High Selectivity Microstrip Bandpass Filter Integrate with Ring Resonator Bandstop Filter

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***Abstract*— An integrated high selectivity microstrip wideband bandpass filter with ring resonator bandstop filter is presented in this paper. The bandpass filter consists of of 6th λ/4 short circuited stubs and two-sections of open circuited stub at one end of the element. The integration with bandstop filter is realized using ring resonator. The experimental result shows that the bandwidth of the wideband bandpass filter is between 2.9 GHz – 5.8 GHz. The bandstop filter produced high selectivity and attenuation at resonant frequency of 5.05 GHz and *Q*-factor of 252.2. This type of filter is suitable for applications such as the multi-service and multiband communication system in order to discriminate the undesired signals.**

***Index Terms*— Bandpass Filter (BPF); Notch Response; Ring Resonator; Tunable Filter.**

I. INTRODUCTION

In modern wireless communication system, the communication industries are highly demanded to produce high selectivity, better insertion loss and compact structure [1]-[5]. In wideband frequency spectrum, interference with unwanted signals is one of the key issues for wideband technology. The solution to mitigate this current issue with designing a notch response to eliminate the undesired signals inside the wideband response such as IEEE 802.11a WLAN [6]-[10]. The transmission zero using parallel-coupled line is produced in [1]. However, this method results in a large size due to the multi-stage coupled-line structure and the selectivity need to be further improved. The wideband bandpass filter presented in [3] is designed based on wave cancellation method with cross-shaped coupled lines. The main limitation of the structure is that it involves separation cross sectional and the response is disturb the out of passband. In [4], the bandpass filter was designed using short circuited stubs. However, the proposed filter has poor selectivity at lower passband. In [6]-[7], a wideband bandpass filter with transmission zeros in the notched band is produced. The filter is designed using two pairs of U-shaped slot-lines on the bottom layer and hollow microstrip resonator. But, the response of return loss is disturbing the overall performance.

These attempts to develop a new technique for ring resonator with bandstop response implementation in wideband bandpass filter in order to produce bandpass and bandstop response simultaneously. This structure microstrip bandpass filter provides a highly selectivity response from 3 to 6 GHz with insertion loss is better than 0.3 dB at the passband and reflection coefficient being better than 15 dB. The ring resonator bandstop filter was designed at a frequency of 5.05 GHz with an attenuation of greater than 20 dB and fractional bandwidth (FBW=1.0%). The integrated structure was designed based on microstrip structure in order to produce good selectivity, low loss and compact structure.

II. DESIGN THEORY OF BANDPASS FILTER

The proposed physical layout is shown in Figure 1. The structure consists of 6th λ/4 short circuited stubs and two-sections of open circuited stub at one end of the element. All the transmission lines are of commensurate length. To reduce the size of the bandpass filter, the λ/4 connecting lines have been bent with 90 degree angle in such a way to avoid connections between end-to-end stubs or junctions.

The equivalent circuited of Figure 1 can be described and shown in Figure 2. The fundamental resonant condition of the short circuited stub bandpass filter is described in [11]. A short circuited stub produces a pair of transmission zeros at f=0 and $f=2f_0$, here f_0 is the mid-band frequency of the filter. By replacing the first short circuited stub with two sections of open circuited stub, the transmission zeros can be obtained at the desired frequency.

Z_1 is the first short circuited stub as shown in [12] is then replaced by a shunt half-wavelength, open circuited stub having an inner quarter wavelength portion with characteristic impedance:

$$Z_1 = \frac{Z_a^2}{Z_a + Z_b} \qquad (1)$$

Each two section open circuited stub can produce a pair of transmission zeros, one in the lower stopband and the other in the upper stopband.

$$Z_b = Z_a \tan^2 \theta_1 \qquad (2)$$

Substitute (2) into (1)

$$Z_a = (1+\tan^2 \theta_1) Z_1 \qquad (3)$$

The simulation and optimization result is presented in Figure 3. As shown in the EM simulation results, the filter exhibited a pair of transmission zeros in each of the stopbands around the wideband passband. As a result, the response shows extremely high selectivity with introducing new methods of two sections open of circuited stub.

