# Design and Fabrication of a Novel Microstrip Dual-Band Bandpass Filter with Harmonics-Suppression

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***Abstract -*** A new Microstrip dual-band bandpass filter design is presented in this article. The design employs source loaded stubs to complete multiple functions: feeding the passband resonators, suppressing their harmonics and introducing attenuation in the out-of-band region. This method removes the passband harmonics without expanding the filter dimensions which is very important to preserve a small size for the filter. The first undesirable harmonic that resides inside the second passband of the filter is cleaned without affecting the passband response; furthermore the other neighboring harmonics outside the passbands are also removed. The achieved overall out-of-band attenuations are better than 20dB. The filter is designed to work at WLAN frequencies and its size is 25.8×22 mm². A prototype is fabricated and the achieved overall practical measurements are in good agreement with the simulations and validate the design.

***Keywords -*** Dual band Filter, Microstrip resonator, harmonic frequencies, Open stub, WLAN.

## I. INTRODUCTION

Recent radio-systems have boosted sever requirements for radio signal processing. The most important criteria are the selectivity and the in/out-of-band signal levels. Moreover, the growing demand for the emerged radio devices, such as the mobile phones, has lifted the need to lower more the production cost to face the commercial competitiveness. Under this emerging needs, radio frequency (RF) filters are being developed using particularly the cheap Microstrip technology for its good compromise between easy fabrication, cost and performances. However, a conventional Microstrip resonator used in filters generates undesirable harmonic frequencies at each multiple of its resonant frequency [1], [2]. The filter's in-band and out-of-band performances are consequently affected by these harmonics. One of the solutions is to make the harmonics generated far from the filter's passbands by employing the stepped impedance resonators (SIRs) [3], [4].

Another solution is to directly suppress the harmonics from the filter response using diverse design techniques. In [5]-[10] specified coupling scheme is used, in [11] source-load coupling and hook-shape feed lines are used to improve the out-of-band rejection. In [12], [13] defected ground structure DGS is used for harmonics suppression, and other techniques in [14], [15].

In this article, a dual-band bandpass filter (DB-BPF) is designed and the undesired harmonics are suppressed by taking advantage from the used feeding lines in the structure. This allowed cleaning the harmonics without size expansion. The out of band is also improved and the filter is designed to work at WLAN frequencies.

## II. DESIGN METHOD AND FILTER DEVELOPMENT

Two half wavelength open lines resonators are used to generate two passbands and they are coupled with pairs of source loaded stubs to directly implement the design idea.

### *A) Main Design Idea*

Theoretically, it is known that an open stub placed on a transmission line, like presented in Fig.1, rejects its resonant frequency and works as a simple band stop filter (BSF) [16]. By comparison to bandpass filters (BPF), the feeding lines that are employed for signal transfer are in fact open stubs and they can be used to reject the undesired frequencies.

In this design, the feeding stubs are set appropriately to remove the harmonics and improve the out-of-band rejection.

The length $l_{ST}$ of a Microstrip open stub is corresponding to the quarter wavelength of its resonant frequency $f_{ST}$. As such $l_{ST} = \lambda_{ST}/4$ and its resonant frequency is determined by (1) [17].

$$f_{ST} = \frac{c}{4\, l_{ST} \sqrt{\varepsilon_{eff}}} \qquad (1)$$

Where: $c$ is the velocity of light in space and $\sqrt{\varepsilon_{eff}}$ is the effective dielectric constant of the used Microstrip substrate.

When employing more than just one stub then, the employed open stubs need to be separated properly using immittance inverters like in Fig.1 where the quarter wavelength line is acting as an impedance inverter.

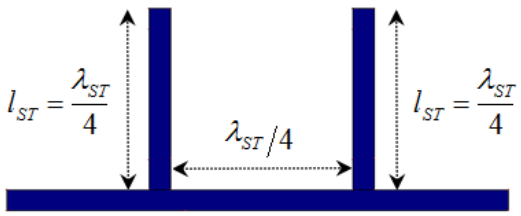



**Fig. 1.** Layout of a typical BSF using quarter-wavelength open-stubs.

### *B) Application to Filter Design*

The design is arranged to use open half-wavelength lines as resonators to generate the desired transmission poles. Afterwards, the desired attenuations are produced using the previously described open stub technique.

The length $l_R$ of an open line is equal to the half wavelength of its resonant frequency $f_R$ as such $l_R = \lambda_R/2$ and its resonant frequency is determined by (2) [17].

$$f_R = \frac{c}{2\, l_R \sqrt{\varepsilon_{eff}}} \qquad (2)$$

To create two passbands, two pairs of coupled open lines are employed to resonate at 2.4GHz and 5.7GHz. Each pair of the resonators is coupled by a pair of source loaded open stubs to feed the signal transfer at their resonances. The second pair of source loaded stubs resonates with the first harmonic of the first passband resonance to introduce the desired attenuation on the harmonic without affecting the overall size.

