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# A Microstrip Quasi-Elliptic Bandpass Filter implemented using stub loaded resonators

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***Abstract*—A highly selective microstrip bandpass filter consists of electromagnetically coupled U-shaped open ring resonators is presented in this paper. The resonators are directly loaded with open-circuited inductive stubs and the feed-lines are interdigital coupled to the resonators. The proposed filter structure provides sufficient degree of freedom to control the centre frequency, fractional bandwidth and transmission zeros. It is shown that the fractional bandwidth of this filter can be adjusted from 15.3 to 9.8% and center frequency from 3.3-3.8 GHz with negligible effect on the stopband characteristics. In addition, the transmission zero $f_{tz2}$ can be relocated from 3.8 to 4.4 GHz and $f_{tz1}$ from 3.1 to 2.7 GHz independently. Filter structure is simple, easy and economical to manufacture as fabricated on a conventional dielectric substrate using standard PCB technology. It is found that the simulation and measured results are in good correlation. The sharp selectivity, low losses and wide stop band characteristics make the proposed filter applicable in cognitive radio systems and in high interference environments.**

***Keywords— Transmission zero, bandpass filter, ring resonator, fractional bandwidth, PCB technology***

## I. INTRODUCTION

The ever-growing demand in the use of the radio frequency (RF) spectrum for new applications has resulted in the need for high performance microwave filters with strict requirements on both in-band and out-of-band characteristics. High selectivity, high rejection, low loss and extremely wide spurious-free performance microwave filters are required for both transmitter and receiver channels. In addition, these devices need to be highly compact, easy to integrate within transceivers and should be amenable to low-cost manufacturing. Bandpass filters with high selectivity, wide stopband, low losses play a vital role in avoiding RF electromagnetic interference from the adjacent systems. More the number of resonators in the filter structure, the higher will be the filter selectivity but increases passband loss [1]. High selectivity, compact and miniature structure size can be achieved by elliptic or quasi-elliptic function bandpass filters. Transmission zeros near the passband edges can enhance the out-of-band rejection level over a wide frequency range with a reasonable out-of-band attenuation level. However, the insertion of transmission zeroes could complex the filter design.

Various techniques are being used to realize elliptic or quasi-elliptic function bandpass filters with tunable characteristics in the literature [2]. Wide Stopband achieved by cascading together complementary split-ring resonators or coplanar waveguide structure at the expense of large filter size [3-5]. Theoretical analysis in [6] shows a three-line coupled microstrip structure that can support three quasi-TEM or dominant modes, where each mode has its modal phase constant, Eigen voltage vector, and characteristic impedance. Compared with the traditional coupled-line design, the three-line section has two important advantages. One is that the tight line spacing for designing wideband bandpass filters can be greatly relaxed, and the other is that the stopband characteristics of the filter can be improved. In [7] a highly selective square loop dual-mode bandpass filter based on capacitive stepped-impendence resonator is realized with reduced circuit footprint. Over the recent years, researchers have proposed many techniques to realize highly selective bandpass filters with wide stopband response such as corrugated structure [8], substrate suspension [9], capacitive loaded dual-mode resonator [10], wiggly coupling [11], over coupled end stages [12], capacitive compensation [13] and defected ground structure [14].

In this paper, a high selectivity bandpass filter with desired characteristics of quasi-elliptical response, low losses and wide stopband with high rejection level is presented. The filter design is based on electromagnetically coupled U-shaped open-loop resonators where each resonator is directly loaded with an open-circuited inductive stub, and the feed-lines are interdigital coupled to the resonators to reduce the in-band insertion loss and realize a wide stopband with high rejection level above and below the passband. The resonators are loaded with open-circuited inductive stubs to suppress the unwanted harmonics near the passband edges. Interdigital feed-lines create a pair of transmission zeros above and below the passband that provide a sharper roll-off and steep skirt selectivity with high rejection over a wide frequency span. The frequency response of the fabricated filter shows the desired passband characteristics and is in good agreement with the simulated ones.

## II. STUB LOADED RESONATOR ANALYSIS

Fig. 1 shows the proposed stub loaded resonator to analyze its effect on the filter response, the SLR comprising of an open-circuit stub and a traditional resonator. The open-circuit stub is tapped at the mid-point of the traditional resonator where $Z_1$, $\theta_1$ and $Z_2$, $\theta_2$ are the characteristic impedance and lengths of the series and shunt connected resonators, respectively.

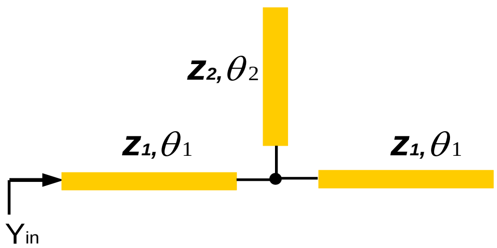



Fig. 1. Structure of proposed stub loaded resonator.

