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A Compact Dual-Band BPF Based on Open Loop Resonator for Satellite Communication Applications

Abstract- *In this paper, a new filter is constructed by inserting two slots in the form of rectangular open loop resonator with folded ends. The insertion of these slots has successfully led to the compact size and the dual bandwidth behavior. The overall filter dimensions are 16×12 mm², which correspond to 0.61λg × 0.4λg using a substrate with Rogers Ro 4003 with a relative permittivity of 3.38 and thickness of 1.0 mm. The resulting structure exhibits a dual-band behavior. The first passband has a center frequency of 6.2 GHz with FBW of 16.833% and input reflection coefficient better than -30 dB and insertion loss is approximately equal to -0.3 dB. In the second passband, the center frequency is 9.6 GHz, and the FBW is 12.57% with an input reflection coefficient better than -25 dB and insertion loss is approximately equal to -0.5 dB. The transmission zero is located between the dual passbands at 7.8 GHz with over -28.66 dB of the stopband. The simulation and performance evaluation of the proposed filter have been carried out using Microwave Studio Suite of Computer Simulation Technology (CST). As a result, this makes the proposed filter candidate for operating in satellite applications.*

Keywords: *open-loop-resonator, microstrip bandpass filter, dual-band BPF filter, multi bandpass filter.*

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1. Introduction

Minimizing components that used in modern communication equipment still the focus of many researchers especially in last decades due to the tremendous development that has occurred in the telecommunication systems where traditional equipment such as waveguide filter and dielectric resonator filter are usually heavy weight and large size compared to microstrip structures. Open loop resonator is one of the most structures that that has used in microstrip filter design. An open loop resonator is initially a folded half-wavelength resonator. So these coupled structures produced from various orientations of a pair of open-loop resonators, which are spaced by a gap [1]. Because of the possibility of obtaining a miniaturized size, so many researchers have adopted the open loop resonators in microstrip filter design [2-9]. Open loop resonator can be found in different configurations fractal line open loop resonator due to the remarkable features of the fractal geometry like self-similarity and space filling [10-13]. Miniaturization of open loop resonator can be realized by loading with different passive elements [14-18]. Most of the works mentioned above adopted the microstrip open loop resonator with different shapes not as slots. On the contrary, it is found that the works that adopted the open loop shaped slot resonator are limited. Four open loop shaped slots were etched with SIW technology is adopted in [19]. In this paper, a microstrip bandpass filter BPF based on open loop resonator with folded ends has been adopted in a different form by creating two rectangular slots in the form of B-shape in upper layer of a cavity such that the open ends are in the opposite direction to each other. A proposed filter has been designed and fabricated to work with dual-band microstrip BPF for satellite applications. The slot structure is supposed to be etched on the front plane of a Rogers RO4003 substrate with relative dielectric constant of εr = (3.38), a thickness of h = (1) mm and dielectric loss of tan (δ) = 0.0027.

2. The Filter Design

The first step in the design is accomplished by considering a structure as shown in Figure 1 to operate as a BPF these dimensions will determine the operating frequency (s). The overall dimensions are to be 12×16 mm² while cavity dimensions are to be 10×11.6 mm² as shown in Figure 1; these dimensions are more common in satellite systems. The simulation results showed that the filter resonates at the frequency of 8.75 GHz and offers bandwidth of 0.730 GHz as shown in Figure 2. For making the proposed filter operates at a frequency, less than 8.75 GHz requires increasing the physical dimensions of the filter and this contradicts the requirements of components miniaturization in satellite systems. Therefore, for gaining miniaturization and dual-band behavior at the same time, an open loop slot with folded ends like B-shape has been created with its counterpart as shown in Figure 3. The role of this slot is specified by a number of parameters. To obtain best results, a process of sweeping for these parameters is accomplished.