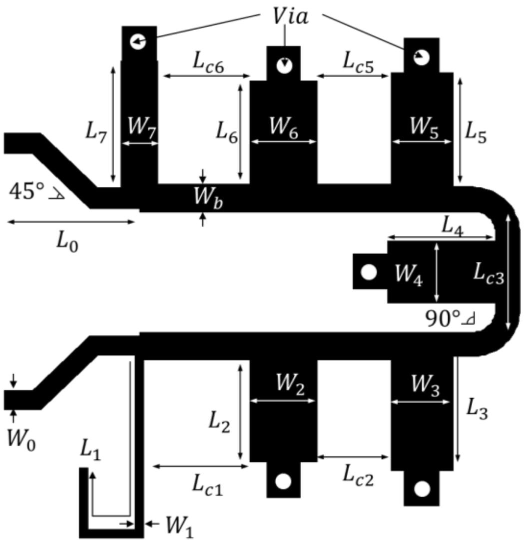


Figure 1: Proposed physical layout for 7th order short circuited stubs bandpass filter by replacing the first short circuited stub with two sections of open circuited stub. *W_0 = 1.5, W_1 = 0.7, W_2 = W_6 = 4.9, W_3 = W_5 = 4.5, W_4 = 4.5, W_7 = 2.7 W_b = 2.05, L_0 = 8.4, L_1 = 20.1, L_2 = L_6 =7.35, L_3 = L5 = 8.2, L_4 =7.7, L_7 = 8.8, L_{c1} = 7.56, L_{c2} = L_{c5} = 5.2, L_{c2} = 8.3, L_{c6} = 6.55, via =1.0. Unit in mm.*

III. RING RESONATOR BANDSTOP FILTER

The technique of ring resonator bandstop filter is depicted in Figure 4 (a). The total circumference of the ring is equal to one wavelength at the operating point f_0. The key point of the ring resonator topology is that both the series and the parallel resonances of the loading circuit are used to achieve bandstop characteristics. This topology are manipulated from the slow-wave bandpass filter where the dual-mode is composed to generate modes or splitting resonant frequency that can be excited by perturbing stub at 135°. This structure will be designed according to its dimension and will produce the notch response at 5.2 GHz. The dimensions of ring resonator are as follows: W_{b1}=1.2, L_{b1}=9.6, L_{b2}=7, g=0.3. Unit in mm. As depicted in Figure 4 (b), the resonant frequency at 5.05 GHz with attenuation is better than 20 dB is produced.

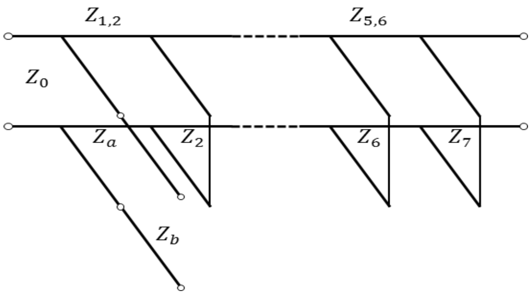


Figure 2: Proposed equivalent circuit for the physical structure of Figure 1 consisting short circuited stubs by replacing the first short circuited stub with two sections of open circuited stub

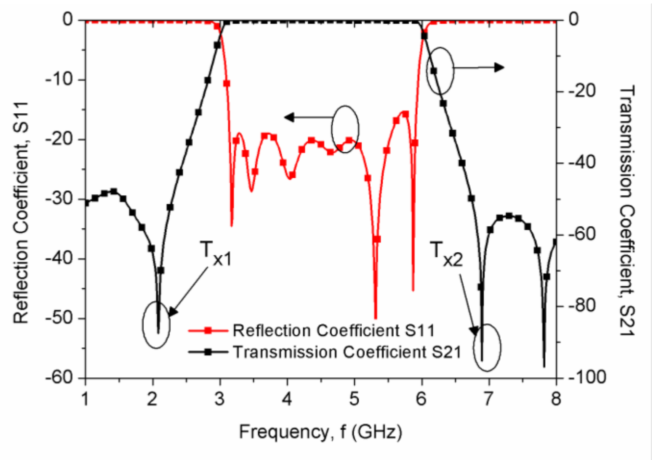
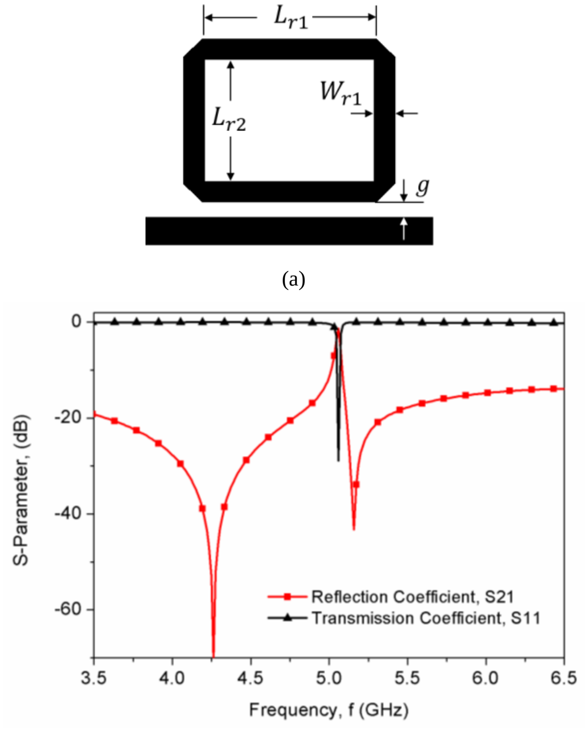


