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Design and Analysis of Compact Microstrip Multiband Bandpass Filter Using U-shape with Triangular Stepped Impedance Resonators

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Abstract

A new class of compact microstrip multiband bandpass using symmetric U-shape with triangular stepped impedance resonator is proposed for wireless application. The multiband filter only employs two symmetric U-shape with triangular stepped impedance resonator. By properly tuning the impedance ratios and length ratios of stepped impedance resonators, a multiband filter response can be achieved easily. Based on the similar characteristics of triangular shaped SIR, a miniaturized multiband band pass filter operating at the center frequencies (0.8GHz, 2.3GHz, 3.8GHz, 5.1GHz and 5.8GHz) are obtained. The filter is characterized by analyzing the filter parameters return loss and insertion loss. The numerical analysis of the proposed filter is derived by using commercially available electromagnetic simulation software IE3D. The results show that the filter has compact size, good return loss and insertion loss characteristics.

Keywords: Triangular Stepped Impedance Resonator, Multiband bandpass filter, impedance ratio.

Introduction

In recent years, multiservice technology is widely and aggressively developed, especially in the radio frequency devices of the wireless communication systems. To achieve the requirement in commercial products with multi-service, the circuit with high integration of multibands has become more significant. In the radio frequency (RF) front end, the bandpass filter (BPF) plays a key component for selecting the desired and high resolution signals. To design a multiband filter with multiple services is becoming an important issue and carried out in many literatures, such as the tri-section stepped impedance resonators (SIRs) [1], combined $\frac{\lambda}{4}$ SIRs [2], stub-loaded SIRs [3], tri-band crossed resonators [4], and ring resonator with three pairs of degenerated resonant modes [5]. Mathematic involved modeling of these resonant structures is thereby required to determine the first three resonant modes based on the prescribed tri-band central frequencies. However, there is no any detailed discussion on independent design of the tri-band external and inter-resonator couplings. To alleviate tri-band coupling design difficulties, various novel coupling topologies and structures for the tri-band filters were proposed in [6]–[8], as one or two resonant structures not only produce self-resonant modes, but also render the appropriate external couplings for the others. Nevertheless, there still lacks design flexibility for the rest dual-band inter-resonator and external couplings; as a result, the coupling structure determination was heavily resorted to time-consuming full wave simulations.

In this paper a compact microstrip multiband BPF based on U-shape with TSIR is presented. The resonant behaviour of the U shape with Triangular stepped impedance resonators (TSIR), much different with asymmetric SIRs, conventional SIRs and TSIR, is analysed and discussed. Fig. 1 shows the schematic of SIR.

Proposed Multiband Bandpass Filter

The proposed multiband bandpass filter consist of two U-shape with TSIR, which are strongly coupled to each other. The input port is coupled to the TSIR1 and output port is coupled to the TSIR2. Fig. 2 shows the schematic of proposed U-shape with TSIR. Since the resonator structure is symmetric, it can support both even and odd modes The triangular SIR have better feature than conventional SIR such as compact size, strong design feasibility as discussed in [8].The impedance ratio K ,input admittance Y_{in}, and the length ratio γ are defined as

$$K=\frac{z_2}{z_1} \quad (1)$$

$$\gamma=\frac{\theta_2}{(\theta_1+\theta_2)} \quad (2)$$

$$Y_{in}=j\frac{K(\cot\theta_2-\tan\theta_2)+K(\cot\theta_1-\tan\theta_1)}{z_2[0.5(\cot\theta_1-\tan\theta_1)(\cot\theta_2-\tan\theta_2)-2k]} \quad (3)$$

The effective dielectric constant and characteristic impedance is given by,

For $\frac{w}{h} \geq 1$

$$\varepsilon_{re} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+12\ \frac{h}{w}\right)^{-0.5} \quad (4)$$

$$Z_c(t) = \frac{n}{2\pi\sqrt{\varepsilon_{re}}}\left[\frac{w}{h} + 1.393 + 0.667\ln\left(\frac{w}{h} + 1.444\right)\right]^{-1} \quad (5)$$