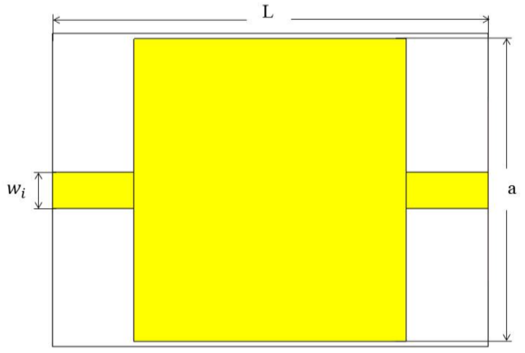


Figure 1: CST MWS model for the proposed BPF (top layer)

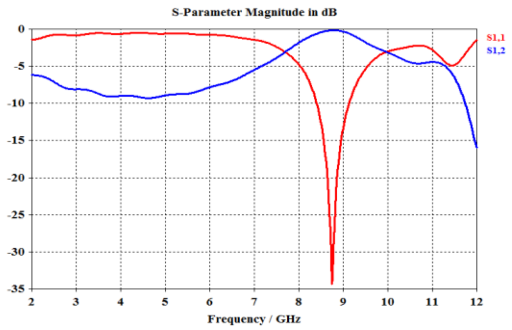


Figure 2: Simulated S11 and S12 results of the BPF

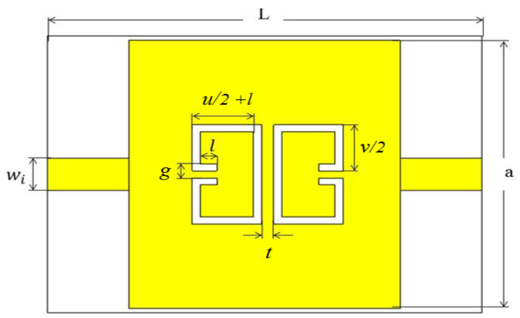


Figure 3: The layout of the folded open loop B-shaped slot BPF

3. The Simulation Results

Figure 4a represents the variations of *v* parameter value, which represents the vertical arm of the open loop. It is clear that increasing this value led to shifting the location of bands down, while the transmission zero location also shift down as shown in Figure 4b. Figure 5a demonstrates the effect of increasing the value of *u* parameter, which represents the horizontal dimension of the open loop. Finding that the center frequencies of the operating bands are moving down; the location of the transmission zero will also move down as illustrated in Figure 5b.

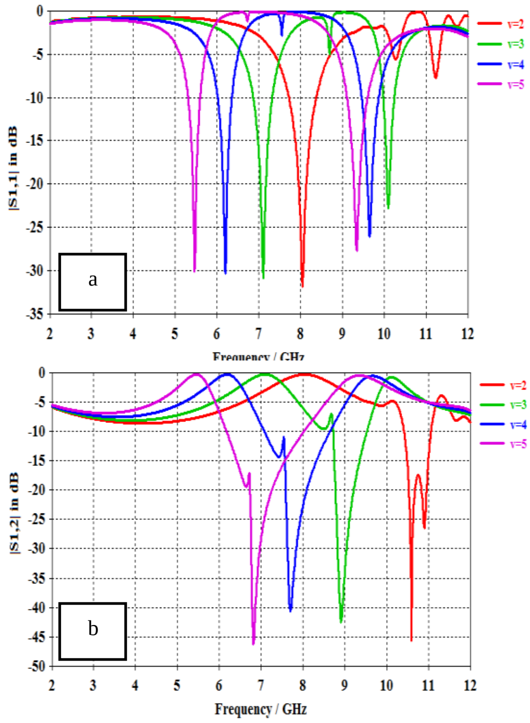


Figure 4: Parametric study of the proposed filter with *v* as a parameter :(a) Input reflection coefficient(S11), and (b) Insertion loss (S12)

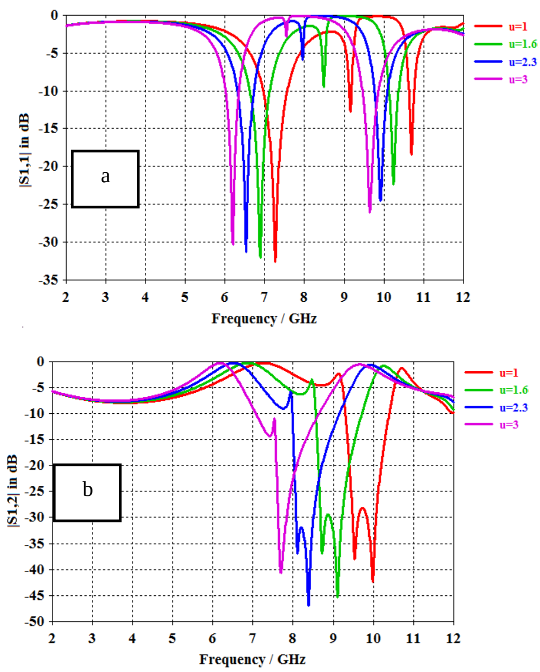
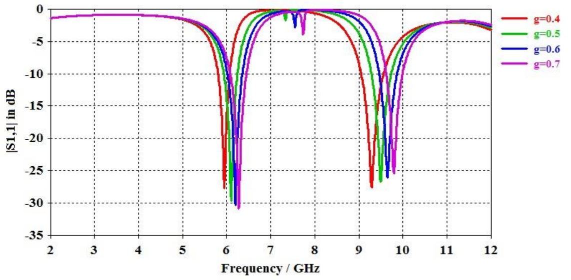


