An Open Loop Resonator Using Interdigital Hairpins and C-Shaped Dgs for the S Band Frequency Bandpass Filter

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Abstract

Using a C-shaped defective ground structure (DGS) and an interdigital hairpin resonator within the ring resonator, this article designs a dual-band band pass filter (BPF). To improve the filter performance of the open-loop resonator filter, half-wavelength micro-strip lines are used in its construction. In addition to facilitating the development of mutual coupling between the resonators, DGS is used to reduce the size of the microwave filter. When interdigital structures with parallel linked lines are used, the miniaturisation of hairpin resonators becomes possible. This filter operates within the S-band frequency range (2-4 GHz) with centre frequencies of 2.2 GHz and 3.2 GHz, bandwidths of 14.4% and 9.4%, insertion losses of -0.38 dB and -0.58 dB, and return losses of >-20 dB, respectively. Utilising computer simulation technology (CST), the filter's performance was simulated and evaluated.

***Keywords*•** A band-pass filter (BPF), an interdigital hairpin, and an open loop resonator (OLR)

1. INTRODUCTION

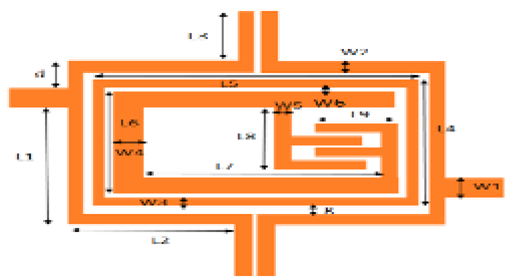
Dual band wireless systems have attracted a lot of academic interest due to the rising demand for them. Researchers are showing a growing interest in dual band band pass filters (BPFs) as they are an essential component of RF front end devices. Multiple resonators, parallel coupled lines, stepped impedance resonator (SIR), defective microstrip line, etc. are among the approaches that have been used to realise dual-band BPFs [1–5]. In [1], the bigger size is mentioned for a parallel coupled line based filter, which is often required. The length and breadth of the two transmission line sections that make up a SIR-based filter determine the resonant frequency [2]. In [3], a triple section SIR is used to augment the number of tuning degrees of freedom. The arrangement of two resonators with distinct resonance frequencies is shown in [4]. One resonator serves as the feed for the other. Although the arrangement is larger, it allows for more tuning of the resonant frequencies. To achieve dual-band BPF, an F-shaped spurline is inserted into the transmission line of a parallel linked bandpass filter [5]. To improve selectivity, asymmetric SIRs are used in [6] to include additional transmission zeros close to the passband margins. To further enhance the selectivity, a SIR-based dual-band BPF is equipped with extra stubs [7]. Using linked transmission lines integrated within SIRs may reduce size while increasing selectivity [8]. In [9], the authors provide a small dual band BPF that makes use of embedded SIRs. In order to enhance the selectivity, stub loaded asymmetric SIRs are used in [10].

This study proposes and designs a small

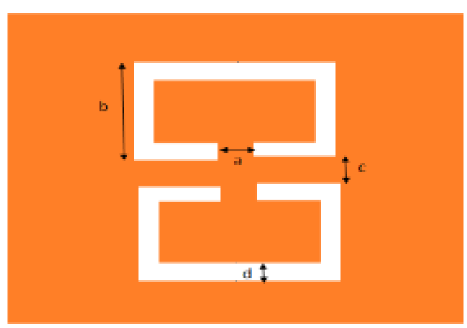
dual-band bandpass filter (BPF) that uses two open loop resonators loaded with near ring resonators and interdigital hairpin resonators to achieve low insertion loss and good selectivity. In order to span the S-band frequency range, plane C-shape DGS is designed at ground level. Through the use of mutual coupling between the resonators, DGS is used to reduce the size of the microwave filter. The use of an interdigital structure with parallel linked lines allows for the miniaturisation of hairpin resonators. The filter has two bands that it uses, each having a fractional bandwidth of either 14.4 or 9.4 percent. A broad variety of coupling coefficients may be easily adjusted using an interdigital capacitor, which increases bandwidth. The implementation of a filter for dual mode operating in the S-band is based on this. Radiolocation, stationary microwave, and mobile satellite services (MSS) all make use of this filter, which covers frequencies between 2.12 and 2.45 GHz as well as 3.12 and 3.43 GHz. The following is the paper's structure: Part 2 delves into the filter's architecture, Part 3 covers the design process, including the impact of different parameters, and Section 4 covers the outcomes and potential future developments.