The used open stubs generate rejection harmonics at every odd number of their fundamental stopband resonance like it is demonstrated in Fig.2 which represents the simulation results of the BSF of Fig.1 resonating at 1GHz. This features is used to suppress the passband harmonics.

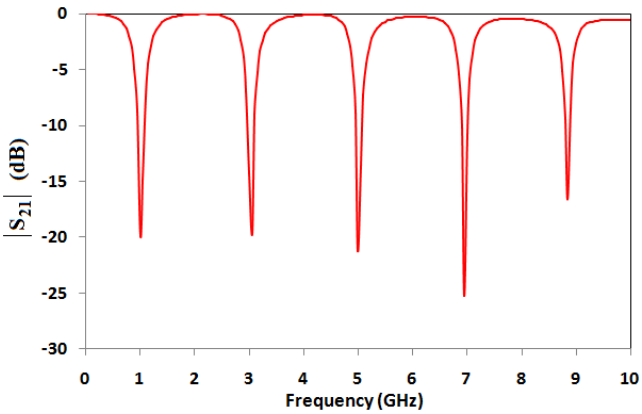
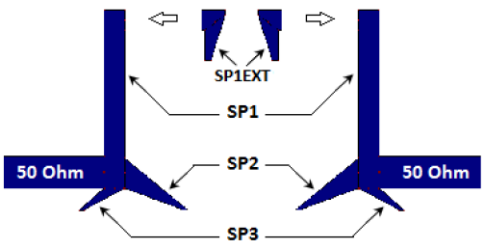


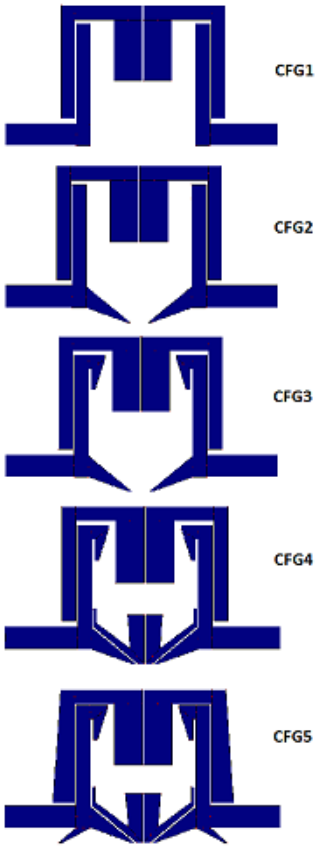

**Fig. 2.** Simulated response of an open stub BSF at 1GHz.

So, the first pair named SP1 as depicted in Fig. 3(a) is coupled with the twin 2.4GHz resonators and the second pair named SP2 is coupled with the twin 5.7 GHz resonators. The resulted structure is shown in Fig.4 where the dimensions are all in millimeters and all the coupling gabs are equal to 0.2 mm. The design is made on PCB FR4 substrate with 4.3 relative dielectric constant, 0.017 loss tangents and 1.62 mm substrate thickness. The overall size of the design is 25.8×22 mm².

Fig. 3b represents the design steps from CFG1 to CFG5 to figure out how the desired attenuations are introduced in each step of the design up to the final achieved structure.




(a)




(b)

**Fig.3.** (a) Presentation of the source loaded stubs.
(b) Configuration of the design steps.

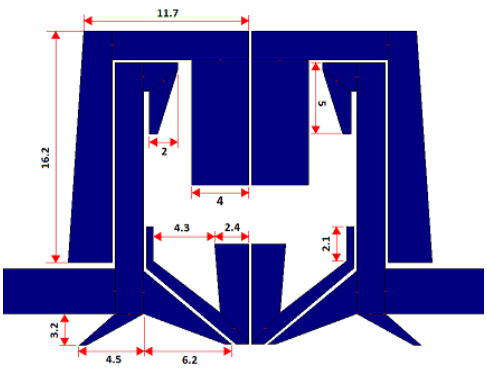
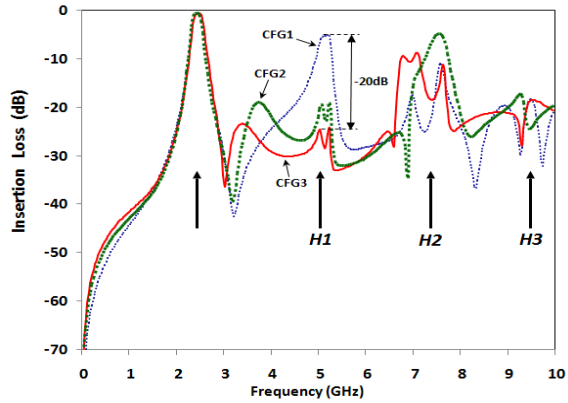


