A New Microstrip Dual-Band Bandpass Filter Design using SIRs and Open Stubs

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Abstract
A novel design of microstrip dual-band bandpass filter is presented in this article. The structure contains stubs loaded feeding and Stepped Impedance Resonators. The design allowed achieving a harmonic free characteristic for the filter and achieving a good and stable out of band attenuation. The measured return losses are better than 20 dB and the measured insertion losses are around 3dB in both passbands. The out-of-band attenuation levels are 40dB up to 10GHz. The overall measured results are in good agreement with simulations and the filter dimensions are 18×16 mm². The filter is designed to work at the center frequencies 3.45 GHz and 5.75 GHz to suit WLAN and WIMAX applications.

Keywords
Planar Microwave Filters — Attenuation Poles — Harmonic Frequencies

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Introduction

Filtering circuits are a compulsory part in almost every radio or microwave system. Historically, filtering design started with lumped elements components and when applied to microwave frequencies the lumped element components become very difficult to fabricate [1]. Since then many researches on new technologies for Microwave circuits have been emerging notably the successful planar Microstrip technology. The circuits on these technologies are distributed element circuits and so they suffer from many negative effects at microwave frequencies such as harmonic frequencies generation, radiations, losses…etc.

Harmonic frequencies generation is the most critical problem in multi-band filters designs, because it can seriously distort the signal at the upper frequency bands as in [2]. Many researches were made to give solutions to this problem like in [3] [4] [5] [6] [7]. However, the effects of the undesired frequency components are still not well resolved.

In this design, the undesired harmonic is removed from filter response and the out of band attenuation is reinforced using open stubs (OS) and stepped impedance resonators (SIR).

1. Developing The Filter Structure

1.1. SIR and OS Resonant Frequency

In order to improve a dual band BPF, the most crucial criteria is to get rid of the generated harmonics. Stepped Impedance Resonators have the characteristic of shifting far away the harmonics from the resonant frequency [8] [9]. The resonant frequency can be determined from the electrical length of the used lines θ_1 *and* θ_2 and their impedance Z_1 *and* Z_2 verifying formula (1) [9].

$$\frac{Z_1}{Z_2} = \tan\theta 1 \tan\theta 2 \qquad (1)$$

Frequency rejection is used to reinforce the attenuation level in the desired band and the simplest line form to reject a frequency is an open line which is also known as an open stub. An open stub rejects its resonant frequency which is calculated from its length l_{OS} that represents the quarter wavelength of its resonance. When using Microstrip technology with an effective dielectric constant ε_{eff} of the substrate, the length of an open stub required to reject a frequency f_{OS} is given by (2) [10]:

$$l_{OS} = \frac{c}{4 f_{OS}\sqrt{\varepsilon_{eff}}} \qquad (2)$$

When a line is open in both of its sides, it also resonates and works as a resonator. However unlike an open stub, an open line resonator of a length l_R when coupled to a transmission line, it can transmit a signal when its frequency is the same as the resonance f_R of the resonator. Its resonant frequency can be determined by (3) [10].

$$f_R = \frac{c}{2l_R\sqrt{\varepsilon_{eff}}} \quad (3)$$

The open line resonators could be used to generate transmission poles and conversely, the open stubs could be used to generate attenuation poles but the generated harmonics are also introducing distortions and some measures need to be taken to remove or attenuates them.

1.2. Application to Filter Design

In bandpass filters (BPF), the open stubs could be used as feeding lines or could be integrated therein to reject the undesired frequencies [11]. In this design, the feeding stubs are set to improve the out-of-band rejection.

The applied lengths of the open stubs and the resonators can be calculated from equations (1) (2) and (3). They can be directly optimized by using simulation software.

The used laminate in this design is RO4003C with substrate dielectric constant ε_r=3.38, and substrate thickness of 0.813mm. The dissipation Factor in the substrate is tanδ =0.0021. The applied OSs feeding to the coupled resonators are shown in Figure 1 and the coupling-routing diagram of the proposed structure is presented in Figure 2.

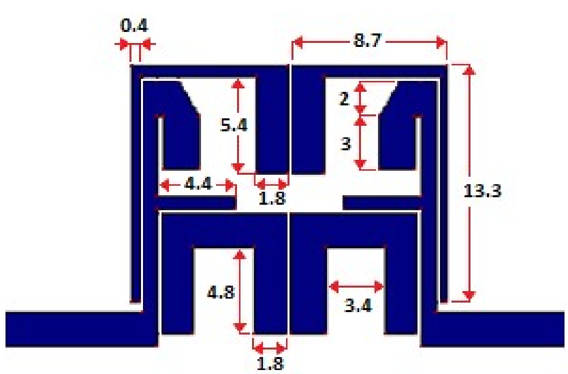

Figure 1. The layout of the proposed filter with its dimensions in millimeters.

