

A Dual-Band Bandpass Filter Using SIR Suitable for WiMAX Band

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Abstract. In this paper a dual band bandpass filter with sharp rejection is proposed. The filter is realized by using two half wavelength stepped impedance resonator to operate at the passband 2.5 GHz and 3.5 GHz. To increase the band width further interdigital capacitors are introduced between resonator and input and output combining network. A finite transmission zero in between two pass band at 2.84 GHz is realized to improve the selectivity of the filter. The design procedure to get highly selective response of the proposed filter is explicitly explained. An equivalent circuit model of proposed filter is developed that matches well with full wave electromagnetic simulations.

Keywords: Dual-band Filter, Stepped Impedance Resonator (SIR), Interdigital Capacitor (IDC).

1. Introduction

Worldwide Interoperability for Microwave Access (WiMAX) technology has great potential in the development of modern communication system, for instance, mobile broad band connectivity, wireless connectivity, providing telecommunication services and also to facilitate machine to machine communications. Bandpass filter is a key component in receiver front end for frequency selection purpose. In the present scenario of multiband communication systems, single front end devices catering to different band simultaneously is desirable. The conventional topology of filter design fails to meet this requirement due to its large area requirements and also suffers from uncontrollable spurious pass band response [1-2] which restricts to design a multiband bandpass filter. Stepped Impedance Resonator (SIR) is widely used for designing dual band filter, where the first spurious mode is shifted to the second pass band [3-5]. SIRs with a new coupling scheme is used to realize a compact dual band BPF is reported in [6]. A new topology has been proposed to improve the response to some extent by using defected SIR [7-8]. A compact size dual band characteristic is realized by implementing Meander Loop resonator with CSRR DGS [9]. In [10] by inserting transmission zeros in either side of the passband a compact dual band BPF is realized using periodic stepped impedance ring resonator.

However a dual band pass filter with highly selective response in conjunction with lower insertion loss with wide stopband is still a challenging task in microwave circuit design paradigm. Here a dual band pass filter is realized by using two SIRs of resonating frequency 2.5GHz and 3.5GHz. Impedance ratio is chosen to shift the spurious mode above 9 GHz. A new coupling scheme is also presented to combine both the resonators. Finally Interdigital Capacitors (IDC) is used to increase the bandwidth of the proposed dual band BPF.

2. Design of Proposed Dual-Band Band Pass Filter

The filter is designed using half wavelength ($\lambda/2$) open end SIR. The basic structure of the $\lambda/2$ SIR is shown in Fig. 1. The resonator composed of high impedance (Z_1) section of electrical length (θ_1) followed by two low impedance (Z_2) section of electrical length (θ_2). The resonance condition of the resonator can be derived by

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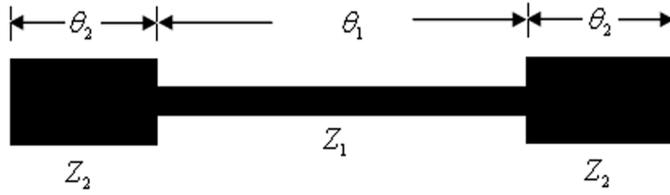


Fig. 1: General geometry of $\lambda/2$ SIR.

$$R_Z = \frac{Z_2}{Z_1} = \tan \theta_1 \tan \theta_2 \quad (1)$$

Where R_Z is the impedance ratio of the SIR. The fundamental frequency (f_0) and first spurious frequency (f_{SB1}) of the resonator are related by

$$\frac{f_{SB1}}{f_0} = \frac{\pi}{2 \tan^{-1} \sqrt{R_Z}} \quad (2)$$

Fig. 2 shows the plot of impedance ratio against the normalized first spurious frequency of the SIR. It can be observed that by proper selecting the impedance ratio the first spurious mode can be shifted at high frequency range to get wide stop band.

The layout of the proposed dual-band BPF with two $\lambda/2$ Stepped Impedance Resonator is shown in Fig. 3.

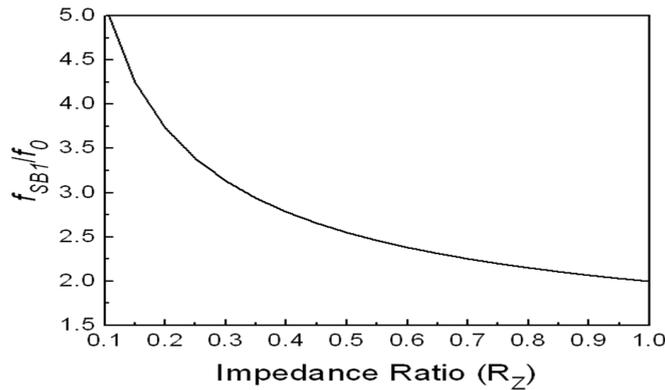


Fig. 2: Relationship between Impedance ratios with normalized first spurious resonance frequency of SIR.