Figure 3: Simulated response of wideband bandpass filter with high selectivity transmission zeros



(a)

(b)

Figure 4: (a) Structure of ring resonator and (b) Simulated result of ring resonator

The coupling structure as shown in Figure 5(a) includes the transmission coupling line, the square ring resonator as a main component and coupling gap. This structure can be serve as symmetrical coupled lines. The coupling gap between symmetrical coupled lines can be modeled as a capacitive L-network as shown in Figure 5(b). The gap capacitance per unit length can be representing as C_g while C_p is the capacitance per unit length between the strip and ground plane. These capacitances, C_g and C_p, can be found from the even- and odd-mode capacitances of symmetrical coupled lines. The equivalent circuit of the capacitive network is shown in Figure 5(c) where the input impedance of the ring resonator Z_r can be obtained from [11]. The input impedance Z_{r1} looks into the line-to-ring coupling structure toward the ring resonator. The input impedance Z_{in3} is

$$Z_{in3} = \frac{Z_{r1} + jZ_0 \tan(\beta l_b)}{Z_0 + jZ_{r1} \tan(\beta l_b)} \tag{4}$$

where

$$Z_{r1} = (Z_r + Z_g) \parallel Z_p,$$
$$Z_g = \frac{1}{j\omega C_g \Delta l}, Z_p = \frac{1}{j\omega C_p \Delta l} \tag{5}$$

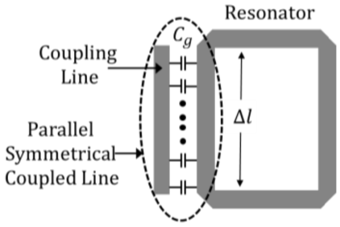
and ω is the angular frequency. The parallel (f_p) and series (f_s) resonances of the ring resonator can be obtained by setting

$$\left|Y_{in3}\right| = \left|1/Z_{in3}\right| \cong 0 \text{ and } \left|Z_{in3}\right| \cong 0 \tag{6}$$

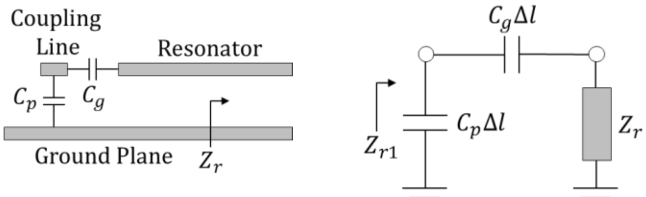
In Figure 6, the parametric analysis of transmission coefficient S_{21} was performed by varying g with fixed value of width and length. The result showed the bandwidth decrease when decreasing the gap separation. In additional, the quality factor can be calculate as:

$$Q_u = \frac{2\omega_0}{\Delta\omega} \tag{7}$$

where ω_0 is the resonant frequency and $\Delta\omega$ is the bandwidth of the resonant frequency.



(a) Top View



(b) Side View

(c) equivalent circuit

Figure 5: Line-to-ring coupling structure (a) top view, (b) side view and (c) equivalent circuit.

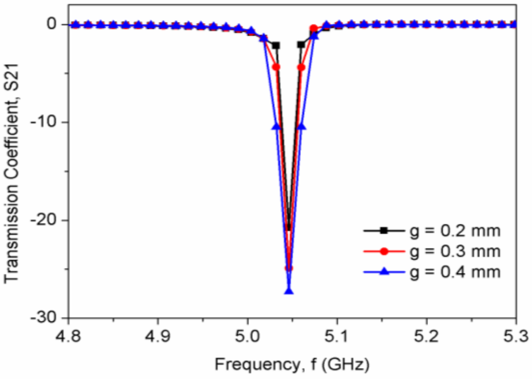


Figure 6: Effect of varying the gap of the coupled lines in ring resonator

IV. BANDPASS FILTER WITH RING RESONATOR BANDSTOP FILTER

The ring resonator bandstop filter was then integrated with high selectivity bandpass filter to produce bandpass and bandstop responses simultaneously. The ring resonator was placed at connecting line, L_{c3} short circuit stub ith the specific dimension. Figure 7 shows the structure of bandpass filter with ring resonator bandstop filter. In Figure 8, the simulated result was shown with high selectivity and an FBW of 66.67%. The bandstop response was produced at 5.05 GHz with attenuation greater than 20 dB. The filter is then manufactured using Roger Duroid RO4350B with dielectric constant of ε_r=3.48 and thickness of h=0.508 mm. The photograph of wideband bandpass filter with tunable notch response is shown in Figure 9. The overall dimension of the filter is 48 mm x 40 mm and it is measured by Vector Network Analyzer (VNA).

