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Miniaturized Tri-Band BPF using Asymmetric SIRs and DGS

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Abstract

In this paper, we proposed a tri-band microstrip Bandpass Filter (BPF) for the application of GSM (1.8GHz), WiMAX (2.86GHz) and UWB (3.32– 5.12GHz). By integrating two narrow passbands filter with UWB filter; a tri-band response is achieved. The filter response performance is improved by introducing the asymmetric SIRs with Defected Ground structure (DGS). An appearance of transmission zeroes of the proposed structure guarantee the sharpness, the skirts of scattering parameters of triple-band Band pass filter (BPF). The proposed filter shows very low return loss of -42.57 dB, insertion loss of -0.04dB, and compact which shows that the filter is more efficient.

Keywords: *BPF, GSM, WiMAX, UWB, Impedance ratio, triple band, FWB, Asymmetric SIRs, DGS*

1. Introduction

In RF communication systems, Filter is one of the most important elements. A high quality filter improves performance in communication system. BPF is an important component, used both at the transmitter and receiver in communication system. In RF communication system, BPF plays a key role in selecting the desired band in a specific bandwidth and attenuate unwanted signals. To select the desired frequency in commercial products like multi-service, the integration of multi-bands has become more significant. To design a multiband filter with multiple services are become an important issue and carried out in many ways [34-35]. Triple-Band transceivers have shown their abilities in modern multiband wireless communication systems [1, 2]. The tri-band BPF have development a lot of attention over the past few years. In recent years, multiple service technology is widely and aggressively developed, especially in the RF wireless communication systems [3]. In traditional filter design, stepped-impedance resonator (SIR) is widely used to realize the multi-band responses because of compact in size with low insertion loss, proper coupling flexibility, high design freedom of selecting the length ratio (u) and impedance ratio (R) in the desired structure to achieve the desired Band [5–20]. In this paper, an integration of two narrow passband with the wide pass band has been presented in Figure 1 to achieve the tri-band response. An asymmetric SIRs and U-shape DGS is used to achieve the multi-bands response. The coupling structure of the propose tri-band filter is shown in Figure 2. The obtained tri-bands are uses in Global System for Mobile Communications (GSM) at 1.8GHz and Worldwide Interoperability for Microwave Access (WiMAX) at 2.86GHz and a wide pass band at Ultra Wide Band (UWB) from 3.32GHz to 5.12GHz. The Centre frequency and Fractional Band width (FWB) [34, 3] can be calculate using (1) and (2)

$$\omega_0 = \sqrt{\omega_1 \omega_2} \qquad (1)$$

$$FBW = \frac{\omega_2 - \omega_1}{\omega_0} \qquad (2)$$

Where, $\boldsymbol{\omega}_0$, $\boldsymbol{\omega}_1$ and $\boldsymbol{\omega}_2$ are the centre frequency, lower cut-off -frequency and upper cut-off-frequency of the BPF. This proposes tri-band filter was design on Duriod 5870 substrate with thickness of 0.787mm, dielectric constant, ε_r of 2.23 and tangent loss, $\boldsymbol{\delta}$ of 0.0012 and the width of the microstrip are 0.2mm.