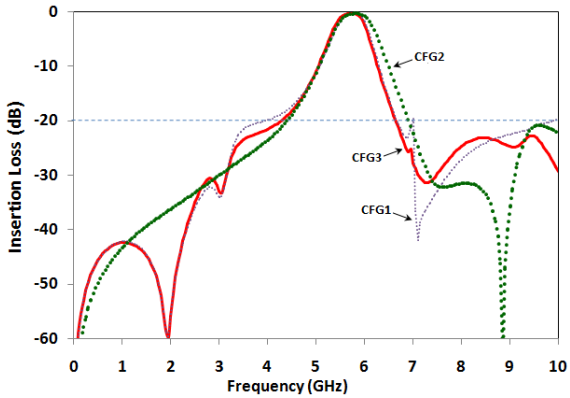

**Fig. 4.** The proposed DB-BPF with its dimensions in millimeters.

The generated stopband harmonics are used to suppress the passband harmonics as presented by H1, H2 and H3 in Fig. 5(a),. The use of the existing feeding stubs is very useful to preserve small filter size. The harmonics H1and H3 are suppressed by an attenuation of about 20dB and 15dB respectively as indicated in Fig. 5(a). The harmonic H2 is suppressed by the attenuation pole generated at the upper edge of the second passband as presented in Fig. 5(b).

In the results of Fig.7, both twin resonators are implemented showing no effect on the second passband signal transfer. Furthermore, the figured out-of-band attenuations are improved by adding the last couple of stubs SP3 to the structure which introduces an additional 10dB attenuation at around 10 GHz. At the same time, the shapes of the resonators are slightly customized to introduce some minor improvement in the upper out-of-band frequencies.

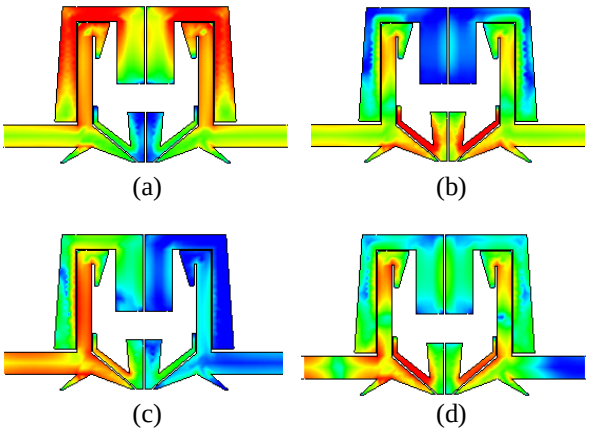



(a)




(b)

**Fig. 5.** The simulated filter response:
(a) for the first passband, (b) the second passband.



(a) (b)

(c) (d)

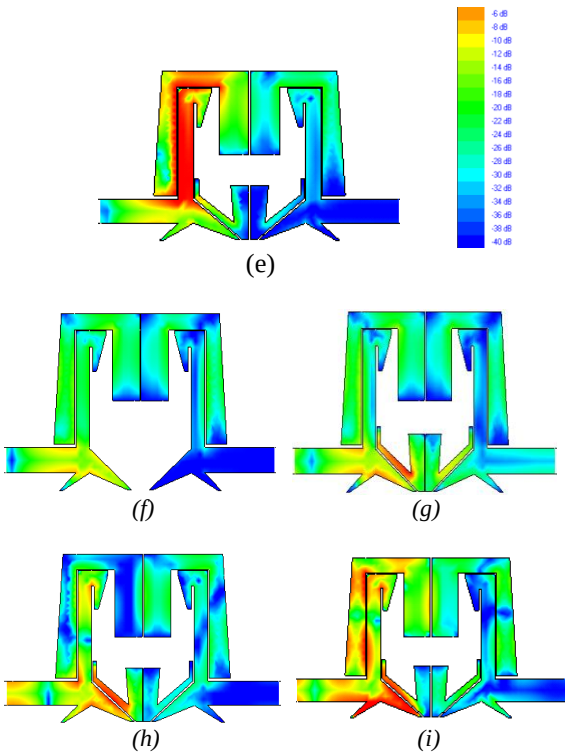



**Fig. 6.** Distribution Current in the proposed filter at: (a) 2.4 GHz, (b) 5.7 GHz, (c) 3.45 GHz, (d) 6.9 GHz, (e) 3.2GHz, (f) and (g) at 4.8GHz, (h) at 7.2GHz and (i) at 9.6GHz

