Compact Microstrip Band Pass Filter using Fork & EBG Resonator for UWB application

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Abstract

A novel Ultra-Wide Band (UWB) microstrip band pass filter is proposed using tunable electromagnetic band gap (EBG)-embedded resonator and fork resonator. In this case, a compact Band Pass Filter (BPF) is designed using a cascade of a multimode fork resonator with tunable EBG resonator. The fork resonator forms the basic structure yielding multiple band-pass realization and the EBG selects the desired band. This yields a compact band pass filter with sharp cut-off characteristics, wide bandwidth and low insertion loss with good roll off. The simulated results are provided with insertion/return losses over the plotted frequency range of 3.1GHz to 10.6GHz. All simulations were performed with ADS Momentum 2.5D Method of Moments (MOM)). *Keywords:* **Band Pass Filter (BPF), Multi-Mode Resonator (MMR), Ultra Wide Band (UWB), Electromagnetic Band Gap (EBG), Fork Resonator (FR).**

I. INTRODUCTION

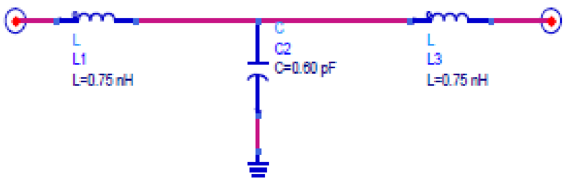
The U.S. Federal Communication Commission (FCC) authorized the unlicensed use of the Ultra Wide Band (UWB)-(3.1GHz-10.6GHz) frequency spectrum for indoor and hand-held wireless communications in early 2002. *FCC definition of UWB:* Fractional bandwidth (measured at the -10dB points) = (f H -f L)/f C> 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/defected ground 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 pass filter in which pass-band covers the entire bandwidth of (3.1-10.6) GHz. The rejections beyond the pass-band are achieved through cascading EBG structure with FR structure. Multiple-mode resonator (MMR) filters have 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 size can be significantly reduced with better performance. 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 and wideband performance.

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 performance. A tunable EBG is combined with the fork resonator to reduce the undesired resonance in the resonator. *A. Design of the EBG cell I) Schematic design specification* Cut-off frequency fc=10.6GHz Source/Load impedance=50Ω Order of the filter n=3 The design equations are as follows L3(actual) = RLL3(table)/2πf3dB=0.75nH C3(actual) = C3(table)/ 2πf3dBRL=0.60pF Where, RL=50 Ω The following values are obtained from the following Butterworth table L3(table) =1.000 C3(table) =2.000

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)	C_7 (L_7)
2	1.0	1.4142	1.4142				
3	1.0	1.000	2.000	1.0000			
4	1.0	0.7654	1.8478	1.8478	0.7654		
5	1.0	0.6180	1.6180	2.0000	1.6180	0.6180	
6	1.0	0.5176	1.4142	1.9319	1.9319	1.4142	
7	1.0	0.4450	1.2470	1.8019	2.0000	1.8019	0.44



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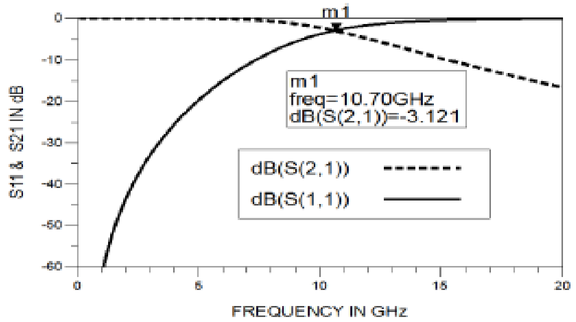

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II) Layout design of EBG resonator The characteristic impedances of the high- and low-impedance lines are chosen as $Z0L$ = 150 ohms and $Z0C$ = 25 ohms. [2] *Design specification* Re lative electric permitt ivity εr = 4.6 Thickness of the substrate, h = 1.6mm Power d issipation factor, tan δ = 0.002 *Design formulae* For w/h ≥ 1

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

Where,

$$A=\frac{Zoc\sqrt{2(\varepsilon_r+1)}}{60}+\frac{1}{2}\frac{\varepsilon_r+1}{\varepsilon_r-1}\left[\frac{ln\frac{\pi}{2}+\frac{1\ ln4}{2}}{\pi}\right]$$

$$\lambda_{gc}=\frac{300}{f(GHz)\sqrt{\varepsilon_{re}}}$$

$$\varepsilon_{re}=\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2\sqrt{1+12h/w}}$$