For $\frac{w}{h} \leq 1$

$$Z_c(t) = \frac{n}{2\pi\sqrt{\varepsilon_{re}}}\ln\left[\frac{8}{w/h} + 0.25\frac{w}{h}\right] \quad (6)$$

$$\varepsilon_{re} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(\left(1+12\ \frac{h}{w}\right)^{-0.5} + 0.04\left(1-\frac{w}{h}\right)^2\right) \quad (7)$$

Guided wavelength is given by,

$$\lambda_g = \frac{\lambda}{\sqrt{\varepsilon_{re}}}\ , \text{ where } \lambda = \frac{c}{f_c} \quad (8)$$

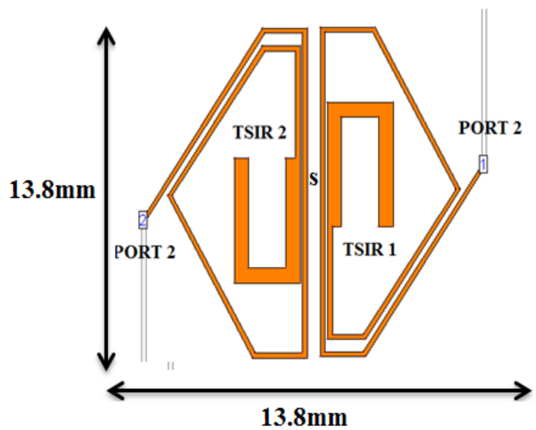

Fig. 1 schematic of proposed multiband bandpass filter.

Corresponding parameters for the proposed bandpass filters are $\varepsilon_{re1} = 3.177$, $Z_{1,} = 81.73\Omega$, $\lambda_g = 70.12mm, \theta_1 = 59.5^{\circ}, Z_{2,} = 121.06\Omega$, and $\theta_2 = 229.72^{\circ} and\ k = 1.5$**Fig. 1** schematic of proposed multiband bandpass filter.

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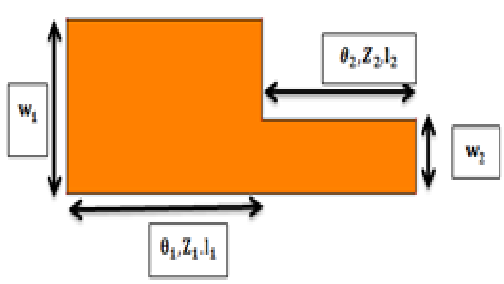

Fig.2 schematic of SIR.

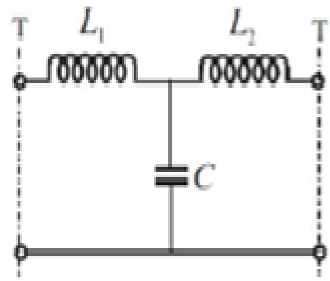

Fig. 3 Equivalent Circuit of SIR

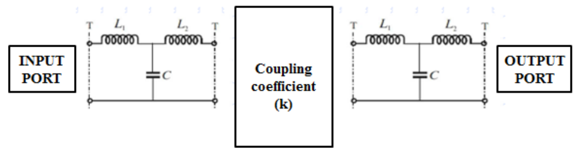

Fig.4 Equivalent Circuit of Proposed Multiband bandpass filter.

The proposed filter is designed to have f1=0.8GHz, f2=2.3GHz, f3=3.8GHz, f4=5GHz and f4=5.8GHz respectively. The passband ripple is set as 0.01db.The element value of low pass filter prototypes are G0=1, G1=1.3782, G2=1.2693 and order of the filter is 2. The stepped impedance resonator of width W1 is 0.6mm the corresponding lower impedance is 81.73ohm and another width W2 is 0.2mm corresponding to the impedance 121.06ohm. Generally, a smaller gap S results in a stronger I/O coupling or a smaller external quality factor of the resonator. For providing the strong coupling between two TSIRs, the gap S is chosen to be 0.05mm. Each passband can be implemented individually, low insertion loss and good passband selectivity of each pass band can be well achieved.

