Investigation of dualband fan-shaped microstrip bandpass filter

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ABSTRACT

In this study, design and simulation of microtrip bandpass filter is presented using RT/Duroid 6010.2 lm substrate. This filter has fan-shaped topology with small dimensions of 12x12 mm^2, designed for dual band frequencies at 3.41 and 6.14 GHz. The insertion loss and return loss of initial band at 3.41 GHz are -0.7 and -38.224 dB respectively and its bandwidth ranged from 3.3561 to 3.48 GHz. On the other hand, for 2nd band at 6.14 GHz, the insertion loss and return loss have been -1.377 and -14 dB respectively with bandwidth ranged from 6.0951 to 6.1782 GHz.

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1. INTRODUCTION

Microstrip technology has been widely adopted in many RF and microwave devices in numerous wireless applications due to its cost effectiveness, smallness and desired frequency responses. Microstrip devices may include microstrip filters [1-7], microstrip diplexers [8, 9] and microstrip antennas [10-15]. In recent years, specifically, bandpass filters (BPFs) have a significant role in modern wireless mobile communication systems. The demand for new designs and approaches of this filter is increasing and intensively investigated. There are many applications used the filters in approximately all aspects and operate in a single-frequency band. The development of the filter technologies approach new method and demand a higher level of applications which can support dual band in a single device. For example, the global system for mobile communications (GSM) and code-division multiple-access (CDMA) mobile phones operate at 900 MHz and 1.8 Hz as well as WiMAX cover dual frequency band which are 2.5 GHz and 3.5 GHz. Therefore, dual-band filter are significant elements at microwave frequency for wireless communication [16].

Miniature microstrip narrow BPFs have been favored progressively in newly wireless communication systems owing to their flexibility in design and extraordinary selectivity. Dual-mode resonators possess extremely desired properties for BPF design, such as size smallness, small radiation loss and design easiness for the reason that transmission-line concept and design tools are straightforwardly realized. Their diminishment techniques are due to existing double circuit in distinct structure as compared with single mode BPF designs as dual degenerate modes have coupled to each other through appropriate perturbation induction [17].

In [18] a small dual-band BPF was simulated and manufactured using loop resonator loaded by dual reformed T-shaped resonators, open bended stubs and double T-shaped resonators. The measurements indicated insertion losses of 0.64 dB and 0.76 dB in the 1st and 2nd pass-bands. Adaptable 2nd center frequency, miniature size, small insertion loss, noble suppression level as well as a symmetrical topology have been the noticeable characteristics of a projected BPF. Lastly, a worthy covenant among measured and simulated results has perceived.

In [19], a microstrip filter with small insertion losses and two band response has designed to generate dual passbands at 2.35 and 5.68 GHz for Multimode Wireless LANs application. Some step impedance cells have employed in loops and tapped line feed configurations for obtaining a new dualband BPF with a miniature size. In [20], a new filter is constructed by inserting two slots in the form of rectangular open loop resonator with folded ends. The insertion of these slots has successfully led to the miniaturized size and the dual bandwidth behavior. The total filter surface area has been 16×12 mm^2 that stand for 0.61λg×0.4λg employing a substrate with Rogers Ro 4003 with a relative permittivity of 3.38 and thickness of 1.0 mm. The resulting structure shows a dual-band performance. The 1st passband has a center frequency of 6.2 GHz. In the 2nd passband, the center frequency is 9.6 GHz.

In [21] small dualband microstrip BPF was designed at 1.8 and 3.4 GHz application using asymmetric stepped impedance resonators (SIRs). The designed BPF has highly small insertion loss (S21) and huge selectivity level for the desired band. The insertion losses have been -0.24 and -0.14 dB while the return losses have been -14.71 and -25.01 dB in each frequency band respectively. In [22], a dual-mode dualband microstrip BPF based on SIR for wireless systems has presented. Through selecting an appropriate impedance ratio, a BPF functioning in 2.4/5.2 GHz was investigated. Dual transmission zeros are located on each side of the 1st passband. A fractional bandwidth (FBW) of dual passbands have been 8% and 6%, individually. A highest insertion loss has been superior than 0.9 dB and the return loss is superior than -20 dB.

In [23], uncomplicated, small topology of dualband BPF has presented. The projected BPF is designed by Rogers TMM10 substrate and stub loaded resonator at 2.4 and 4.3 GHz. The size of BPF has been about $0.3\lambda_g \times 0.32\lambda_g$. Simulated consequences are agreed with the measured ones they indicate that the projected BPF has noble S11 and S21 responses in addition to high rejection band levels. Parametric studies were done to investigate dual band resonant performance with the ratio of resonant bands for feasible wireless communication applications.