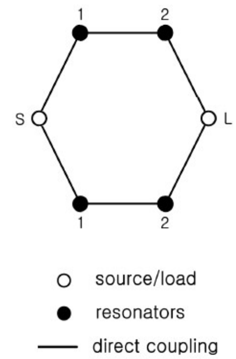

Figure 2. The coupling-routing diagram of the proposed structure.

Figure 3 and Figure 4 demonstrate no harmonic frequency because of the used SIRs and there are three attenuation poles generated from the OSs in the feeding at 4.5GHz, 6.6GHz and 7.3GHz to improve the out-of-bands attenuations.

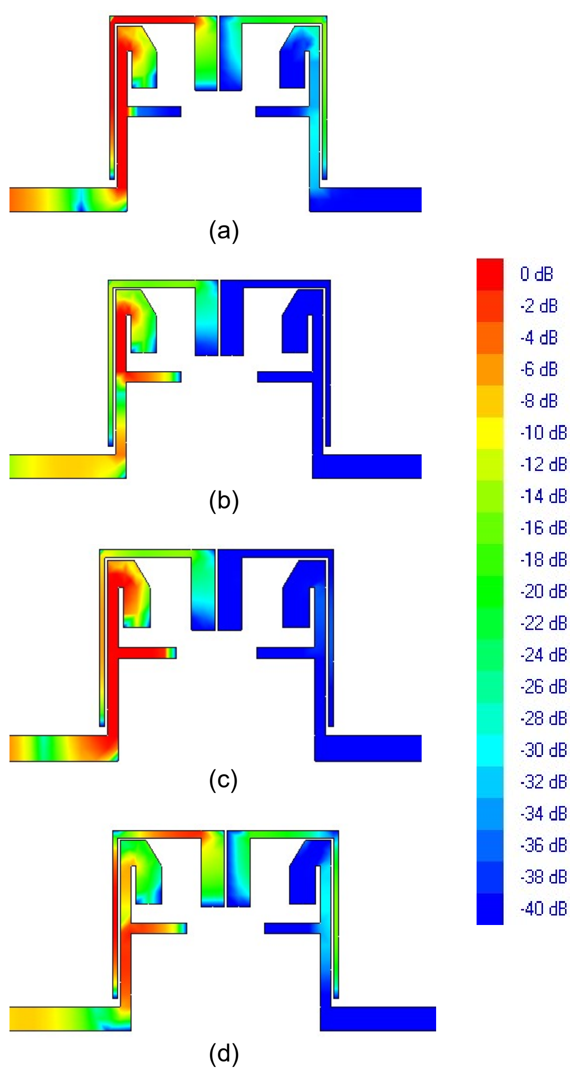

Figure 3. The current distributions on the design layout at: (a) 4.5GHz, (b) 6GHz (c) 6.6 GHz, (d) 7.3 GHz

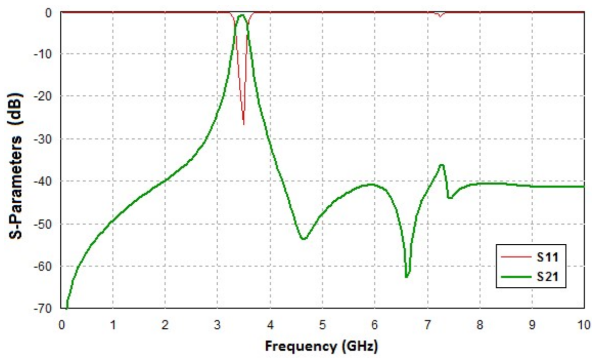

Figure 4. First passband response

Figure 5 and Figure 6 demonstrate the filter response after inserting the second passband resonators. There are no changes on the out-of-band performances and the first band remains unchanged.