Results Discussion

Based on the above discussion the compact microstrip multiband band filter is designed and verified using EM fullwave simulator. Fig. 1 illustrates the proposed multiband filter design, and Fig. 6 plots the fullwave simulated frequency in good agreement over the frequency range from 0 to 7GHz.

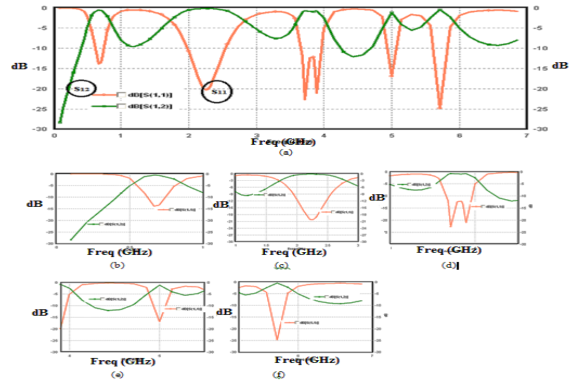

Fig. 5. Simulated results of the fabricated quad-band BPF. (a)Wideband response view. Narrowband view of (b) the first passband, (c) the second passband, (d) the third passband, (e) the fourth passband.(f) fifth passband.

Frequency(GHz)	S11(dB)	S12(dB)
0.8	12	0.71
2.3	19.3	0.37
3.8	22	0.9
5.1	16	1.5
5.8	18	0.6

Table.1 S-parameters versus frequency response

Ref	S11(dB)	FREQ(GHz)	CIRCUIT SIZE(mm)
[3]	9/18.9/13.5	1.57/2.4/3.5	49.7x56.7
[11]	Better than 10/11/12/16.5	1.19/3.33/5.87/8.39	31.1 x 23.45
Proposed work	12/19.3/22/16/18	0.8/2.3/3.8/5.1/5.8	13.8 x 13.8

Table.2 Performance comparison with reported multiband bandpass filter

Table 1 shows summarized the frequency and s-parameter of the proposed filter, which is uses the FR4 substrate with the relative dielectric constant $\mathcal{E}_r = 4.4$, loss tangent $\tan\delta = 0.0008$ and thickness $h = 0.8mm$. The circuit size of the fabricated filter is $13.8 \times 13.8mm^2$, approximately. The maximum insertion loss are found to be 0.8,0.37,0.9,1.5 and 0.6 dB, in the multi-passband at the frequency 0.8GHz (GSM), 2.3GHz, 3.8GHz (mobile Wi-MAX),5.1GHz (Wi-Fi), and 5.8GHz (WLAN) and their minimum in-band return loss are 12, 19.3, 22, 16 and 18dB.The arrangement of the resonator can generate the cross coupling effects. The transmission zeros near each passband will occur due to multipath propogation with electric and magnetic coupling is generated [9].The proposed filter shows the low insertion loss, compact size, good passband selectivity and wide stop band.

Conclusion

A compact multiband bandpass filter has been proposed and investigated through the EM simulation and experiment. Simulated results reveal that the filter achieves a compact size, good quad-band performance, low insertion loss, good selectivity at passbands edges and wide stopband. The filter has strong design feasibility, since the passbands can be easily determined by tuning the dimensions of the asymmetric SIRs. This study provides a simple and effective method to design a quad-band bandpass filter without complex fabrication process. The electrical size if the proposed filter is $0.19\lambda_g \times 0.19\lambda_g$.The superior features indicate that the proposed filter has a potential to be utilized in multi-service wireless communication system.

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