The resulting input impedance is

$$Z_{in} = -jZ_1\left(\frac{Z_2 - (Z_2 tan\theta_1 + Z_1 tan\theta_2)tan\theta_1}{2Z_2 tan\theta_1 + Z_1 tan\theta_1 tan\theta_2}\right) \quad (1)$$

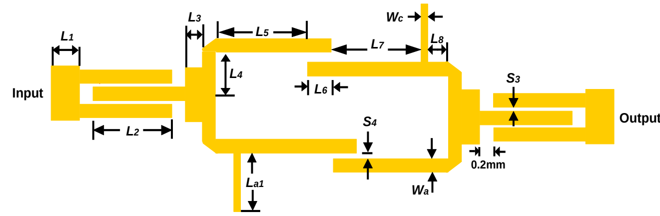
For resonance condition, $Y_{in} = 0$, which is obtained as

$$cot\theta_1 tan\theta_2 = \frac{-2Z_2}{Z_1} \quad (2)$$

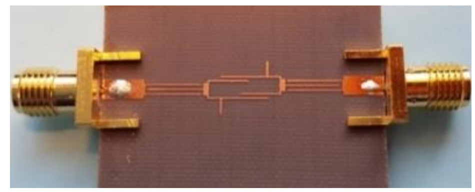
From equation (2), it is evident that the open stub not only suppresses the unwanted harmonics near the passband edges but can control the bandpass filter response by changing the length or the width of the open stub.

## III. BPF CONFIGURATION AND RESULTS

Based on the stub loaded resonator structure shown in Fig. 2, a quasi-elliptic function highly selective bandpass filter is designed. It comprises of coupled open-loop resonators, where each resonator is directly loaded with an open-circuited. The wideband bandpass filter is constructed on a dielectric substrate Arlon CuClad217LX with h = 0.794 mm, $\varepsilon_r$ = 2.17, t = 35 µm, and tanδ= 0.0009. The physical dimensions are optimized using ADS™ software, which are: Wa = 0.2 mm, Wc = 0.2 mm, $W_{a1}$ = 0.2 mm, La = 0.79 mm, $L_{b1}$ = 2 mm, $L_{b2}$ = 1 mm, $L_1$ = 16.436 mm, $L_2$ = 0.9 mm, $L_3$ = 11.89 mm, $L_4$ = 2.84 mm, $L_5$ = 7.46 mm, $L_6$ = 7.4 mm, $S_1$ = 0.56 mm, and $S_2$ = 0.314 mm. The simulated filter response shown in Fig. 3 has a center frequency 3.3 GHz with insertion-loss of 1.4 dB, return-loss better than 11 dB, and 3-dB fractional bandwidth of 15.3%. The compact filter exhibits a sharp 3-dB skirt with a wide stopband with stopband rejection >-20 dB between 1 to 2.9 GHz and 3.7 to 5.8 GHz.



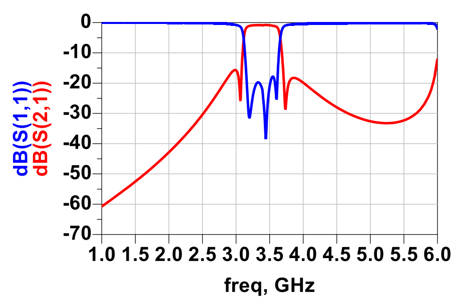

(a)



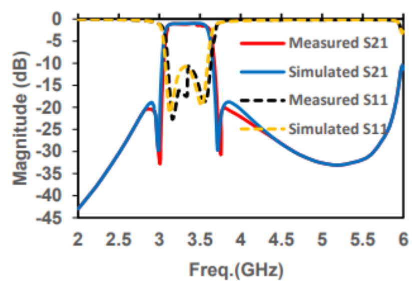
(b)

Fig. 2. (a) Layout of three-finger interdigital coupled feed-line bandpass filter (b) photograph of the implemented filter.

The filter's out-of-band rejection without the loaded resonators was about -15 dB, as shown in Fig. 3(a). The out-of-band rejection level with loaded resonators is > -19 dB from 1 to 3 GHz and > -19 dB up to 5.8 GHz, as depicted in Fig. 3(b).




(a)




(b)

Fig. 3. (a) Simulated S-parameter response without stub loaded resonators (b) Measured and simulated S-parameter response

Fig. 4 shows as the stub length ($L_{a1}$) varies from 0.864 to 4.454 mm, lower transmission zero $f_{tz1}$ shifts downward in frequency significantly from 2.7 to 3.0 GHz; However, the upper transmission zero remains virtually constant and out-of-band rejection improves from -19 dB to -28 dB. Fig. 5 shows as the length $l_5$ varies from 11.4 mm to 9.4 mm, the transmission zero $f_{tz2}$ slides downward in frequency from 3.7 GHz to 4.0 GHz and lower transmission zero $f_{tz1}$ remains fixed. However, out-of-band performance on the upper side of the passband varies from -17 dB to -23 dB but remains unchanged on the lower side of the passband and resulted a narrow passband filter with 3-dB fractional bandwidth of 9.8%.