In [24], a new dualband BPF based on stub-loaded quad-mode resonator has been reported. Owing to the structural topology, even-odd-mode investigation was applied two times for explaining the BPF features. Every four modes equivalent circuits have been based on the quarter-wavelength resonator. Consequently, a quad-mode resonator has small dimensions. The measured and simulated fallouts are in noble agreement. In [25], a novel varactor-tuned microstrip dualband BPF using tri-mode stub-loaded stepped-impedance resonators (SL-SIRs) was simulated and fabricated. By using the dual coupling paths, the dual passbands are feasibly completely organized and designed individually. Noble conformity has been realized among simulated and measured consequences. In this research article, new dualband filter was designed based on ceiling fan-shaped resonator. This projected filter has compact surface area and useful bands for contemporary wireless applications. It has different and simpler topology, different and simpler design and frequency responses as compared with fan-shaped filters in [26, 27].

2. FILTER TOPOLOGY

The structure of microstrip is based on fan-shaped topology using single layer substrate (RT/Duriod 6010.2 lm) with dielectric constant of 10.2, thickness of 1.27 mm and loss tangent of 0.0023. A topology and detailed dimensions of suggested dualband filter are depicted in Figure 1 and Table 1 respectively. The first band, in general, is based on the structure and dimensions of proposed filter acquired by trial and error procedure of dimensions scaling, the filter size is inversely proportional to the fundamental frequency. The orthogonal I/O feeders in the left side and bottom side of designed filter as illustrated by Figure 1, has electromagnetic perturbation to shift the second harmonic and produce the second band. The filter is designed for dual band frequencies at 3.41 and 6.14 GHz.

A significant issue from the compactness of microstrip filters comes in the practicality that resonating BPFs need including the absolute dimensions based on the guided wavelength and calculated resonant frequency (f). Hence, a guided wavelength is calculated as:

$$\lambda_g = \frac{c}{f\sqrt{\varepsilon_e}} \quad (1)$$

The effective relative dielectric constant ε_e, designed for BPF is computed based on (2) [28]:

$$\varepsilon_e = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(\frac{1}{\sqrt{1+12\mathrm{H/A}}}\right) \quad (2)$$

Even so, ε_e in this research work has was determined via an approximated equation as [1, 2]:

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} \quad (3)$$

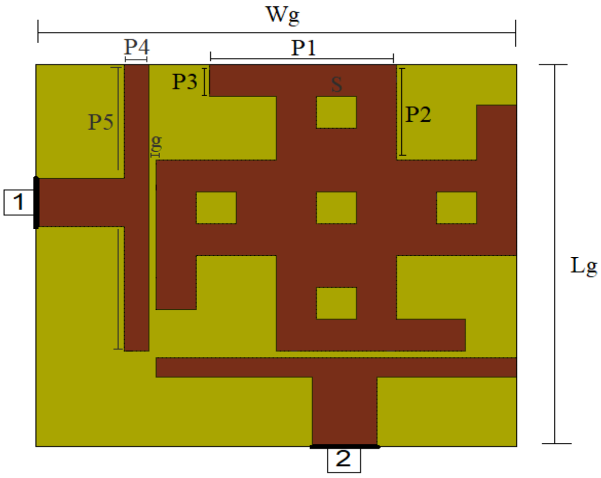

Figure 1 Topology of proposed dual-band filter

Table 1. Dual band fan microstrip bandpass filter

Parameter	Value(mm)
Wg	12
Lg	12
P1	4.7
P2	3
P3	1
P4	0.6
P5	9
S	1
g	0.2

3. SIMULATION RESULTS

Figure 2 presents the frequency response of fan-shaped microstrip bandpass filter for both S11 and S21 parameters. The insertion loss and return loss of first band at 3.41 GHz are -0.7 and -38.224 dB respectively and its bandwidth ranged from 3.3561 to 3.48 GHz. On the other hand, for 2nd band at 6.14 GHz, the insertion loss and return loss are -1.377 and -14 dB respectively with bandwidth ranged from 6.0951 to 6.1782 GHz. The fan-shaped resonator has dynamic perturbation outcome to the electromagnetic steadiness of the resonator formation and may stand for the reasons for dualband frequency response at 3.41 and 6.14 GHz respectively. This filter has very small bandwidth responses that are typically a huge objective in wireless systems to cause the filter capable of avoiding the interfering signals working in the neighboring bands. Besides, it has an acceptable return loss and insertion loss magnitudes to be applied in C band wireless systems.

Figure 3 explains the phase response of fan-shaped microstrip bandpass filter for both S11 and S21 parameters. The dualband filter has an appropriate level of linearity for S11 and S21 angle responses within sweeping frequency from 3 to 7 GHz. Figure 4 shows the group delay response of fan-shaped microstrip bandpass filter. As a result of the transmission line of the fan-shaped resonator, resonance modes with negative group speed (akin to group delay) are possible in floating solid plates. Their interpretation comes from the broader analysis of the resonances in the structure. In the plate, a mode with negative group speed always has a companion resonance with a positive group speed. You cannot physically excite one of the pairs without exciting the other. The phenomenon is therefore not an isolated resonance with negative group speed but of resonance +/- pairs that together constitute standing waves.

