A Novel Wideband Bandpass Filter Using Open Stubs Multi-mode Square Ring Resonator

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***Abstract*—A novel wideband bandpass filter (BPF) using open stubs multi-mode square ring resonators is proposed in this paper. The filter simultaneously realizes a broad passband, a compact size, and two transmission zeros at upper stopbands. The common-mode resonant frequencies is mainly determined by the length of ring resonator, while differential-mode resonance frequency can be flexibly controlled by the two identical stepped-impedance open stubs. A wideband bandpass filter is designed and fabricated for demonstration, indicating good agreement with the theoretical expectation.**

Index Terms—Multi-mode square ring resonator, open stub, wideband bandpass filter.

I. INTRODUCTION

The bandpass filters (BPFs) with high performance are essential for the design of receivers and transmitters in a microwave communication system. Planar microstrip BPFs have been receiving much attention due to the advantages such as small size, low cost, easy fabrication, and especially, since the Federal Communications Commission allocated 7.5 GHz of spectrum for unlicensed use of ultra-wideband (UWB) devices [1], several schemes have been developed in [2]-[8]. In [2], a novel wideband bandpass filter (BPF) using a cross-shaped microstrip multiple-mode resonator was reported. Operation of the dual mode resonator has been investigated with an analysis of the even- and odd-mode method. However, the out-of-band rejection level which is below -20dB over the frequency only from 3.99 GHz to 5.14 GHz. The resonator having two controllable transmission zeros on the upper stop-band has been proposed for filter applications [3]. In [4], a novel compact wideband bandpass filter using the asymmetric stepped-impedance resonator (SIR) is proposed, in which one step discontinuity is designed and implemented to achieve low loss, wide stopband and very high passband selectivity, simultaneously. However, there resulted in larger circuit size. A highly selective wideband bandpass filter implemented with microstrip ring resonator bandpass filters under multiple resonances was presented [5]. Multiple

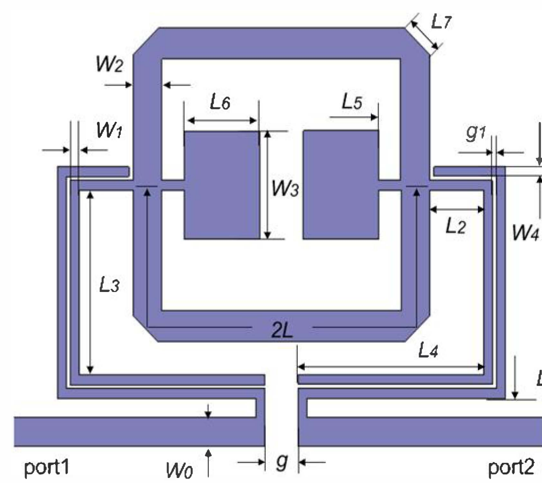

Fig. 1. Layout of the proposed wideband bandpass filter.

resonances behavior of a ring resonator with loading of open-circuited stubs will be characterized in a comprehensive way and it will be further utilized to constitute a new class of wideband ring resonator bandpass filters with compact size, sharpened rejection skirts, good dc-choked, and improved out-of-band performance. The ring resonator with multiple open stubs is introduced to exhibit the tunability of the passband bandwidth, as also proposed in [6-8]. However, due to the limitation of the fabrication precision, it is very difficult to realize the coupled lines of high impedance and a tight coupling gap.

To solve this problem, a novel microstrip wideband bandpass filter using open stubs and ring resonator is presented in this letter. The structure of the filter is symmetrical and contains a square ring resonators with two identical stepped-impedance open stubs. The common -mode resonance frequencies is mainly determined by the length of ring resonator, while differential-mode resonance frequencies can be flexibly controlled by the stepped-impedance open stub. A wideband BPF with center frequency 1.9 GHz, and fractional bandwidth of 64.5% is designed. It is constructed on a substrate with relative

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permittivity of 4.4 and thickness of h = 0.8 mm. The measured results agree well with the theoretical expectations.

II. Design of Proposed Filter

The layout of the proposed wideband bandpass filter is shown in Fig. 1. It consists of a square ring resonator and two identical stepped-impedance open stubs. As analyzed in [6] and [8] the passband can be obtained by tuning the the ring resonators and open stubs. In addition, for center frequency of passband is 1.8 GHz, the physical length L is chosen to be 14.6 mm. Then the bandwidth of the wideband filter may be controlled by adjusting the length of the open stub, while their widths are kept unchanged.

In Fig. 3 shows the simulated results of the proposed wideband BPF with different W_3 (W_3 = 6.7mm, 5.7mm, and 4.4mm) while the other dimensions are fixed. It is found that mid-upper passband bandwidth can be increased by decreasing W_3.

In this design, to improve filter selectivity, a new technique has been developed [9-11], in which is to introduce a cross coupling between the I/O feed lines is introduced, by placing two sections of the feed lines of length L_1 parallel to each other separated by spacing g.

Fig. 4 illustrates the change in filter properties in cases of different coupling spacing g from 1.4mm to 2mm, while the other dimensions are fixed. We may note that, the passband performance is almost the same, but the harmonic rejection level of harmonic is improved. Two transmission zeroes at the edges and uper band are thus produced. A wideband bandpass filter with controllable bandwidth and good selectivity is designed, the center frequency is set at 1.9 GHz. It is constructed on a substrate with relative permittivity of 4.4 and thickness of h = 0.8 mm. The design parameters obtained by Ansoft HFSS 10.0 EM simulator are given as follows: W_0 = 1.55 mm W_1 = 0.5 mm, W_2 = 1.6 mm, W_3 = 5.65 mm, g_1 = 0.2 mm, g = 1.75 mm, L = 14.6 mm, L_1 = 1 mm, L_2 = 2.9 mm, L_3 = 9.55 mm, L_4 = 10.1 mm, L_5 = 1.4 mm, L_6 = 3.9 mm, L_7 = 1.98 mm. Fig. 5 and 6 illustrate the simulated frequency response, the resulting 3 dB fractional bandwidth for the passband centered at 1.9 GHz is about 1.3-2.52 GHz (1.22MHz).