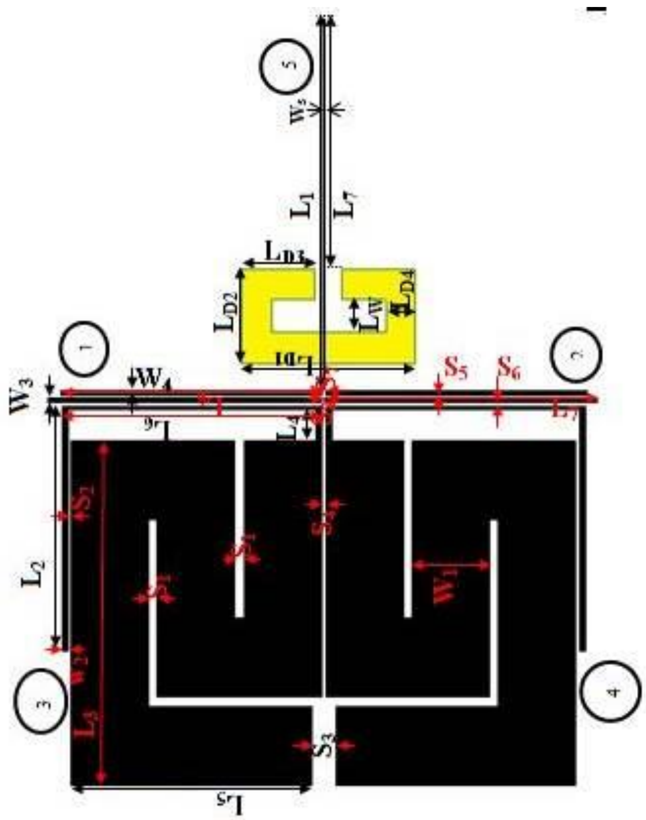

Figure 1. Design Layout of Tri-band Filter using Coupling Asymmetric SIR

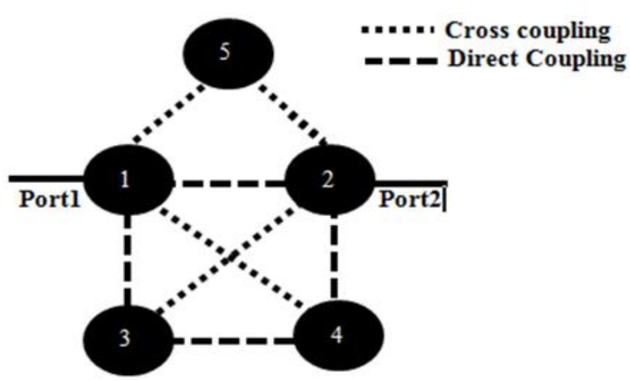

Figure 2. Coupling Structure of the Tri-band BPF

2. Design for GSM AND WiMAX

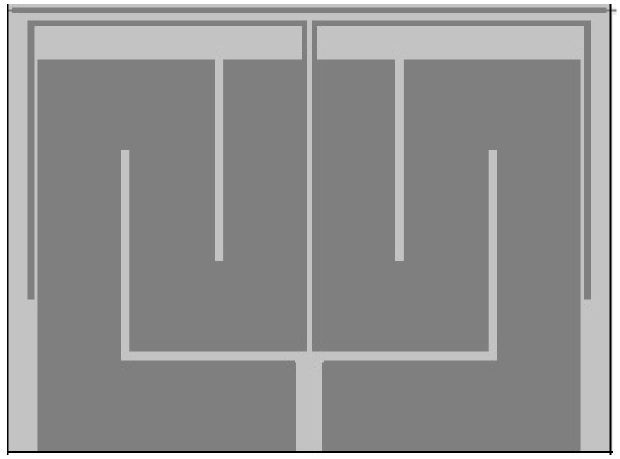

Figure 3. Design for GSM and WiMAX

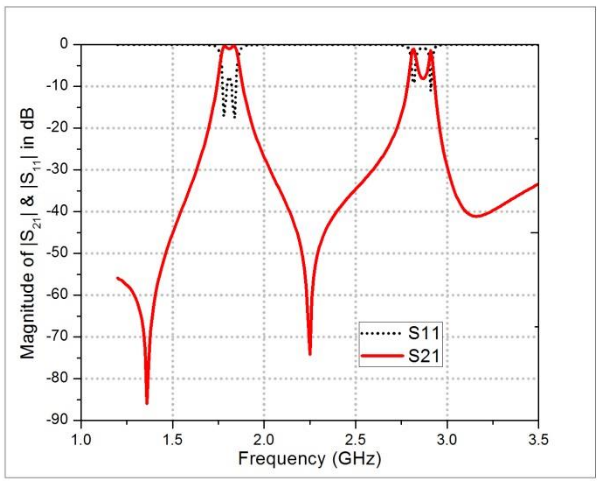

Figure 4. Magnitude of $S_{21}$for GSM and WiMAX Response and their Phase Difference

