Novel Compact Wideband Based On Square Ring Short Stub Loaded Resonator

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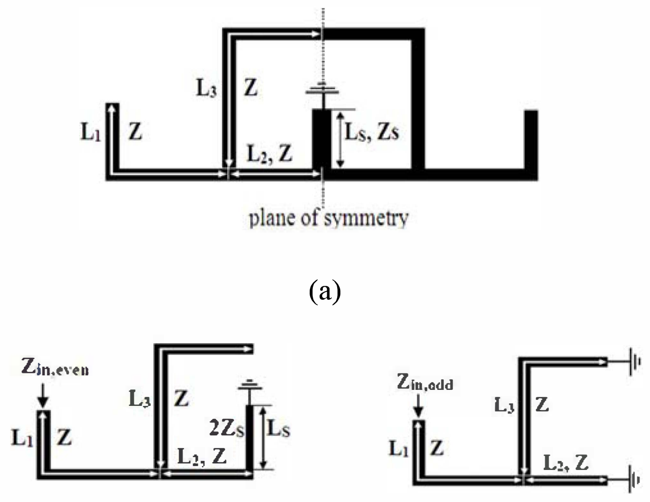
Abstract—**This letter presents a novel compact microstrip wideband bandpass filter (BPF) based on square ring short-stub loaded resonator (SRSLR). The SRSLR is able to generate three resonances over the wide frequency band, while the fourth resonance is far away. In this design, by tuning the lengths of square ring and short-stub, the filter has an adjustable fractional bandwidth from 29.8 to 71.9%. Moreover, two transmission zeros are created to improve the filter selectivity. A prototype of wideband BPF with high performance is designed and fabricated for demonstration. Good agreement can be found between the measured and simulated results.**

***Index Terms*—Wideband bandpass filter, square ring short-stub loaded resonator, fractional bandwidth.**

I. INTRODUCTION

In recent years, wideband bandpass filters with compact size, low loss, flat group delay and high out-of-band selectivity are essential for the design of modern broadband wireless communication systems. The wideband bandpass filters can be realized on microstrip stepped-impedance resonator (SIR) [1, 2]. The wideband bandpass filter using the asymmetric SIR is proposed in [1], and an open stub connected with two section coupled transmission lines are used to design a wideband bandpass filter [2]. However, it is difficult to realize an adjustable fractional bandwidth. The ring resonator [3-5] was also used to design wideband bandpass filters. In [3], to achieve a higher out-of-band attenuation, the single square-ring resonators were cascaded for such purpose, but this filter has several drawbacks of large size and complexity in configuration. By using a ring resonator with open stubs [4] and open stepped-impedance stubs [5], a class of wideband bandpass filter with controllable bandwidth has been designed. However, due to the limited fabrication precision, it is very hard to realize the coupled lines with high impedance and tight coupling gap.



(a)

(b) (c)

Fig. 1 Layout of square ring short stub loaded resonators
(a) SRSLR
(b) Even-mode equivalent circuit
(c) Odd-mode equivalent circuit

In this letter, a novel compact wideband bandpass filter using a SRSLR is proposed. The fractional bandwidth of the bandpass filter can be conveniently controlled by adjusting the lengths of square ring and short-stub. The theoretical design, simulation and experimental results are given and discussed.

II. ANALYSIS AND DESIGN OF PROPOSED FILTER

A Characteristic of the Resonators

Figure 1(a) shows the layout of proposed SRSLR. It consists of two open folders, a square ring and a short-stub, where (L_1, Z), ($2(L_2 + L_3)$, Z) and (L_s, Z_s) are the lengths and