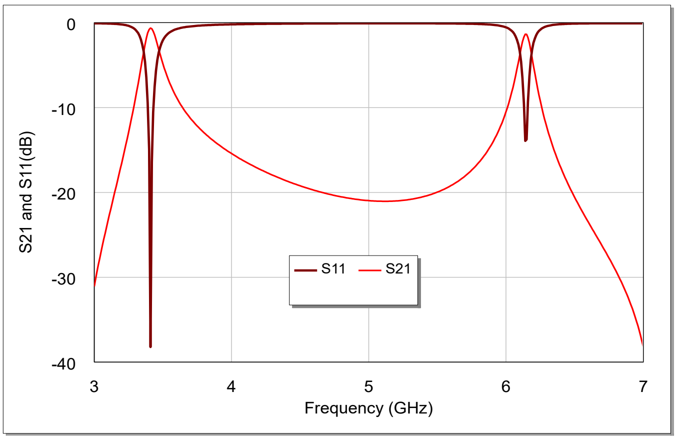

Figure 2. The frequency response of fan-shaped microstrip bandpass filter

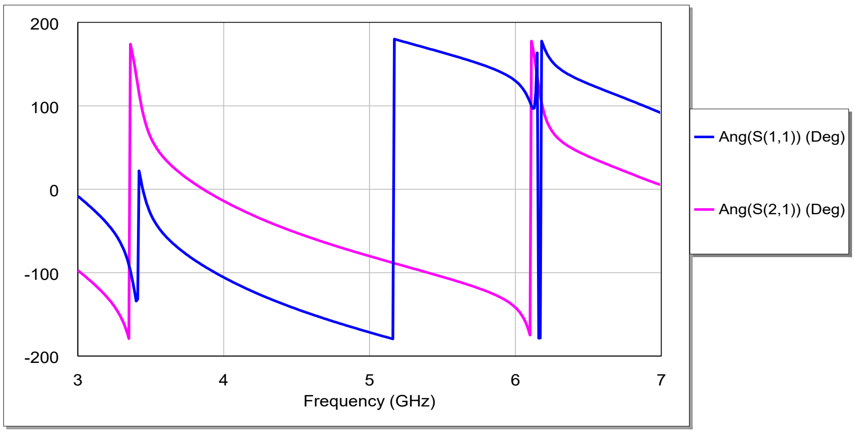

Figure 3. The phase response of fan-shaped microstrip bandpass filter

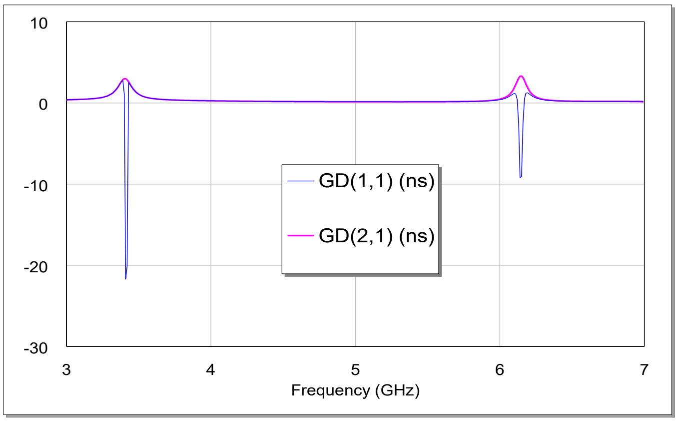

Figure 4. The group delay response of fan-shaped microstrip bandpass filter

To further analyze the designed bandpass filter, the simulated magnetic current distribution is depicted in Figures 5 and 6 band frequencies of 3.41 and 6.14 GHz. All these results are performed using Sonnet simulator under minimum memory storage. The utmost coupling effect is indicated by red color, whereas a slightest one has been ostensible by blue color. From Figures 5 and 6, the current intensity patterns for both designed filters are symmetrically distributed. The physically powerful current values are concentrated within 2^{nd} band frequency case especially in I/O coupling feeders with magnetic intensities of 11 amp/meter as compared with first band case with current intensity of 5.7 amp/meter.