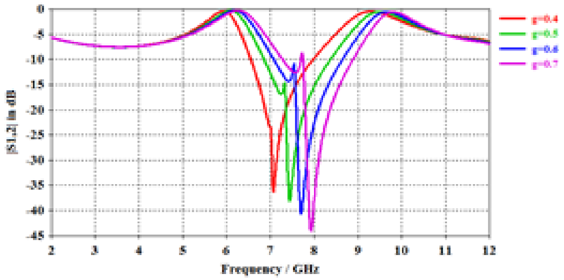
Figure 5: Parametric study of the proposed filter with *u* as a parameter: (a) Input reflection coefficient (S11), and (b) Insertion loss (S12)

Monitoring Figure 6a, it shows the increasing gap, *g* between the two loops led to shift the bands up and at the same time the transmission zero location also moves up as shown in Figure 6b.



(a)

Parameter *l* represents the increased amount in folded ends of the slot loop.



(b)

Figure 6: Parametric study of the proposed filter with *g* as a parameter: Input reflection coefficient (S11), and (b) Insertion loss (S12).

It is shown that increasing this parameter led to move frequency bands down as in Figure 7a while the transmission zero location also moves down as shown in Figure 7b.

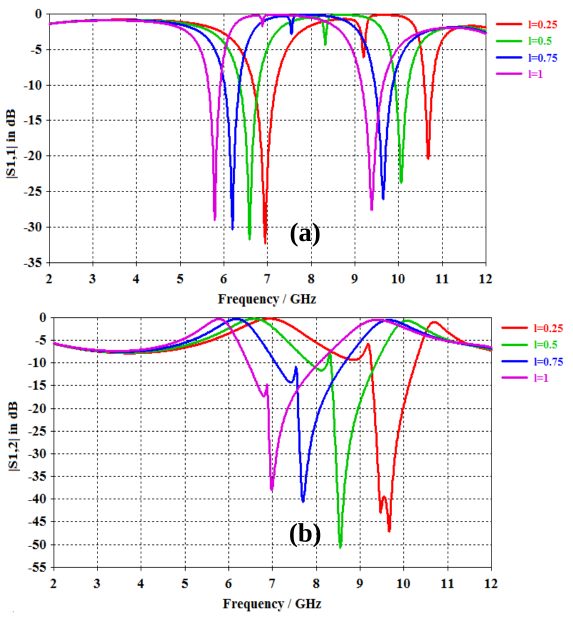


Figure 7: Parametric study of the proposed filter with *l* as a parameter: (a) Input reflection coefficient (S11), and (b) Insertion loss (S12).

According to the latest testing of different parameters that determine the behavior of this filter, the appropriate values for this design are shown in Table 1.

The resonant frequency with respect to the lowest frequency and parameters that affecting BPF response can be calculated by following equation:

$$f_r = c/[8 \sqrt[2]{\varepsilon_r} \times l_s] \quad (1)$$

Where:

$l_s = l+v+0.5u+0.5g$

c = the speed of light in free space

ε_r= dielectric constant of the substrate

It is clear that the proposed filter has a dual-band extending from 5.57 to 6.61 GHz as a first band, while the second band is with range from 9.14 to 10.35 GHz as shown in Figure 8.