III. Measured Results and Discussions

One prototype of the wideband bandpass filter with size of 32 mm x 34 mm is fabricated to demonstrate the design strategies, as shown in Fig. 7. The measurement is accomplished using Agilent 8753ES network analyzer. For comparison with the simulations, the measured results are illustrated in Fig. 5, 6 also. It may be seen that the measured results agree well with the simulated results, the passband is centered at 1.9 GHz, with 3 dB bandwidth from 1.3GHz to 2.52 GHz (64.5%). The minimum insertion losses is 0.45 dB, while the return losses is 16 dB. The group delay is less

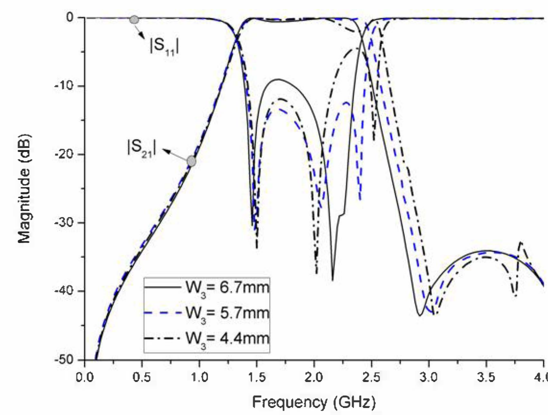

Fig. 3. Simulated frequency response $|S_{11}|$ and $|S_{21}|$ of the filter under different values of W_3

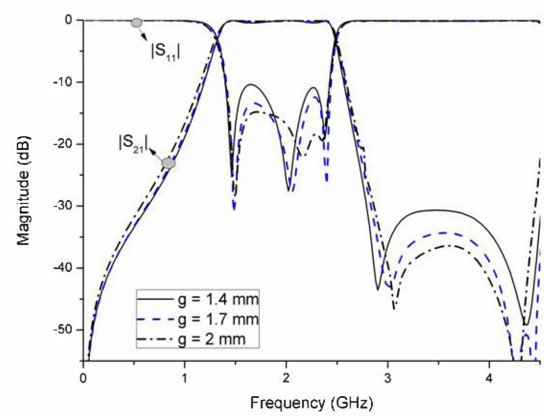

Fig. 4. Simulated frequency response $|S_{11}|$ and $|S_{21}|$ of the filter under different values of g

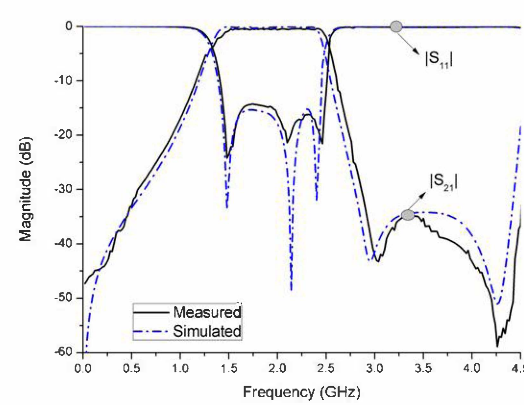

Fig. 5. Measured and simulated results S parameter of the wideband bandpass filter.

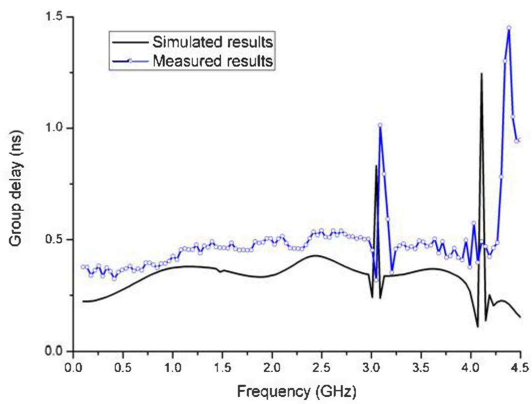

Fig. 6. Measured and simulated results group delay of the wideband bandpass filter.

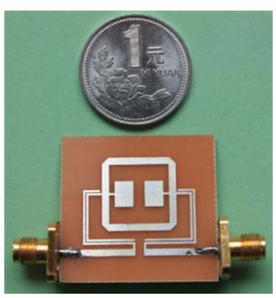

Fig. 7 Photograph of the fabricated wideband BPF.

than 0.55 ns in the whole passband. Meanwhile, the BPF has a high out-of-band rejection level which is below -20.0 dB over the frequency range 2.74–4.57 GHz, below -30.0 dB over the frequency range 2.86–4.50 GHz, and two transmission zeroes can be observed outside its passband. The slight frequency discrepancy may probably be caused by unexpected fabrication tolerance and measurement error.

IV. Conclusion

In this work, a novel compact microstrip wideband bandpass filter using open stubs and multi-mode ring resonator is presented. The characteristics of the resonator are investigated by using even-odd mode analysis. The odd-mode resonance frequency is mainly determined by the length of ring resonator, while even-mode resonance frequencies can be flexibly controlled by the impedance-stepped open stubs. Both measured and simulated results show that the wideband BPF has a good performance including a low insertion loss, a small group delay variation, and a high out-of-band rejection level, indicating the validity of the proposed design strategies. This BPF may be applied in communication systems requiring wide operation frequency band.

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