2. PROPOSED FILTER DESIGN

The structure of the filter is shown in Figure 1, which consist of two open loop resonator (OLR) loaded with close ring resonator and interdigital hairpin resonator along with a C-shape defected ground structure (DGS). The filter is designed on Rogers RT 5880 whose relative permittivity is 2.2 and has a thickness of 0.787mm.



(a)



(b)

Figure 1 Configuration of proposed bandpass filter (a) top layer, and (b) ground plane with defect.

As shown in Figure 1, two 50 Ω lines of width w_1 are connected to resonators acting as input and outing ports. The arrangement of outer resonator consist of two transmission lines of width W_1 and lengths L_1+L_2, and L_3+d generating the lower passband with centre frequency f_1. A rectangular ring resonator is embedded inside with dimensions L_4 and L_5, the thickness of this resonator is W_3. The gap between ring resonator and outer resonators is g. Such arrangement results in two passbands withlimited bandwidth. Another stub loaded ring resonator with interdigital capacitor is added inside the ring resonator. The width of each strip of this resonator is W_5 and the interdigital strips have a width of W_6 and the lengths are L_6, and L_7 for open resonator whereas for interdigital capacitor has lengthsL_8 and L_9. Two C shaped defects symmetrically etched in the ground plane with dimensions a, b, c and d.

For generating extra band to simple stepped impedance resonator symmetric ring resonator structure is used. In addition to increase the response C- shape DGS resonators is designed using the same defected ground structure shape, the overall but with different feed line configurations The open loopresonator filter is constructed by placing a half wavelength microstrip lines to achieve enhanced filterperformance. An open loop resonator is generally derived from one and half wavelength resonator, odd and even mode to enhance bandwidth and introduce transmission zeros in the pass band.

3 FILTER DESIGN METHODOLOGY

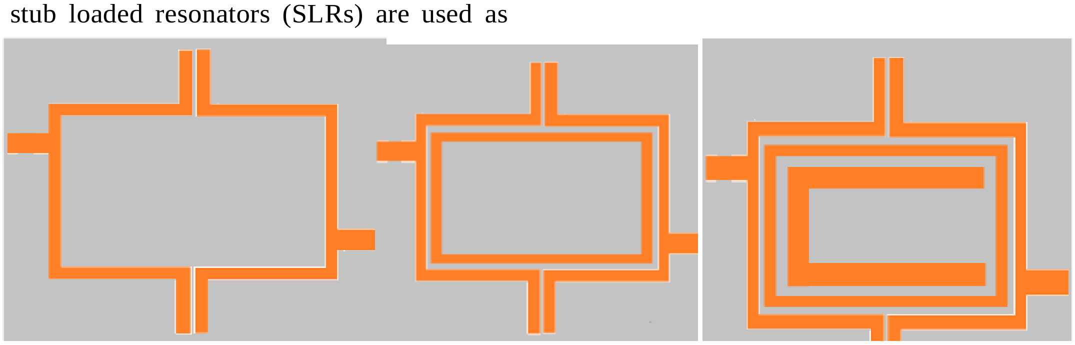
Evolution of dual band BPF

A bandpass filter with two half wavelength resonators is taken for initial investigations as shown in Figure 2 (a), the filter has full ground plane that is no defect in the ground.

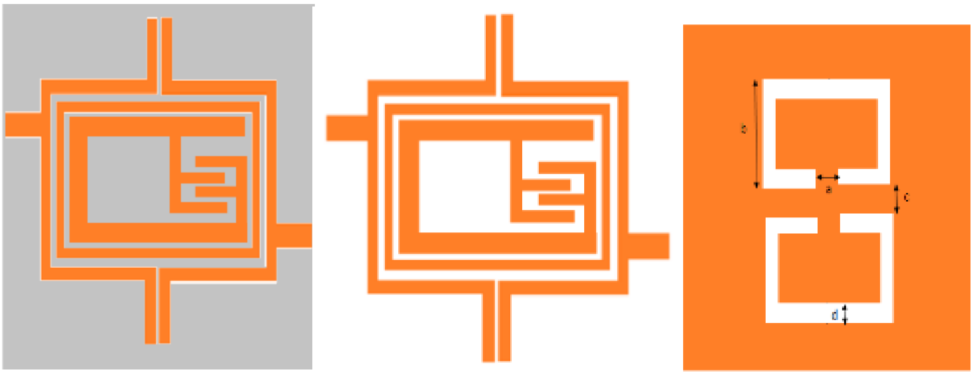
The resonance frequency of this filter is 2.4 GHz, and direct feed lines of 50 Ω are connected. Open circuited couple lines are employed to realize electrical coupling, the overall length of the lines, is given by

