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Miniaturized UWB Dual Band Pass Filter with Multiple Transmission Zeros and Wide Rejection

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ABSTRACT:*This paper focus on the design of miniaturizedUWB dual band pass filter (BPF) with multiple transmission zeros using multimode resonator (MMR) and low-pass structure. The fork resonator (FR) forms the basic structure to introduce multiple transmission zeros in the desired pass band .The unwanted transmission zeros in the stop band are rejected by stepped impedance low pass structure. This structure is modified to achieve high attenuation and wide stop band rejection at higher frequency side. The proposed design covers both lower and upper UWB band within the frequency range of 3.1 to 10.6GHz where the lower band covers 1 to 4GHz, with insertion loss -0.1dB and the return loss of about -10dB and the upper band covers 6 to 10GHz with insertion loss of-0.1dB and the return loss of above-10dB.All the simulationswere performed with ADS Momentum 2.5D Method of Moments (MOM).The substrate used here is FR4 with dielectric constant 4.4and thickness 1.6mm.*

KEYWORDS:Band Pass Filter (BPF), Multi-Mode Resonator (MMR), Ultra Wide Band (UWB), transmission zeros (TZs), Fork Resonator (FR).

I. INTRODUCTION

The U.S. Federal Communication Commission (FCC) authorized the unlicensed use of the UWB (3.1GHz-10.6GHz) frequency spectrum for indoor and hand-held wireless communications in early 2002.As per FCC UWB Fractional bandwidth is defined as $(f_H - f_L)/f_C > 20\%$ or total BW > 500 MHz .Since then, new methods and structures have been used to develop new UWB filters, design of such BPFs at high frequencies, especially in the range of GHz presents considerable challenge since parasitic and transmission line effects cannot be compensated adequately. This problem will be magnified if the filter is required to be compact as well. Recently, several BPFs are reported in the literature [1-3] employing different approaches like stepped impedance structures and hybrid microstrip/defectedground plane structures. However, these solutions increase component count, circuit size and power consumption. Also, the band pass filters presented are relatively narrowband and do not fall in to the UWB category. This paper presents the design of new band passfilter for both single and dual UWB band. In case of single band, pass-band covers the entire UWB bandwidth of (3.1-10.6) GHz. In case of dual band, lower pass band is from 3.1GHz to 4.7 GHz and upper pass band is from 6.3GHz to 9.6GHz, since (5-6) GHz is allotted for IEEE 802.11. The stop band attenuation beyond the pass-band is achieved throughcascading SIR structure with FR structure. Multiple-mode resonator (MMR)has been increasingly applied to design a class of ultra-wideband (UWB) band-pass filters (BPFs) [4-6]. Even though all of the above described UWB filters have exhibited satisfactory performance in the desired wide pass-band, it is still a challenging research topic to make up such a UWB BPF with small size, sharp rejection skirts and wide upper-stop-band. By using EBG structures in a conventional band-pass filter, the sizecan besignificantly reduced with betterperformance. This paper discusses the design of a band-pass filter by cascading a fork resonator [5] and an EBG [6] structure. It is observed that this cascading provides inherently good matching between the two structures resulting in a filter with good return loss, insertion loss and wideband performance.

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II. DESIGN

The design of a UWB Fork-form resonator is discussed in [5]. By the appropriate choice of the dimensions of the fork resonator, the pass band can be realized with good return loss and insertion loss. A SIR structure is combined with the fork resonator to reduce the undesired resonance in the resonator.

A. DESIGN OF THE SIR STRUCTURE

Schematic designspecification

Cut-off frequency f_c=10.6GHz

Source/Load impedance=50Ω

Order of the filter n=3

The design equations are as follows

$L_{3(actual)} = (R_L L_{3(table)}/2\pi f_{3dB}$=0.75nH

$C_{3(actual)} = C_{3(table)}/\ 2\pi f_{3dB} R_L$=0.60pF

Where, R_L=50 Ω

TABLE I

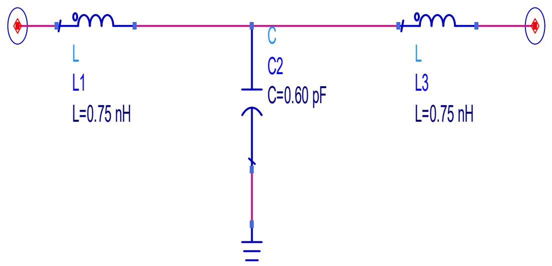
BUTTERWORTH TABLE

n	R_s	C_1 (L_1)	L_2 (C_2)	C_3 (L_3)	L_4 (C_4)	C_5 (L_5)	L_6 (C_6)	C_7 (L_7)
2	1.00	1.4142	1.4142					
3	1.00	1.000	2.000	1.0000				
4	1.00	0.7654	1.8478	1.8478	0.7654			
5	1.00	0.6180	1.6180	2.0000	1.6180	0.6180		
6	1.00	0.5176	1.4142	1.9319	1.9319	1.4142	0.5176	
7	1.00	0.4450	1.2470	1.8019	2.0000	1.8019	1.2470	0.44