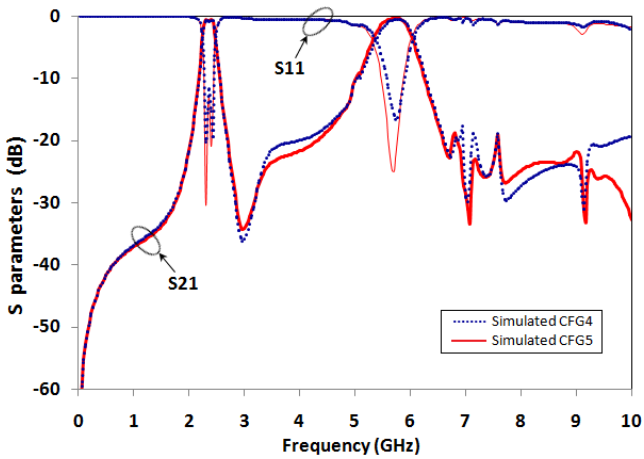



**Fig. 7.** The simulated filter response with both passband.

Fig. 6 shows the current distribution in the structure at some critical frequency points in both the passband and out-of-band regions to verify the filtering function of the filter.

Fig. 6(f) shows very weak current of the 4.8 GHz harmonic; however in Fig. 6(g) the increased small flowing current at this same frequency is due to the insertion of the second passband resonators. Fig. 6(h) and Fig. 6(i) show very weak flowing current at the 7.2 GHz and 9.6 GHz harmonics.

All the presented simulations in this article are obtained using IE3D software that uses the method of moments (MOM) to perform the simulations.

## III. FABRICATION AND MEASUREMENT

The designed filter is fabricated using MITS precision milling machine and its photograph is presented in Fig.8. The measurements are performed using Rohde & Schwarz network analyzer and they are presented together with the simulation in Fig.9. The measured out-of-band attenuation levels are greater than 20dB and the measured overall response is in good agreement with the simulations. The resulted narrow bandwidth of the first passband is due to the use of low impedance lines for the 2.4GHz resonators resulting in a relatively high quality factor of the passband and conversely, the resulted wide bandwidth of the second passband is due to the use of high impedance lines for the 5.7GHz resonators resulting in a relatively low quality factor of the passband. Table 1 summarizes the achieved passbands characteristics.

**Fig. 8.** Photograph showing the fabricated filter.

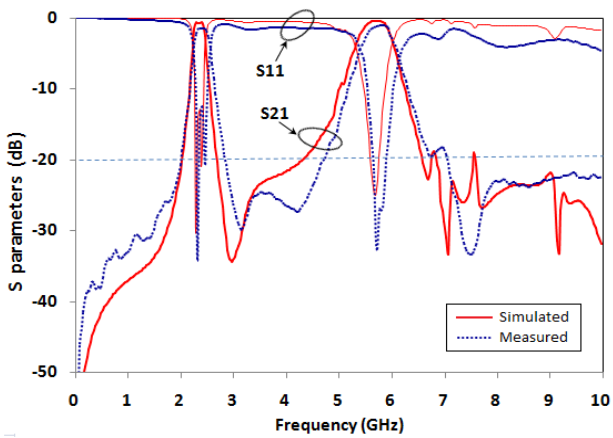



**Fig. 9.** Simulated and measured responses of the proposed filter.

**Table 1.** Summary of the measured and simulated results.

| ***Design parameter*** | ***1st Band*** | | ***2nd Band*** | |
|---|---|---|---|---|
| | *simulated* | *measured* | *simulated* | *measured* |
| Center frequency $f_0(GHz)$ | 2.40 | 2.44 | 5.68 | 5.75 |
| Insertion loss at $f_0\ (dB)$ | 0.66 | 1.48 | 0.41 | 1.06 |
| Return loss at $f_0\ (dB)$ | 22 | 21 | 27 | 30 |
| 3dB bandwidth *(GHz)* | 0.23 | 0.30 | 0.63 | 0.60 |
| Fractional Bandwidth *(%)* | 9.60 | 12.29 | 11.09 | 10.43 |
| Quality factor | 10.43 | 8.13 | 9.01 | 9.58 |

## IV. CONCLUSION

A harmonics-suppression design is efficiently developed in this article using source loaded stubs. The design is made to develop a novel dual-band band pass filter whereas by adjusting the length of the integrated source loaded stubs, the generated harmonics that follow the passband resonance are suppressed. Particularly, the harmonic that resides inside the second passband is removed without distorting the passband. The filter's out-of-band rejection are consequently improved where the overall achieved out-of-band attenuation levels are better than 20dB. The measurements on the fabricated prototype showed good agreement with the simulations and proved the design purpose.

## V. ACKNOWLEDGMENTS

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