The design specification of the dual-band filter is whose centre frequency are f_1 = 1.8GHz, and f_2 = 2.86GHz, respectively. Based on the design response of Figure 3 the filter structure of the first two narrow pass bands, shown in Figure 4 achieve high impedance (Z_1 = 79.21Ω) strip width of 0.2mm and the low- impedance (Z_2 = 45.78Ω) with a strip width of 3.85mm. The fractional bandwidths with different coupling spacing were calculated by Ansoft HFSS. The centre frequency for the first pass band 1.8GHz and the fractional Bandwidth (FBW) 5% and second pass band centre frequency is 2.86GHz and the FBW is 6.96% are obtain from the SIR 3 and SIR 4. To achieved good insertion loss S_{21} is -0.43dB and -0.95dB and the returns loss is S_{11} is -14.99dB and -10.92dB for the GSM(1.8GHz) and WiMAX(2.86GHz) respectively .The coupling spacing can be as chosen S_4 = 0.2mm to obtain the low insertion loss.

Figure 3 shows the magnitude of S_{21} of the two narrow band responses and the phase difference of transmission. It shows that the first passband and second passband are cantered at the desired frequencies of 1.8GHz and 2.86GHz respectively. The appearing of transmission zeros in both side of the passband is granted that sharpness of the scattering parameters of the design filter. The first transmission path is between the resonator 1 and resonator 2, and the second transmission path in between resonator 3 and resonator 4. The coupling topologies formed by Input/output port of resonator 1, resonant 2.

3. Design of UWB characteristics

It is hard to obtain UWB response by using only two resonant modes of the SIRs. To generate UWB response the DGS is arranged under the resonator 5 symmetrically to avoid the design complexes and reduction of the losses. However, the DGS will affect the resonant modes of the asymmetric SIR, thus, the same length ratio u and impedance ratio R, taken to obtained UWB response with center frequency 5.08GHz. It was known that DGS under the coupling resonators can be seen as a parallel LC resonator [21]; the capacitance and the inductance are calculate using (3) and (4)

$$C = \frac{\omega_c}{Z_0 g} \cdot \frac{1}{\omega_0^2 - \omega_c^2} \quad (3)$$

$$L = \frac{1}{4\pi^2 f_0^2 C} \quad (4)$$

Where ω_c , ω_o is the cut-off frequency and Centre frequency of the low-pass filter, Z_0 the Characteristic impedance of the input/output ports, and 'g' given by the element value of the prototype LPF. The operating frequency of DGS can be lowered while the reactance is increased by generally increasing the area or the number of DGSs. To design the third band we use a pair of asymmetric SIRs for the UWB response and DGS formed under the asymmetric SIRs of Resonators 5 to minimize the losses of the bandwidth, as shown in Figure 5. It is verify that by increasing the coupling length of the resonator 1 and resonator 2 significantly affect the UWB characteristic.