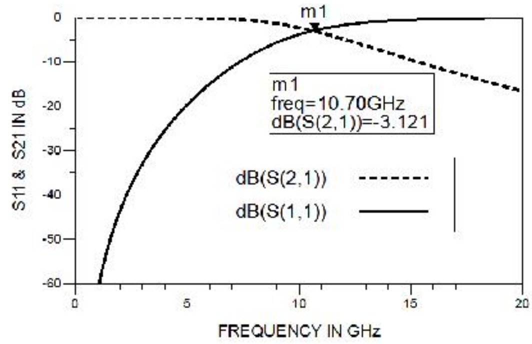
The following values are obtained from the following Butterworth table

$L_{3(table)}$ =1.000

$C_{3(table)}$ =2.000



(a)



(b)

Fig. 1a shows the schematic diagram of the SIR with the calculated values

Fig.1b represents the simulated frequency response of the schematic SIR structure

LAYOUT DESIGN OF SIR STRUCTURE

The characteristic impedances of the high- and low-impedance lines are chosen as Z_{0L}= 150 ohms and Z_{0C}= 25 ohms. [2]

DESIGN SPECIFICATION

Relative electric permittivity ε_r= 4.6

Thickness of the substrate, h = 1.6mm

Power dissipation factor, tan δ = 0.002

DESIGN FORMULAE

For w/h ≥ 1[9]

$$\frac{w}{h} = \frac{1}{\frac{e^A}{8} - \frac{1}{8e^A}}$$

Where,

$$A = \frac{Z\ \sqrt{2(\varepsilon_r+1)}}{6} + \frac{1}{2}\frac{\varepsilon_r+1}{\varepsilon_r-1}\left[\frac{l\ \frac{\pi}{2} + \frac{1\ l\ 4}{2}}{\pi}\right]$$

$$\lambda_{gc} = \frac{3}{f(G\quad)\sqrt{\varepsilon_r}}$$

$$\varepsilon_{re} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2\sqrt{1+1\ h/w}}$$

$$l_c = \frac{\lambda g}{2\pi}\sin^{-1}[\omega\qquad]$$

$L_1 = l_c$ = 2.42mm, W_1=2.43mm

For w/h≤1

$$\frac{w}{h} = \frac{1}{\frac{e^A}{8} - \frac{1}{8e^A}}$$

Where,

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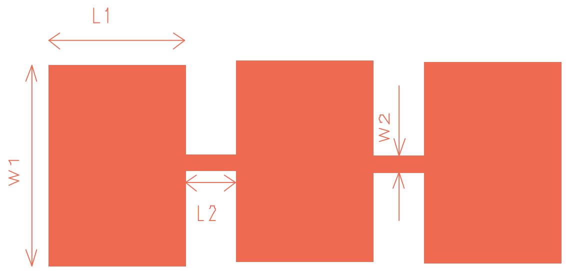
$$A = \frac{Z \quad \sqrt{2(\varepsilon_r+1)}}{1 \quad .9} + \frac{1}{2}\frac{\varepsilon_r+1}{\varepsilon_r-1}\left[\frac{l \frac{\pi}{2} + \frac{1 \; l \; 4}{2}}{\pi}\right]$$

$$\lambda_{gc} = \frac{3}{f(G \quad)\sqrt{\varepsilon_r}}$$

$$\varepsilon_{re} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2\sqrt{1+1 \;\; h/w}}$$

$$l_l = \frac{\lambda g}{2\pi}\sin^{-1}[\omega \;\; /Z \quad]$$

L_2=l_l=0.9mm, W_2=0.14mm.