Table 1: The final dimensions of the modeled BPF with folded open loop B-shaped slot

Parameter	Value (mm)	Parameter	Value (mm)
L	16.0	*u*	3.00
a	11.6	*v*	4.00
w_i	1.40	*l*	0.75
g	0.60	*t*	0.45

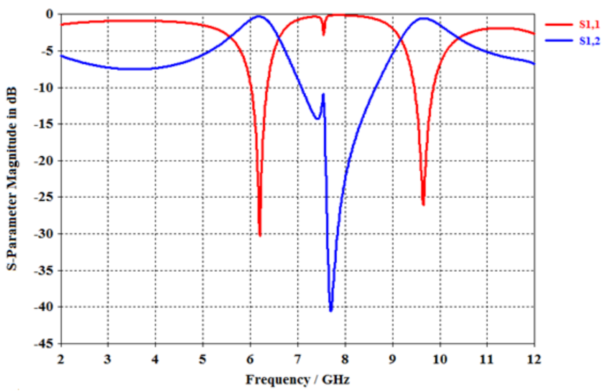


Figure 8: The simulated S11 and S12 responses of the folded open loop B-shaped slot BPF.

The first passband has a center frequency of 6.2 GHz with FBW of 16.833% and input reflection coefficientbetter than -30 dB and insertion loss is approximately equal to -0.3 dB. In the second passband, the center frequency is 9.6 GHz, and the FBW is 12.57% with input reflection coefficientbetter than -25 dB and insertion loss is approximately equal to -0.5 dB. The transmission zero is located between the dual passbands at 7.8 GHz with over -28.66 dB of stopband rejection.

4. Fabrication and Measured Results

A standard PCB process has been used for fabricating and measuring the proposed dual-band BPF, as shown in Figure 9.

The experimental results are in agreement with the EM simulation results. For the 6.2 GHz band, the insertion loss is about -1 dB with FBW of 24% while for the 9.6 GHz band, the insertion loss is about -3 dB with FBW of 8.55% as shown in Figure 10.
A comparison of the proposed work with that presented in [19] is introduced in Table 2:

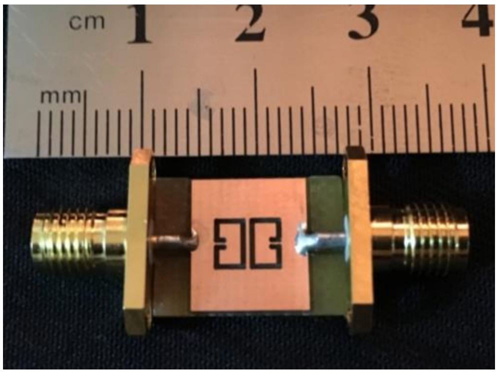


Figure 9: Photograph of the fabricated prototype of the folded open loop B-shaped slot BPF.

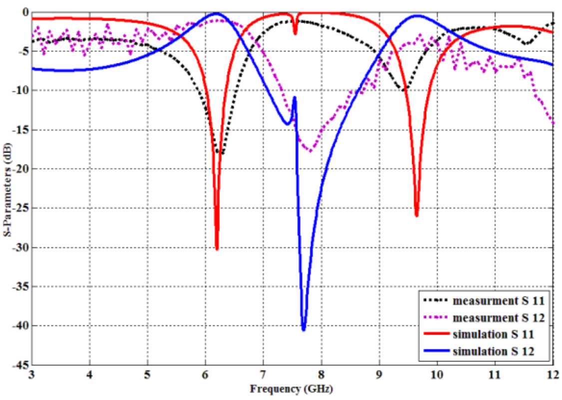


Figure 10: Comparison between the simulated and the measured S-parameters for the fabricated folded open loop B-shaped slot BPF.

Table 2: Comparison of the proposed filter with Ref. [19]

	Ref[19]	This work
Freq. (GHz)	8.2/11.2	6.2/9.6
S_{11}	30/30	30/25
S_{21}	-0.2/-0.1	-0.3/-0.2
Tz's	3	3
Area (mm^2)	22.1×10.8	16×12
Topology	4 open loop shaped slots at both top and bottom layer s	Only 2 open loop shaped slots at top layer

5. Conclusion

In this paper, a microstrip BPF based on two rectangular open loop resonator with folded ends was simulated and fabricated. Some critical parameters that are controlling the open loop configuration have been adopted; these parameters played an imported role in the performance of proposed filter. Increasing the value of some of them like *g*-parameter produces an increase in the center frequency of resultant bands and the location of transmission zero is moved to a higher frequency. On the other hand increasing the value of other parameters like *u*-parameter causes a shift down in frequency and at the same time, the location of transmission zero is moved to a lower frequency. It is found that. These parameters make the proposed filter characterized by flexibility in design where they can make this filter works at any frequency within the range (6-8) GHz with respect to the first band and (9-11) GHz for the second band.

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