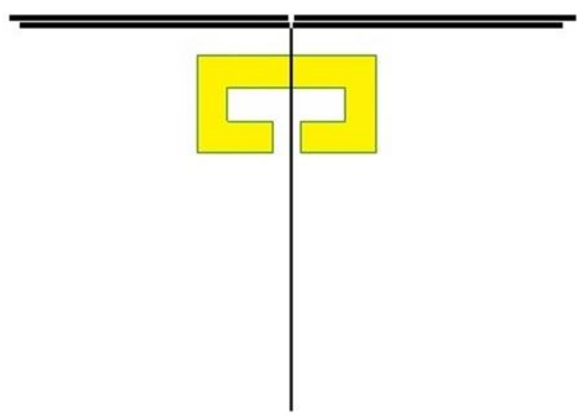

Figure 5. Design Model for UWB Response

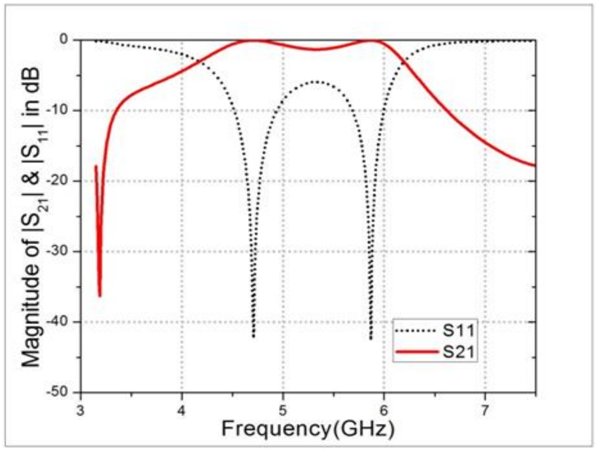

Figure 6. S_{21} and S_{11} Response and Phase different

When coupling line (L) are increased from 0mm to 13.8mm and with DGS, improves the insertion loss up to -0.04dB. The UWB response with low insertion loss (S21) is -0.04dB and the FWB is 39.76% and the return loss (S11) is -42.57 dB that is shown in the Figure 5.

4. Design for GSM, WiMAX and UWB and Responses

The tri-band response and their group delay of the design BPF is depicted in Figure 7, Figure 8 and Figure 9. The centre frequencies of the three bands are 1.8GHz, 2.86GHz and 3.32-5.12GHz for GSM, WiMAX and UWB respectively. In this design the Bandwidth in UWB is improve. In single UWB designed structure its bandwidth was 4.17GHz-6.19HGz, but after integrating the two narrow passband with UWB structure the spectrum is shifted to 3.32HGz-5.12GHz in tri-band design shown in Figure 7, which mean that it increases about 20% of Bandwidth than the other work in UWB. As we know that after the unlicensed the UWB band (3.1GHz-10.6GHz) operation from the FCC decision in February 2002 [22]. The UWB systems have many pleasing features such as transmitting higher data rates and requiring lower transmit power. The dimension taken for this design is shown in the Table 1 in above for obtaining the batter result.

Table 1. Design Parameters Dimension Table

Dimension used for designing the GSM, WiMAX and UWB response in mm.						**Dimension for DGS in mm**			
Space between two pec		Length		width		Length		Width	
S_1	0.5	L_1	18.2	W_1	3.85	L_{D1}	8.8	L_{W1}	1.5
S_2	0.25	L_2	11.85	W_2	0.2	L_{D2}	4.6		
S_3	1.3	L_3	16.9	W_3	0.2	L_{D3}	3.7		
S_4	0.3	L_4	1.5	W_4	0.2	L_{D4}	1.6		
S_5	0.2	L_5	12.05	W_5	0.05				
S_6	0.2	L_6	13						
S_7	0.05	L_7	10.4						
S_8	0.2								