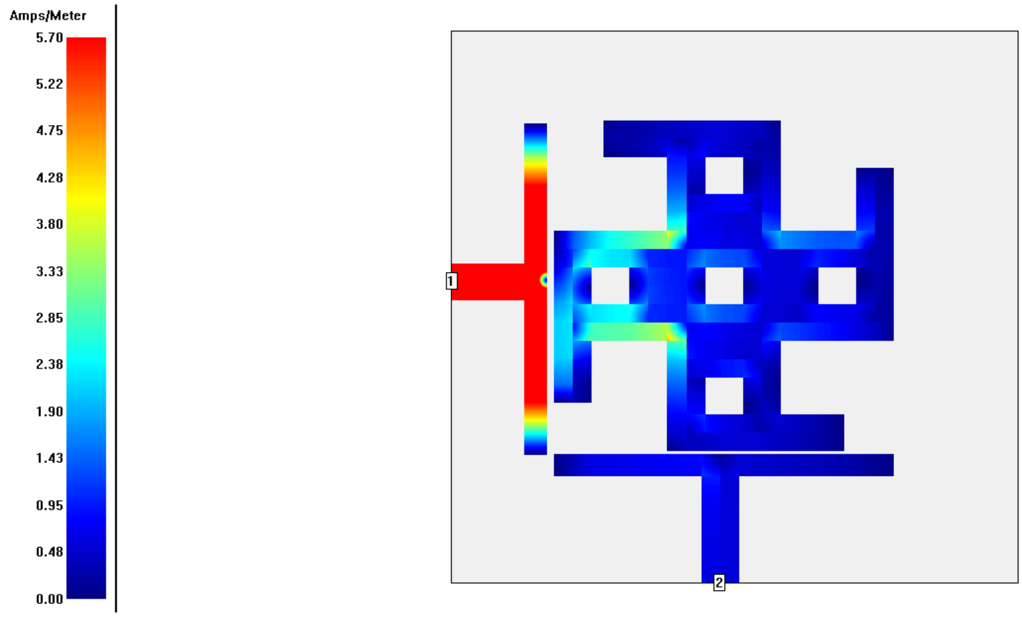

Figure 5. Magnetic intensity distribution of proposed filter at first band frequency

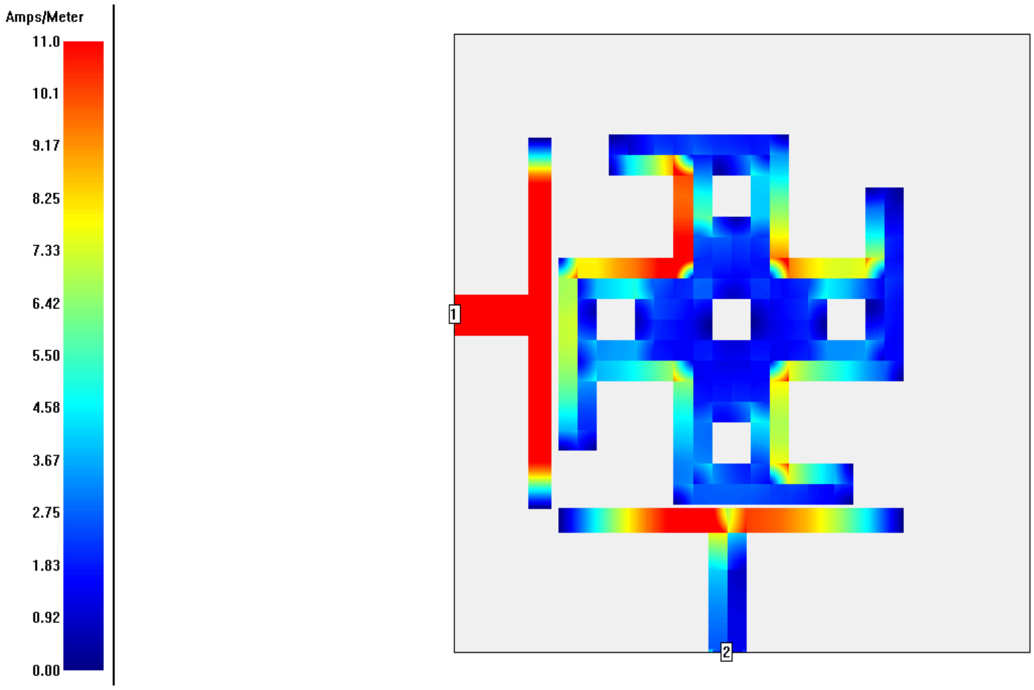

Figure 6. Magnetic intensity distribution of proposed filter at first band frequency

4. CONCLUSION

New microstrip BPF is presented in this paper using RT/Duroid 6010.2 lm substrate using fan-shaped resonator topology for dual band frequencies at 3.41 and 6.14 GHz. The insertion loss and return loss of first band at 3.41 GHz are -0.7 and -38.224 dB respectively and its bandwidth is 123.9 MHz. On the other hand, for 2nd band at 6.14 GHz, the insertion loss and return loss have been -1.377 and -14 dB respectively with bandwidth 83.1 MHz. This filter has very small size that can be integrated within many portable wireless systems.

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