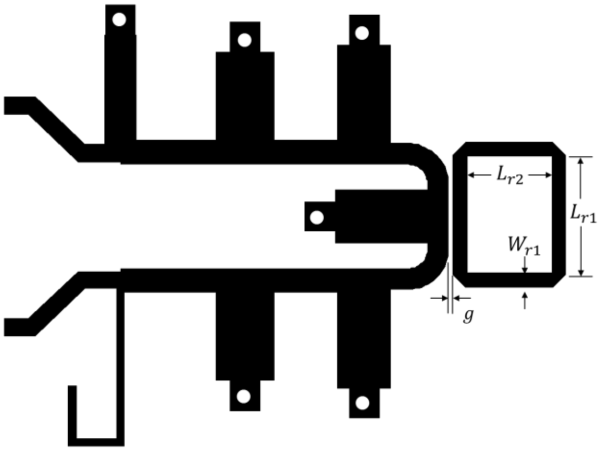


Figure 7: Simulated response of integrated wideband bandpass filter with ring resonator

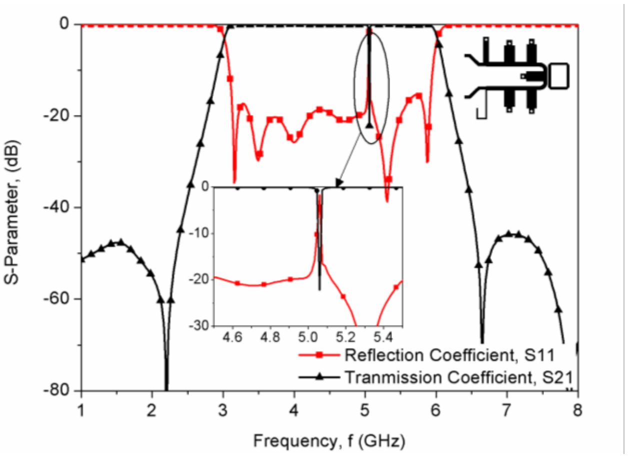


Figure 8: Physical layout of the proposed wideband bandpass filter with tunable notch response. The dimensions of tunable ring resonator are as follows: L_{N1}=13.5mm, W_{N1}=0.35mm and W_{N2}=0.35mm

The comparison of simulated and measured of the integrated structure is shown in Figure 10. The filter exhibit a highly selectivity wideband bandpass response with a fractional bandwidth of about 65% at a centre frequency of 4.4 GHz. The measured transmission and reflection coefficient were found to be less than 0.3 dB and better than 16 dB, respectively. The bandstop response was measured at 5.03 GHz with a fractional bandwidth of about 1.2% and *Q*-fctor of 252.2. The attenuation at the bandstop response was better than 20 dB. The overall measured results were in good agreement with the simulations.

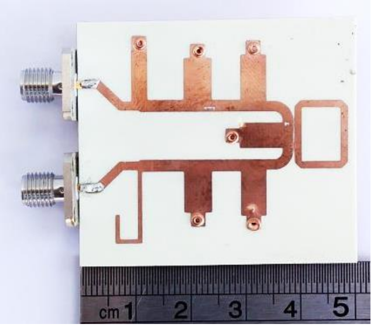


Figure 9: Photograph of wideband bandpass filter with tunable notch response

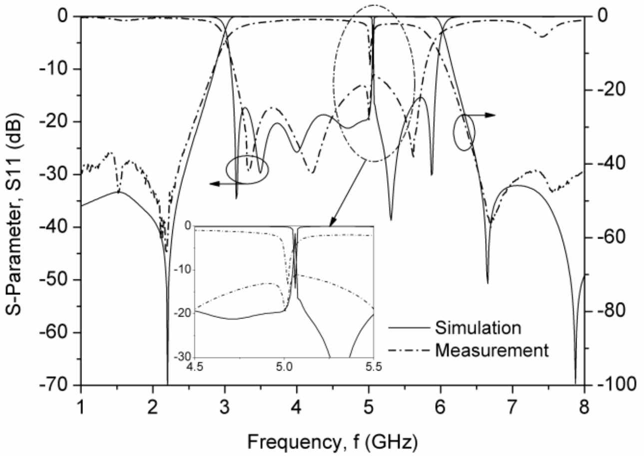


Figure 10: Measured S-Parameter of the wideband bandpass filter with tunable notch response

V. CONCLUSION

A new structure for high selectivity wideband bandpass filter with ring resonator bandstop filter has been successfully designed and measured. Two transmission zeros have been successfully introduced in the lower and higher stopband by replacing two sections of open circuited stub. A bandstop filter is realized using ring resonator with attenuation better than 20 dB have been achieved. The measured results are in good agreement with the simulations. This type of microwave filter is suitable for the multi-service and multiband communication system in order to eliminate the undesired signals within the passband response.

VI. ACKNOWLEDGMENT

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