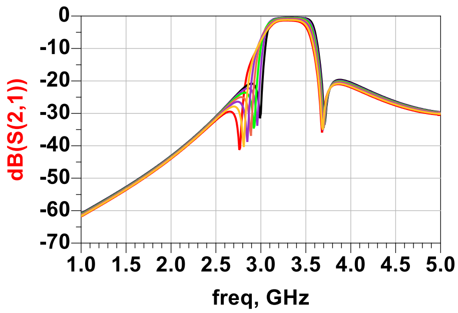



Fig. 4. Effect of open stub length $L_{a1}$ on Frequency response of the filter

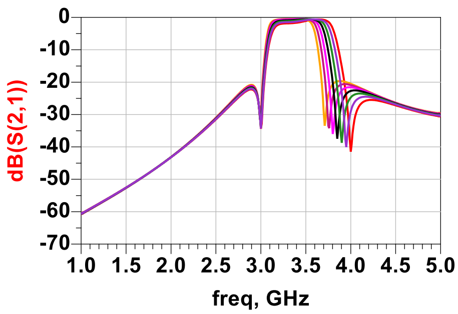



Fig. 5. Effect of length $l_5$ on Frequency response of the filter

Fig. 6 shows the effect of varying the length ($l_6$) on the filter's performance. Passband center frequency and transmission zeros shifts downward synchronously as the length is increased from 2.84 to 3.84 mm without any degradation in the passband shape. Moreover, insertion loss varies between 0.7 to 0.98 dB and return loss between -8 to -28 dB during the entire variation. In addition to that, the 3-dB fractional bandwidth of the filter can be controlled from 15.3% to 9.8% by manipulating its geometric parameters as shown in Fig. 7.

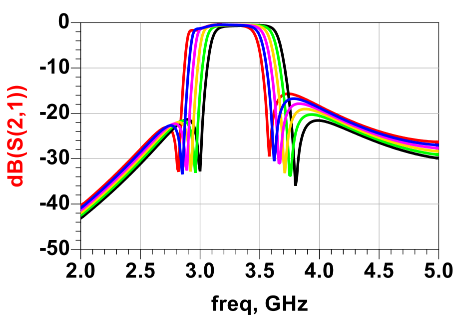
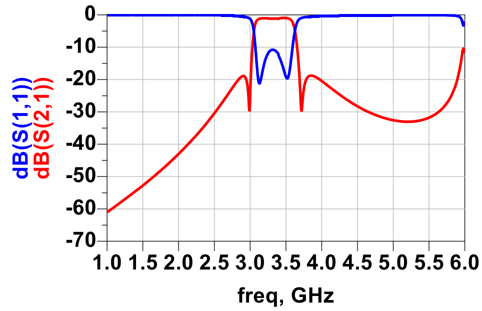
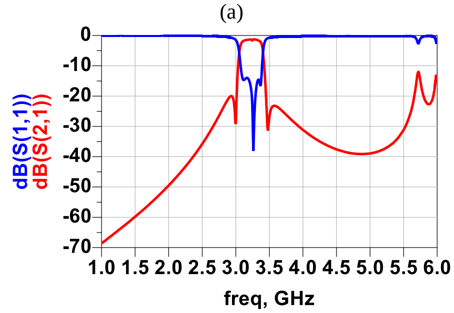



Fig. 6. Effect of resonator length $l_6$ on Frequency response of the filter




(a)




(b)

Fig. 7. Transmission and reflection-coefficient response of (a) Wideband bandpass Filter (b) Narrowest bandpass Filter.

The proposed planar microwave filter is a compact design with desired characteristics of relative low insertion and return-loss, sharp roll-off skirts, high selectivity and a wide stopband with a high rejection level. As the proposed filter is implemented on a conventional lower dielectric substrate without using the defective ground plane for high rejection level which makes filter structure simple, low cost and easy to manufacture. Filters with these characteristics are normally fabricated using high-temperature superconducting (HTS) materials.

## IV. CONCLUSION

The proposed microstrip filter structure is simple and economical to manufacture as fabricated on a conventional dielectric substrate using standard PCB technology. The filter is shown to adjust the bandwidth between (15.3-9.8) % and center frequency from 3.3–3.8 GHz without degradation in passband shape. Besides that, insertion loss varies from 1.4 to 2.3 dB and the return loss from -8 to -28 dB during the entire controlling range with better out-of-band rejection level. Transmission zeros can be adjusted independently over a wide frequency range, resulting in significant improvement in 3-dB fractional bandwidth without affecting the overall filter performance. The bandpass filter with described characteristics finds applications in cognitive radio and 5G communications systems.

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