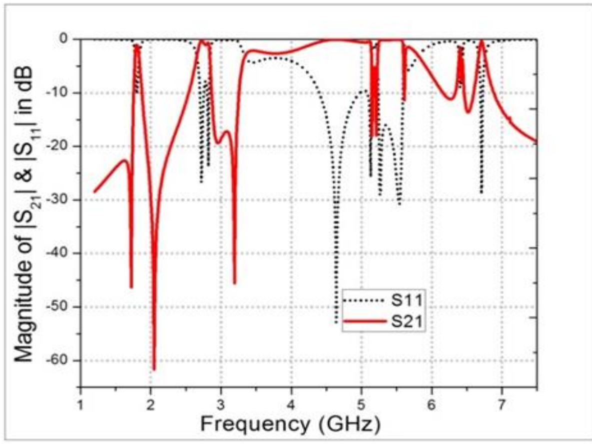

Figure 7. Magnitude Response of S21 and S11 for Tri-band

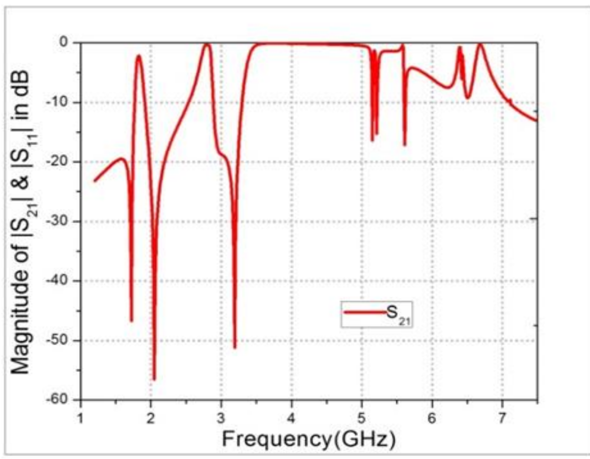

Figure 8. Magnitude Response of S21 for Tri-band

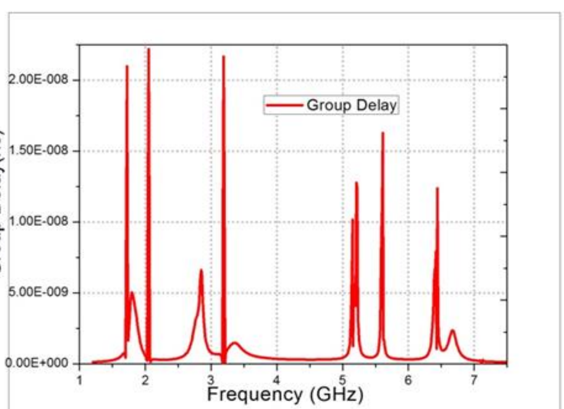

Figure 9. Group Delay (ns)

Table 2. Comparison with Other Proposed Tri-band BPF

Comparison of model	1st/2nd/ 3rd Pass-band (GHz)	$\lvert S_{21}\rvert$ in dB	$\lvert S_{11}\rvert$ in dB	FWB (%)	Application
Ref.[1]	1.8/2.7/ 3.3-4.8	2.2/2.1/1.3	14/13/9	3.9/2.6/40	GSM WiMAX UWB
Ref.[8]	2.4/3.5/5.2	0.9/1.7/2.1	23/15/13	13.5/7/3.5	WLAN WiMAX WLAN
Ref.[16]	2.45/3.5/ 5.25	2/2.4/1.7	18/16/13	2.5/1.7/5	WLAN WiMAX WLAN
Ref.[17]	2.4/3.8/5.7	0.8/2.0/2.5	22/18/28	7.5/3/4	WLAN WiMAX WLAN
Propose filter	1.8/2.86/ 3.32-5.12	0.98/0.28/0 .03	10.19/26.6 9/53.31	2.24/6.96/ 43.69	GSM WiMAX UWB

The group delay is obtain by the taking the derivative of the phase as depicted in Figure 9 and varies in between 0.21-0.22ns at 1.8GHz,6.15-.22ns at 2.86GHz and 0.1-0.13ns for 3.32-5.12GHZ. In this filter design the circuit size is very small and tri-band filter with two narrow bands and one UWB filter.

5. Conclusion

A triple-band BPF has been design using four asymmetric SIRs and U-shape DGS was proposed for the application of GSM (1.8GHz), WiMAX (2.86GHz) and UWB (3.32–5.12GHz). Triple-band response is obtain by intelligently choosing the impedance ratio (R) and length ratio (u) of the asymmetric SIR and the arrangement of the coupling asymmetric SIRs with the U-shape DGS to satisfy required responses for two narrow bands and UWB responses. The Figure 7 shows triple band response, where bandwidth in UWB increases to about 20%. The performance improvement then the others previous work are shown in the table2. The proposed filter demonstrating compact size, low insertion loss and good pass band selectivity.

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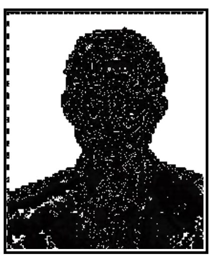

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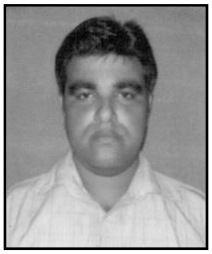

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