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the characteristic impedances of open folder, square ring and short-stub, respectively. The even- and odd-mode frequencies of resonator is analyzed by [8]. From the resonance condition (Y_{in} = 0), when the even-mode (Figure 1(b)) is excited, two resonant frequencies can be obtained as follows:

$$f_{even1} = \frac{c}{4(L_1+L_2+L_s)\sqrt{\varepsilon_e}} \tag{1}$$

$$f_{even2} = \frac{c}{2(L_1+L_3)\sqrt{\varepsilon_e}} \tag{2}$$

Where c is the light speed in free space, and ε_e denotes the effective dielectric constant of the substrate. For the odd-mode (Figure 1(c)), the resonant frequency can be obtained as:

$$f_{odd1} = \frac{c}{4(L_1+L_2)\sqrt{\varepsilon_e}} \tag{3}$$

Equation (1) is valid for the special case of Z = $2Z_s$. From (1)-(3), when $L_s > 0$ and $L_3 < L_1 + 2L_2$, we can obtain $f_{\text{even1}}(f_1) < f_{\text{odd1}}(f_2) < f_{\text{even2}}(f_3)$. Thus, the first three resonant frequencies of the SRSLR could be controlled by tuning L_1, L_2, L_3 and L_s.

B Wideband Filter Design

Based on the above analysis, the proposed new compact wideband BPF is designed on a substrate with ε_r = 4.4 and h = 0.8 mm. Figure 2 shows the layout of the wideband BPF using a SRSLR with two open folders forming a hairpin resonator to reduce the size of filter. In addition, to improve the filter selectivity, the coupling of I/O feeding structure [6], [7] is introduced to achieve two transmission zeros close to the passband. The simulated transmission response of this configuration is shown in Figure 3, where f_i (i = 1, 2, 3 and 4) corresponds to the ith resonant frequency of SRSLR and f_{z1} and f_{z2} are the frequency location of the transmission zeros. We can see that there are three resonances in the passband of the filter and two transmission zeros near the passband edges, while the fourth resonance is far. In this case, we can determine the initial values of the parameters according to the design specifications. Then, fine tuning is performed to achieve the desired frequency response. To obtain desired center frequency of passband at 2.3 GHz, the physical length L_1 and L_2 are chosen to be 16.5 mm, and 1.5 mm, respectively. Then the bandwidth of the wideband BPF may be controlled by adjusting the length of L_s and L_3. Figure 4 shows that the fractional bandwidth for the filter ranges from 29.8 to 71.9%

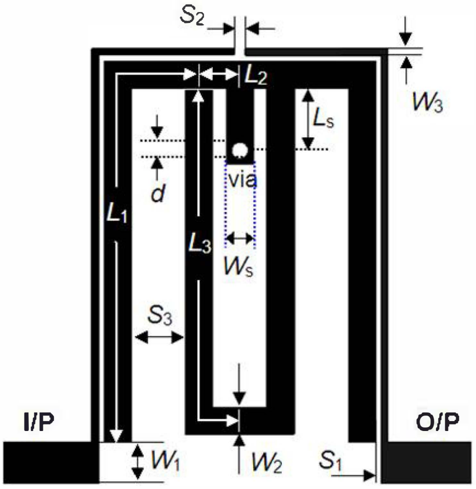

Fig. 2 Layout of proposed wideband filter

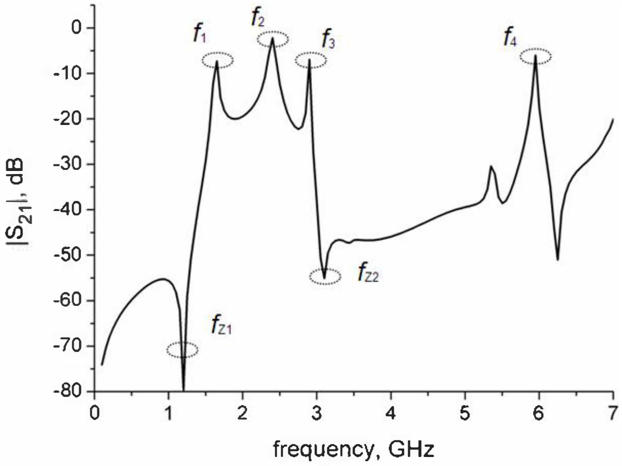

Fig. 3 Simulated frequency response $|S_{21}|$ of the wideband filter under the weak coupling