$$L=L_1+2L_2+2L_3+d+W_1$$

A closed ring resonator is embedded inside as shown in Filter 2(b), this ring resonator creates an additional pass band at 3.6 GHz. The ring resonator has very narrow bandwidth and high insertion losses. To improve the response at higher resonance, stub loaded resonators (SLRs) are used as shownin Figure 2(c). Low insertion losses are achieved using with it. To achieve low insertion loss in the passband, while maintaining a relatively small circuit size interdigital capacitors are used as shown in Figure 2 (d). Defected ground structure is used to further improve the performance of the filter, figure2 (e) and (f) shows the top and bottom layer of final filter.

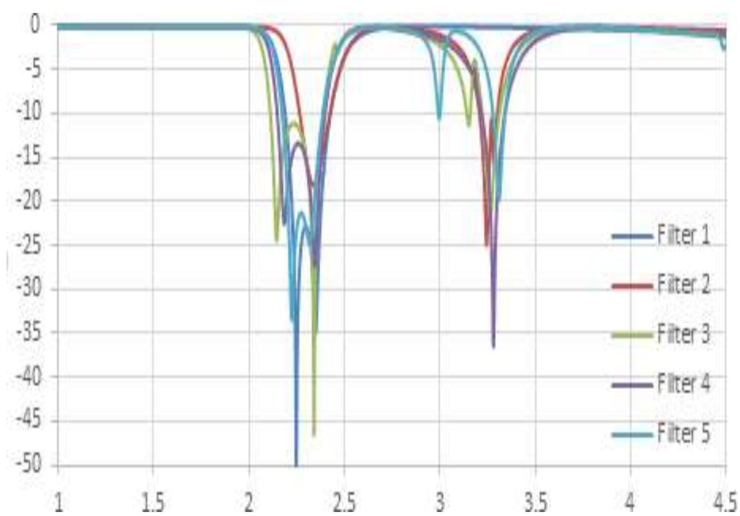


(a) **(b)** **(c)**

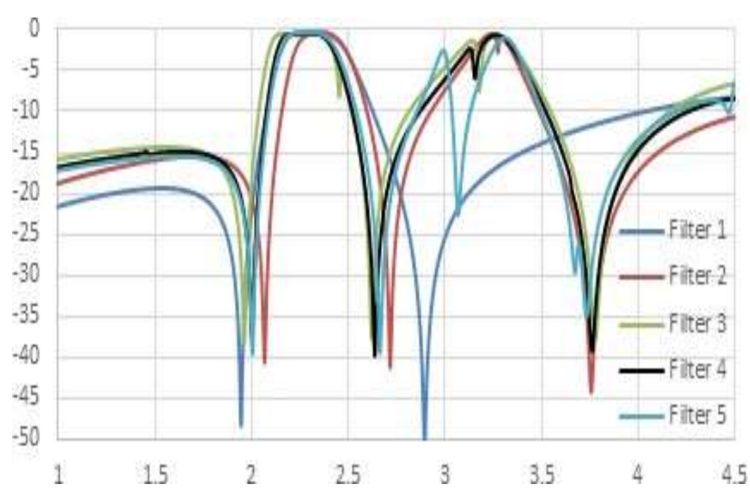


(d) (e) (f)

Figure 2 Evolution of dual band BPF



(a)



(b)

Figure 3 (a) Reflection coefficient and, (b) transmission coefficient of proposed filter in each evolution stage.

Parametric variations

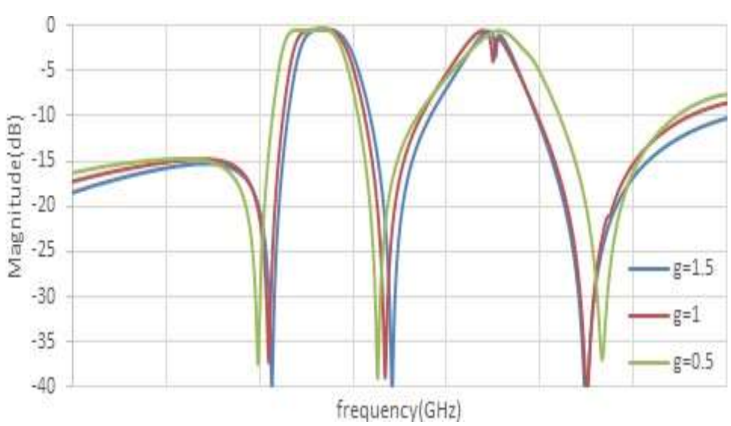
The impact of each parameter on the filter performance is studied by means of simulations, All default values of design parameters tabulated in Table-1. All dimensions are in mm.