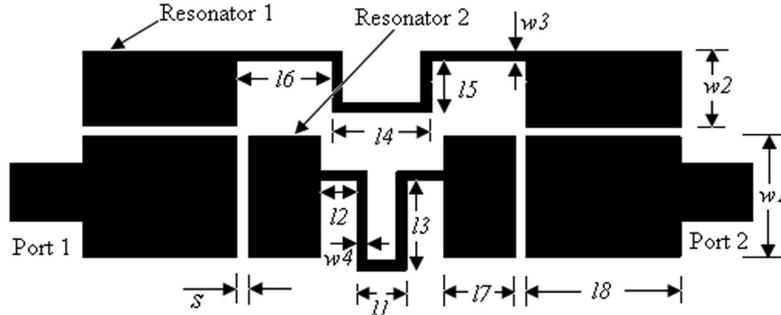


Fig. 3: The layout of the proposed bandpass filter with $l1=2$, $l2=1.5$, $l3=3.32$, $l4=4$, $l5=2.16$, $l6=3.75$, $l7=3$, $l8=6$, $w1=5$, $w2=3$, $w3=0.4$ and $w4=0.4$ (all dimensions are in mm).

The filter is realized using a substrate of dielectric constant 2.2 and height 0.795 mm. Resonator1 is designed to operate at the first passband of 2.5 GHz for which the impedance ratio is chosen 0.32. Resonator2 is realized to operate at second pass band of 3.5 GHz with impedance ratio 0.24. It is seen that for these impedance ratios the spurious modes occur beyond 7 GHz which is useful to get a wide stop band. An additional benefit to choose low impedance ratio is that for a specific fundamental frequency of resonance, the overall electrical length gets reduced which is helpful to realize a compact band pass filter. In order to achieve the dual band operation both the resonators are combined to low impedance sections which is connected to input and output ports of the filter. The spacing between the resonators and the low impedance section is computed using a full wave electromagnetic simulator CST Microwave Studio from

which the spacing for highest coupling is determined. Parametric study yields a spacing of 0.15mm. The frequency response of the above dual band BPF is plotted in Fig. 4 where the bandwidth is narrow due to weak coupling.

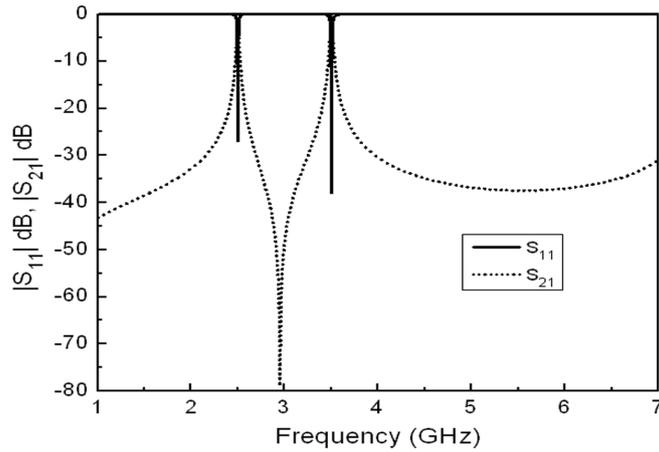


Fig. 4: EM simulated response if the proposed BPF without IDC.

To enhance the coupling further interdigital capacitor is introduced between resonator and low impedance section which is shown in Fig. 5. The length, spacing and width of the fingers of IDC are

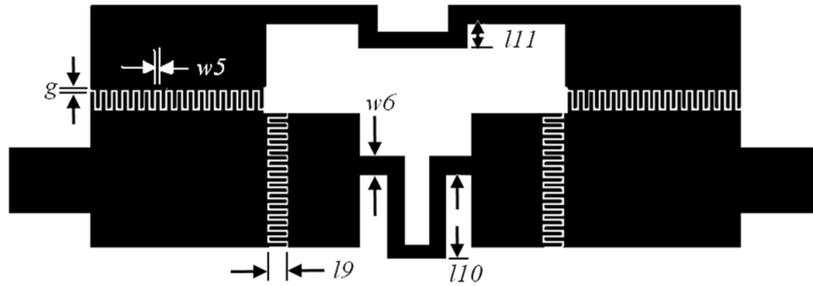


Fig. 5: The layout of the proposed bandpass filter with IDC $g=0.1$, $w5=0.1$, $w6=0.7$, $l9=0.7$, $l10=3.1$, $l11=0.9$ (all dimensions are in mm).

extracted to achieve desired bandwidth to make it suitable for WiMAX application. To minimize the effective area of the filter the length of high impedance section of both the resonators are modified by bending it along the width. The equivalent circuit of the above filter is illustrated in Fig. 6. Each SIR is equal to a LC resonant tank circuit and they have capacitive coupling due to interdigital capacitor with the input and output feed lines. The calculated parameters for resonator1 are $L1=0.308$ nH, $C1=11.76$ pF and for resonator2 are $L2=0.2$ nH, $C2=7$ pF. The series and shunt capacitances associated with interdigital sections are $C11=1.5$ pF, $C21=1.3$ pF, $C12=0.011$ pF and $C22=0.01$ pF.