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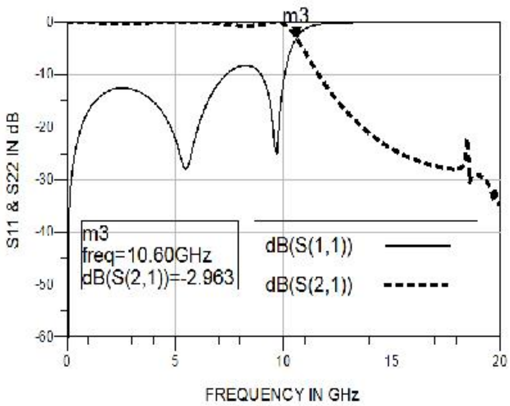


(b)

Fig.2 Tunable SIR structure

a. Layout with L1=2.42mm, W1=2.43mm, L2=0.9mm,W2=0.2mm,

Fig. 2a shows the physical layout of SIR structure with the above calculated dimensions and Fig. 2b shows the simulated frequency response of SIR structure. From

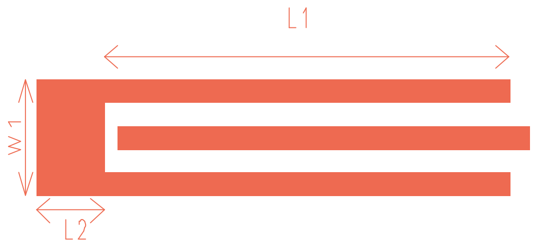
b. Frequency response

The graph, the pass band gets attenuated when it reaches the frequency of 10.60 GHz.

B. DESIGN OF THE FORK RESONATOR

Initially, a parallel resonator is designed and simulated, in order to realize a fork type resonator. The resonating frequency of a resonator is given by, F_c=1/ (2π$\sqrt{L \quad}$) Where, F_c – resonating frequency in GHz, L –inductance in nH,C – Capacitance in pF.By assuming L, C will be calculated for the desired resonant frequency.The proposed parallel resonator circuit has to be transformed into its equivalent distributed structure using the transformation technique used for SIR structure, considering the same design specification.

Designing a resonator using traditional parallel-coupled lines usually obtains very high insertion loss, which is not desirable. So, a fork form resonator [5] is proposed, which generates attenuation pole at the higher pass band edge, lower insertion loss as compared with the traditional parallel-coupled resonator.Fig.3a and 3b shows the layoutand the simulated frequency responses of the Fork resonator.



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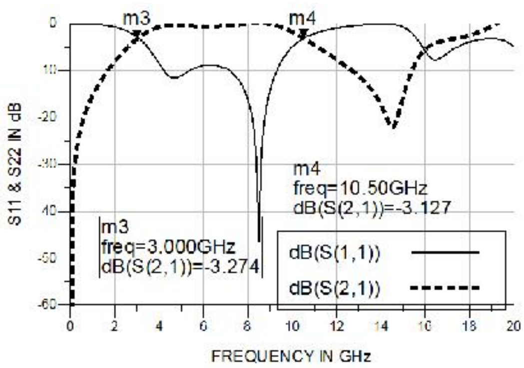


(b)

Fig. 3 Fork resonator

a. Layout with L1=6mm, L2=1mm, W1=1mm

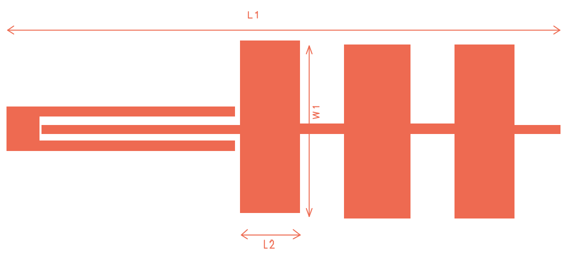
b. Frequency response

From the above layout of the FR,when the length of the fork is decreased, a single band is introduced and the simulated frequency response of the FR

shows that the pass band is in-between 3 to 10.5 GHz with two transmission zeros. Simulated result shows the attenuation and stop band rejection is poor above 10.5 GHz.

C.DESIGN OF THE SINGLE BPF

The FR and the SIR structure designed are combined together to form the BPF for UWB application. When the length of the fork resonator and the vertical stub is increased, then dual band is produced.Optimization is done to meet the required specification for better insertion and return loss performance. Fig. 4 a and 4 b shows the optimized band pass filter and its simulated frequency responses.