$$l_c=\frac{\lambda_{gc}}{2\pi}\sin^{-1}[\omega c Zoc]$$

$L1=l_c$ = 2.42mm, W_1=2.43mm

For w/h≤1

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

Where,

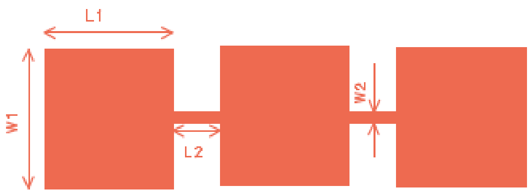
$$A=\frac{Zoc\sqrt{2(\varepsilon_r+1)}}{119.9}+\frac{1}{2}\frac{\varepsilon_r+1}{\varepsilon_r-1}\left[\frac{ln\frac{\pi}{2}+\frac{ln4}{2}}{\pi}\right]$$

$$\lambda_{gc}=\frac{300}{f(GHz)\sqrt{\varepsilon_{re}}}$$

$$\varepsilon_{re}=\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2\sqrt{1+12h/w}}$$

$$l_l=\frac{\lambda_{gc}}{2\pi}\sin^{-1}[\omega L/Zol]$$

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



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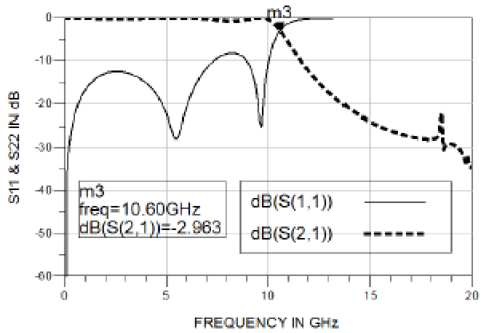

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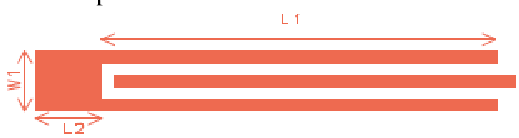
Fig.2 Tunable EBG a. Layout with L1=2.42mm, W1=2.43mm, L2=0.9mm,W2=0.2mm b. Frequency response *B. Design of the fork resonator:* Initially, a parallel resonator is designed and simulated, in order to realize a fork type resonator. The resonating frequency of a resonator is given by Fc=1/ (2π *LC*) Where, Fc – resonating frequency in GHz L –inductance in nH , C – Capacitance in Pf

L & C are assumed and the resonator is designed. The proposed parallel resonator circuit has to be transformed into its equivalent distributed structure using the transformat ion technique used for EBG cell, 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.



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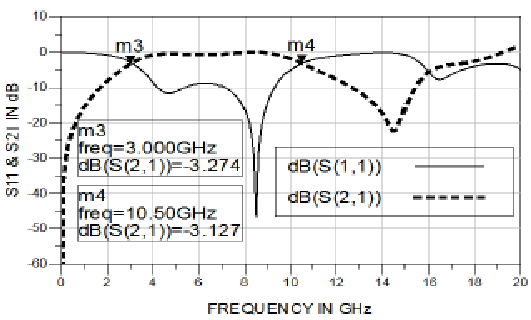

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Fig. 3 Fork resonator a Layout with L1=6mm, L2=1mm, W1=1mm b Frequency response *C.*

Design of the BPF The FR and the EBG resonator designed are combined together to form the BPF for UWB application. Optimization is done to meet the required specificat ion of a better insertion and return loss performance. Fig 4 shows the optimized band pass filter and its simulated frequency response.

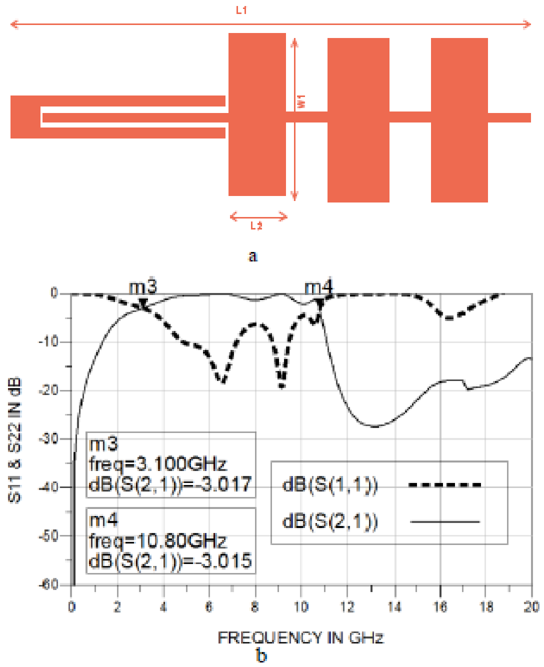

Fig. 4 a Layout of the proposed BPF with L1=16.97mm, L2=2mm, L3=4mm b Frequency response

III.CONCLUSION

In this paper, FR & EBG resonators are investigated and applied to UWB BPFs. This BPF proposed has good insertion and return loss performance, wide bandwidth and compactness is also achieved. Still optimization can be done to achieve a return loss less than -20dB. This work can also be extended for a dual-band UWB BPF by tuning the MMR as required.

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