Table 1: Dimensions of Proposed Filter

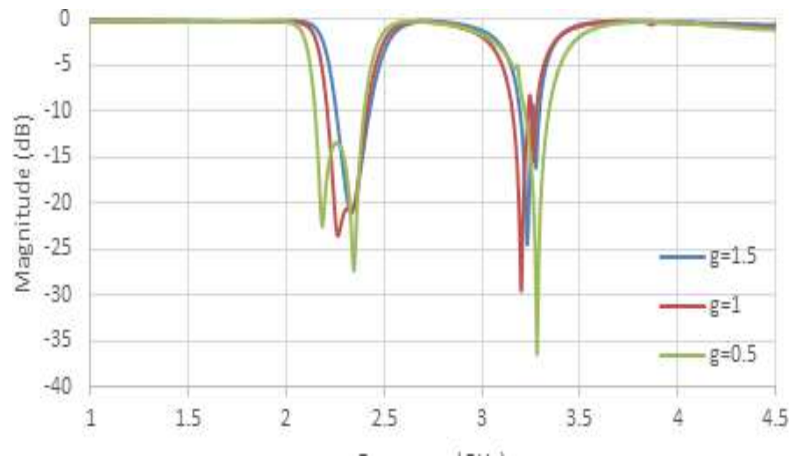
Parameters	L1	L2	L3	L4	L5
Values	12.55	10.65	4.9	16.1	19.65
Parameters	L6	L7	L8	L9	W1
Values	14.1	16.65	8	5	2.4
Parameters	W2	W3	W4	W5	W
Values	0.7	0.5	2	1	32
Parameters	L	D	g	H	h1
Values	32	3.55	0.5	0.787	0.035
Parameters	a	b	c	D	W6
Values	0.5	10	0.7	1	0.5

(A) Effect of g

The gap between the open half wavelength resonators and the ring resonator embedded inside is verycritical and affect the insertion loss at higher frequency. Figure 4 (a) and (b) shows the return loss andinsertion loss for different values of *g*. When *g* increases from 0.5 to 1.5, the bandwidth of both passband decreases and insertion loss decreases thus smaller values of g are suitable for better performance.



(a)

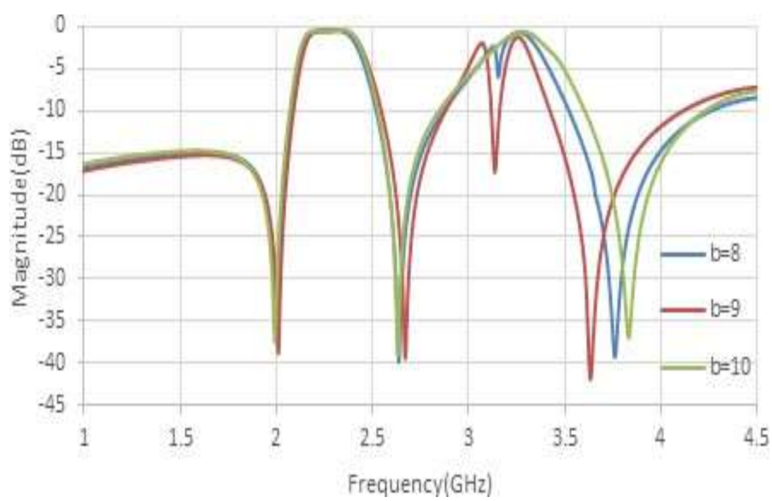


(b)

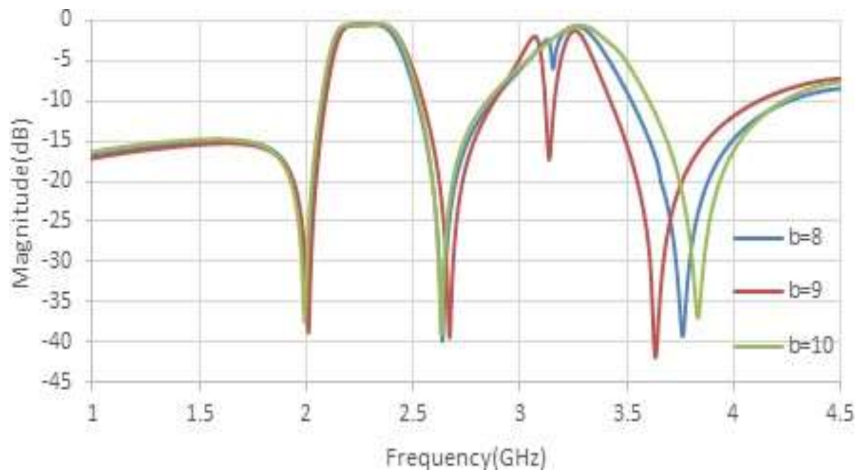
Figure 4 Effect of g on (a) insertion loss (b) return loss