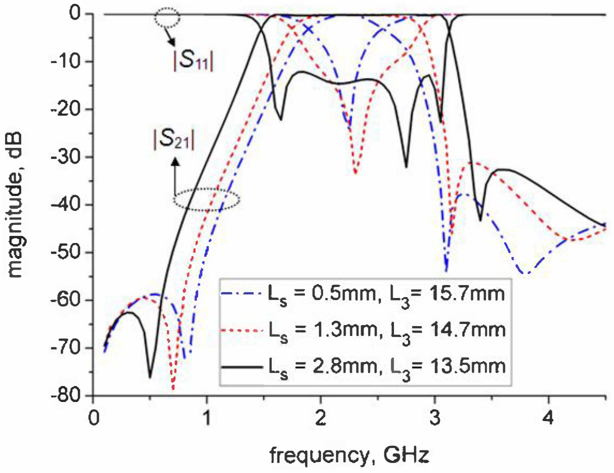

Fig. 4 Simulated frequency response $|S_{11}|$ and $|S_{21}|$ of the filter

under different L_S and L_3

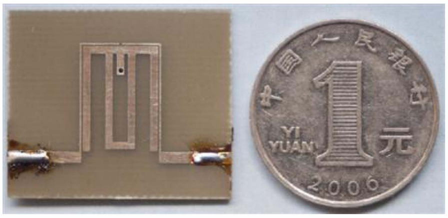

Fig. 5 Photograph of the proposed wideband BPF

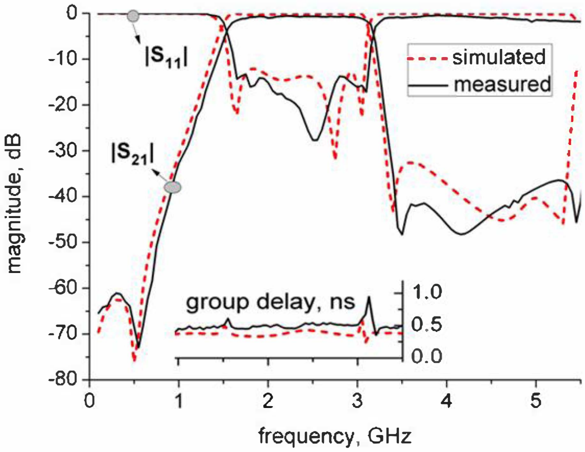

Fig. 6 Simulated and measured results of the proposed wideband BPF

by increasing L_s (from 0.5 to 2.8 mm) and decreasing L_3 (from 15.7 to 13.5 mm) (S_{11} > 10dB). After optimization using Ansoft HFSS 10.0, the design parameters are obtained as: $W_1 = 1.5$, $W_2 = 1$, $W_s = 1$, $W_3 = 0.25$, $L_1 = 16.5$, $L_2 = 1.5$, $L_3 = 13.5$, $L_s = 2.8$, $S_1 = 0.2$, $S_2 = 0.4$, $S_3 = 2$, $d = 0.6$, all in millimeters. Simulated results for wideband BPF are shown in Figure 6, the 3-dB fractional bandwidth is 71.9% (1.47 - 3.12 GHz), and the insertion loss is less than 0.5 dB while the return loss is over 12 dB. Furthermore, over 32.5 dB roll-off skirt rejection is achieved (3.3 – 5.3 GHz), and the group delay is less than 0.45 ns.

III. MEASURED RESULTS AND DISCUSSIONS

To verify the proposed approach, one prototype of the proposed BPF with size of 10.9 mm * 14.5 mm is designed and fabricated, as shown in Figure 5. The measured *S*-parameters and the group delay are also illustrated in Figure 6. The measured 3-dB fractional bandwidth is 68.3% (1.54 - 3.14 GHz) while the measured insertion loss for the filter is less than 0.8 dB, and the return loss is over 12.5 dB. An out-of-band rejection (3.4 – 5.5 GHz) with insertion loss greater than 35 dB is achieved; the group delay is less than 0.65 ns in the whole passband. Two transmission zeros with attenuation more than 72 and 47 dB are created at 0.52 and 3.41 GHz, respectively. They are close to the passband edges, resulting in high selectivity.

IV. CONCLUSION

A novel microstrip wideand BPF using a SRSLR is presented. The fractional bandwidth of the wideband filter can be conveniently controlled by adjusting the lengths of square ring and short-stub. The filter shows the advantages of simple topology, compact size. The measured and simulated results both indicate good performances such as low insertion loss, flat group delay, and a high out-of-band rejection, indicating the validity of the proposed design strategies.

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