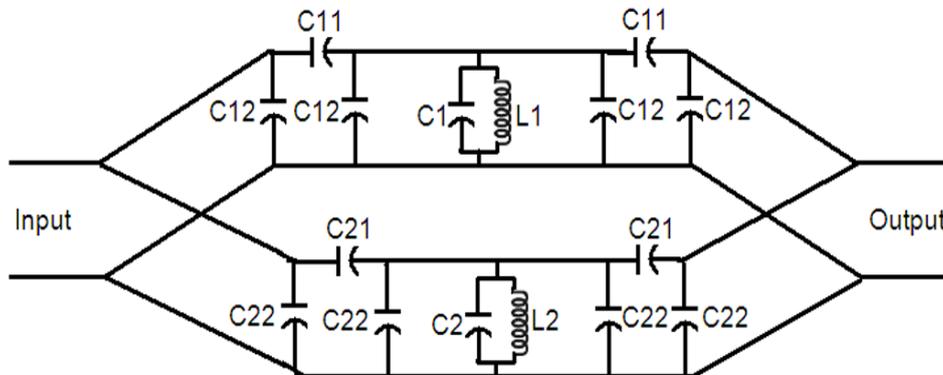


Fig. 6: Equivalent circuit model of proposed dual band BPF with IDC.

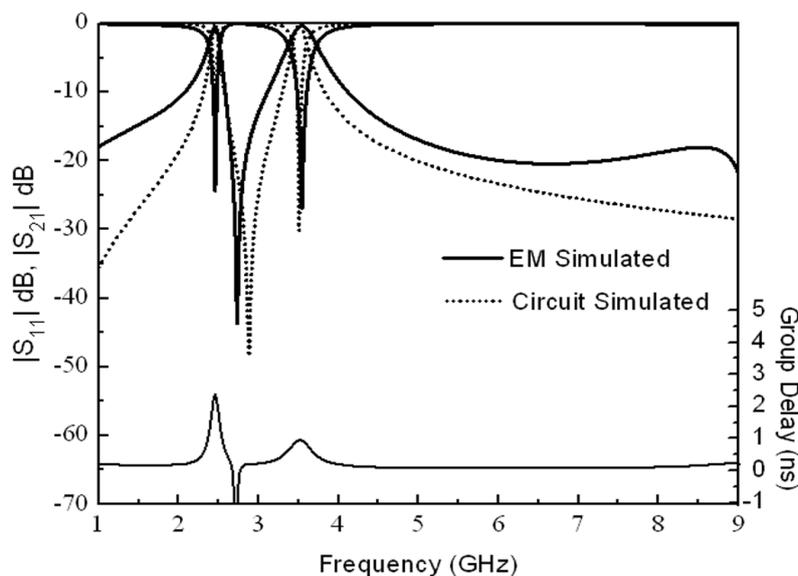


Fig. 7: S_{11} (dB) and S_{21} (dB) plotted against frequency obtained from fullwave electromagnetic simulation and circuit modeling with IDC. Simulated group delay is also plotted.

3. Results and Discussion

The frequency response obtained from EM simulation and equivalent circuit model of the proposed BPF with IDC is shown in Fig. 7 and a good agreement is observed between them. Extracted S-parameter of the proposed filter depicts that for first passband of 2.46 GHz has insertion loss less than 0.5dB with FBW 1.8% and for second passband of frequency 3.51 GHz the filter exhibits insertion loss less than 0.3dB with FBW 3.4%. A transmission zero is found at 2.84 GHz which demonstrate that the filter poses a good selectivity. The proposed filter also shows a wide upper stopband with attenuation more than 15 dB extended up to 9 GHz. The simulated group delay in the two pass bands is less than 2.5 ns.

4. Conclusion

In this paper a compact dual-band bandpass filter using Stepped Impedance Resonators (SIR) is presented. The analytical methods for designing the proposed filter are explained clearly. To meet the bandwidth requirement for WiMAX band Interdigital Capacitors are introduced between SIRs and feed lines. By proper selection of the impedance ratio a wide stopband is achieved. Folding the high impedance section of SIRs a compact dual band BPF is implemented with a total area of $30 \times 10 \text{ mm}^2$ only.

5. Acknowledgment

One of the authors Prof. D R Poddar is grateful to All India Council for Technical Education (AICTE) for awarding him Emeritus Fellowship and supporting this research via grant no.1-51/RID/EF (04)/2009-10 dated 06.01.2010.

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