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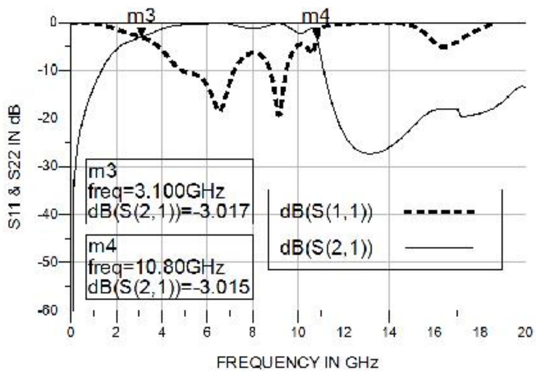


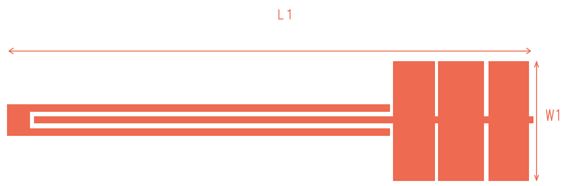
(b)

Fig. 4 a. Layout of the proposed single BPF with L1=16.97mm, L2=2mm, L3=4mm

b. Frequency response

D.DESIGN OF DUAL BPF

The Dual band pass filter is obtained by the optimization of Fork resonator of single BPF in which the length is extended to 16mm and width 1mm.Fig 5a and 5b shows the layout and simulated frequency response of optimized dual BPF.



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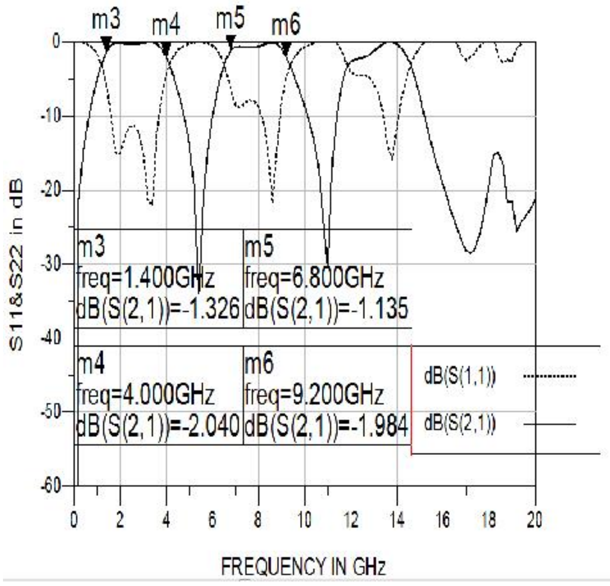


(b)

Fig.5 Dual BPF

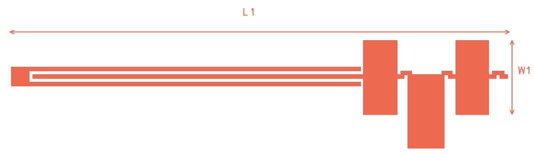
a. Layout od proposed dual BPF with L1=23.4mm, W1=4mm

b. Frequency response

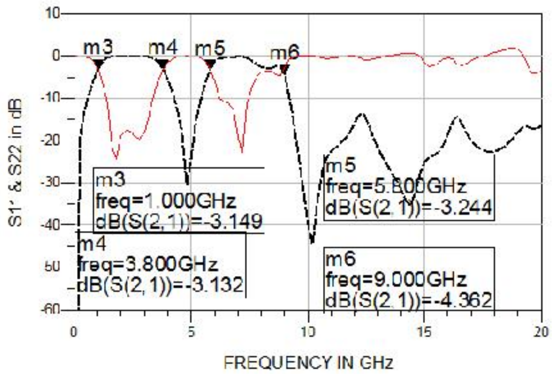
When comparing with the fork resonator and single band BPF, the increased length fork resonator introduces multiple transmission zeros in the pass band and hence dual band BPF is achieved. Here, the lower pass band is 1.2GHz to 4.4GHz and upper pass band is 6.2GHz to 9.4GHz. The return loss is greater than -10dB and insertion loss is -0.1dB for both bands.

E.DESIGN OF DUAL BPF WITH WIDE REJECTION

The dual band BPF is further modified to improve these stop band attenuation about 10GHz.For further improvement, the layout of the dual BPF is optimized by converting horizontal stub into a meander line structure and the center vertical stub shifted down. The optimized layout and its simulated Frequency responseis shown in the fig 6.



(a)



(b)

Fig 6simulated result of dual band BPF with wide rejection

a.Layout with L1=27mm, W1=4mm

b.Frequency response

The modified layout shown in fig 6 is more compact and introduces attenuation up to 45dB at 10GHz with wide rejection of above 10dB till 20GHZ of the EBG layout is increasedand the transmission zero improve the rejection.

CONCLUSION

Dual band BPF is designed using fork resonator and stepped impendence resonator .The fork resonator is used to introduce multiple transmission zeros and hence dual band is achieved SIR structure used in the design introduces steep attenuation and wide rejection. The proposed design is very simple yields good performance and also covers both UWB upper and lower bands.

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