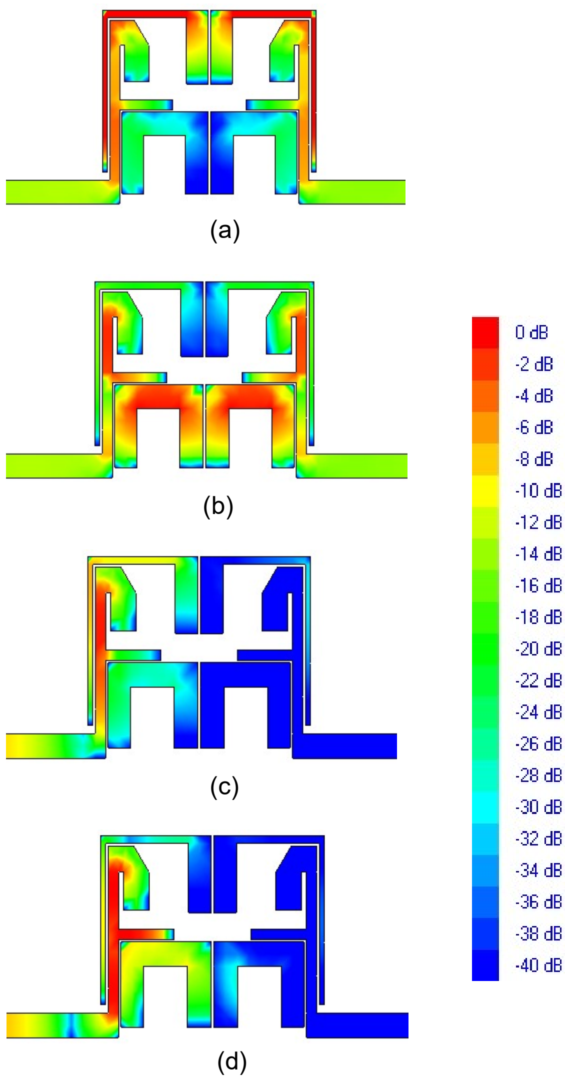

Figure 5. The current distributions on the filter at: (a) 3.45GHz, (b) 5.75GHz (c) 4.6 GHz, and (d) 7 GHz

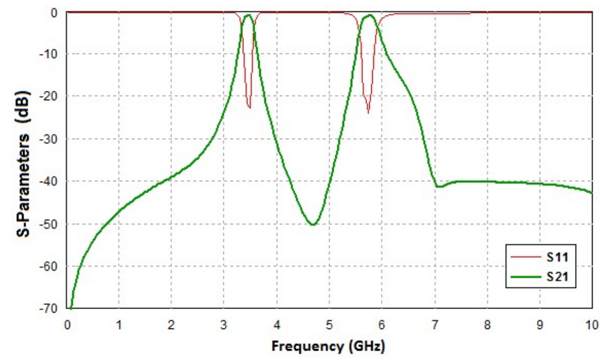

Figure 6. Filter response after the insertion of the second passband resonators

2. Experimental Results

The filter is fabricated using precision Laser drilling machine and its photograph is shown in Figure 7.

The measurements are achieved using Agilent Network analyzer and they are presented together with the simulation in Figure 8.

Figure 7. The photograph of the fabricated filter

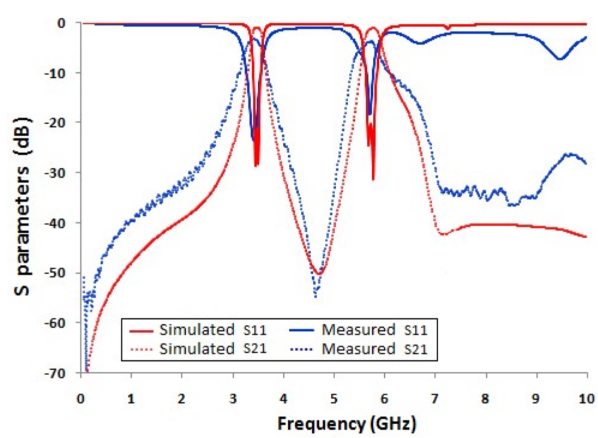

Figure 8. *The measured S parameters compared with the simulated one*

The measured response is slightly shifted toward the lower frequencies and the measured passbands are wider than the simulated one mainly due to the practical additional losses in the substrate and lines conductors that led to lower quality factors for the resonances.

Considering that the manufacturer of the RO4003C substrate gives Ɛr=3.38 ± 0.05 which depends on the operating frequency, the achieved measured frequency shifting is expectable. The manufacturer suggested to use the dielectric constant value Ɛr=3.55 in designing with RO4003C laminates [12]. Table 1 and Table 2 resume the achieved simulated and measured results.

Table 1. Summary Of The Simulated Results

Parameters	Band1	Band2
Center Frequency (GHz)	3.45	5.75
IL at center frequency (dB)	1.00	1.08
RL at center frequency (dB)	30	32
Bandwidth (MHz)	192	287
FBW (%)	5.5	5

Table 2. Summary Of The Measured Results

Parameters	Band1	Band2
Center Frequency (GHz)	3.42	5.74
IL at center frequency (dB)	3.0	3.7
RL at center frequency (dB)	23	19
Bandwidth (MHz)	391	473
FBW (%)	11.4	8.2

3. Conclusion

A new Dual Band Band-Pass-Filter is proposed in this article using source loaded stubs and SIR. The design is free from harmonics within and nearby the passbands to keep good performances and the filter's out-of-band rejection levels are stable with a good attenuation level. The obtained good agreement between the measurements and the simulations confirms the design achievements.

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