(B) Effect of b

The perimeter of the slot etched on the ground plane is controlled by a, b, and c, for simplicity parametric variations of only one parameter are included here. Figure 5 (a) and (b) shows the return loss and insertion loss for different values of b ranging from 8mm to 10 mm. As the perimeter of the slot increases the resonant frequency decreases.



(a)



(b)

Figure 4 Effect of g on (a) insertion loss (b) return loss

4. RESULTS AND DISCUSSION

After studying the impact of various design parameters, the dimensions of the filter are optimized. The optimum values of these dimensions is tabulated in Table-1. The simulation results for proposed filter structure are shown in Figure 6. The filter is operating at from 2.2 2.12 GHz to 2.45 GHz and
3.12 GHz to 3.43 GHz. Also the insertion loss in these bands is better than 1 dB.

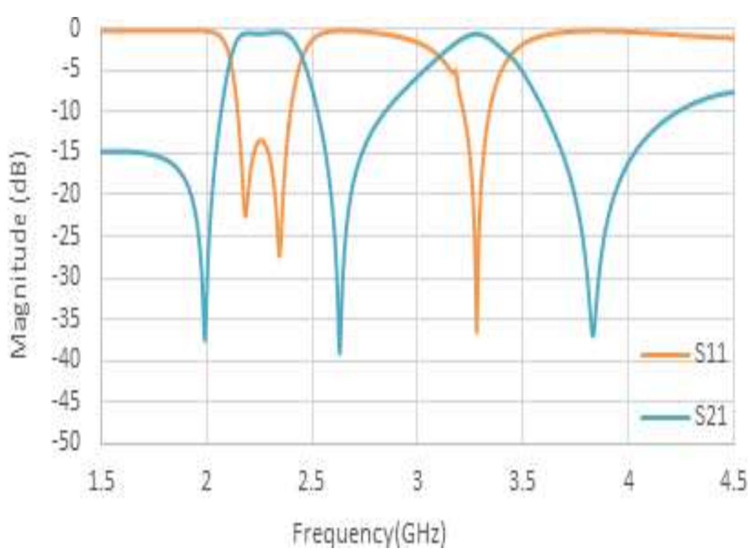


Figure 5 Simulated results

Finally, performance of proposed filter is compared with related works in table -2. Presented filter iscompact in size and has low insertion loss. It is apparent from Table 2, that the proposed filter is morecompact and provides good passband frquency which cover the s band frquency as compared with thefilters.

Table 2 Comparison with Experimental Results

Reference	Passband (GHz)	No. of bands	-3db FBW %	Insertion loss	Return loss	Transmission zeros(TZs)	Filter size Mm x mm
Ref 10	1.57/3.7	Dual	4.5/4	<-2.5	>-12	4	50.4 x 38
Ref 10	1.57/3.7	Dual	4.2/3.8	<-2.3	>-15	6	44 x 50
Ref 5	1.57/2.4	Dual	3/2	<-2	>-15	4	21.1 x 14.1
Ref 3	1.58/2.4	Dual	5/2	<-1	>-16	2	26 x 26
Ref 11	9.3	Single	9.25	<-1.58	>-17.7	3	-
This work	**2.2/3.2**	**Dual**	**14.4/9.4**	**<0.38/<-0.58**	**>-20dB**	**3**	**28.3 x 21.7**

5 CONCLUSION

Here we introduce a dual band BPF that makes use of a ring resonator, a defective ground structure, and an open loop resonator. The filter's total footprint is reduced by using a defective ground structure, which is combined with an open loop resonator and an open stub loaded resonator to provide dual band response. With 14.4% and 9.4% bandwidths, respectively, the filter operates in two bands at 2.2 GHz and 3.2 GHz, with a dB bandwidth of 3 dB. With an insertion loss of -0.38 dB and a return loss of -0.58 dB, both are better than -20 dB. The stationary microwave services, mobile satellite service (MSS), and radiolocation services might benefit from this filter, which covers frequencies from 2.12 GHz to 2.45 GHz and 3.12 GHz to 3.43 GHz.

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