, b) fabricated

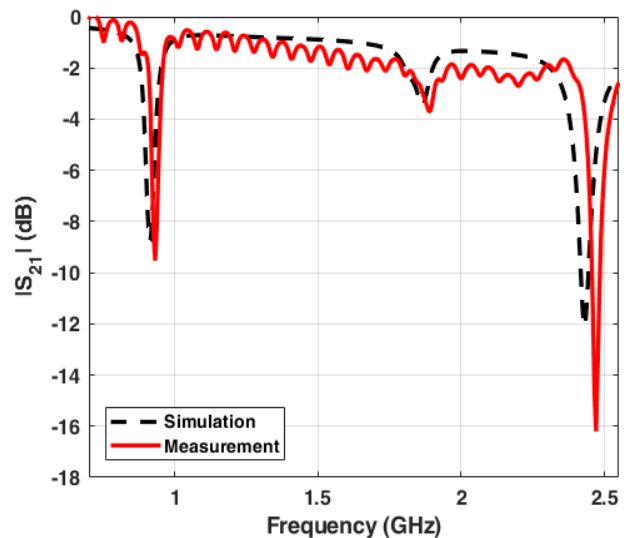


Figure 8. Simulation and measurement results of the transmission coefficients $|S_{21}|$ for the proposed dual band stop filter

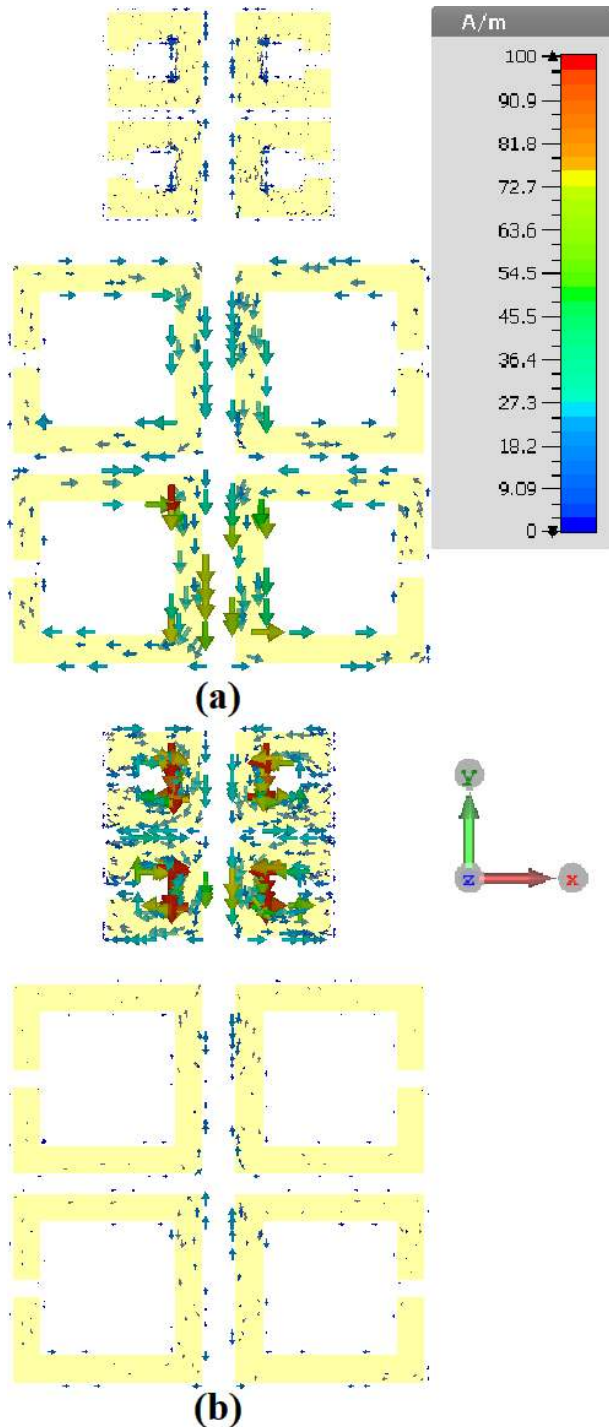


Figure 9. Surface current distributions obtained from the simulation at 0° phase angle a) 0.91 GHz, b) 2.43 GHz.

3. Conclusions

In this paper, a band-stop filter based on split ring resonators loaded on the microstrip transmission line for GSM-900 and 2.4 GHz ISM band was introduced. Two resonator arrays, which had different sizes, were placed on the transmission line. Sizes of one of these arrays were larger than the other and each array consisted of four identical rings. When the simulation and measurement results were examined, the dual-band operation was seen at 0.91/2.43 GHz and 0.93/2.47 GHz in simulation and measurement, respectively. The measured transmission

coefficient $|S_{21}|$ of the fabricated filter proved good agreement with the simulated data obtained from simulation software. Finally, it can be said that the proposed structure can stop two frequencies at the same time and there is no need to design a different filter structure for each frequency.

Declaration

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. The author(s) also declared that this article is original, was prepared in accordance with international publication and research ethics, and ethical committee permission or any special permission is not required.

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