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Novel Compact Tri-band Bandpass Filter Using Square Ring Short Stub Loaded Resonators

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Abstract—**This letter presents a new method to design tri-band filters is used to the square ring short stub loaded resonators. Based on the odd- and even-model analysis, it is found that the first three resonance frequencies of the square ring short stub loaded resonators can be conveniently controlled. Benefiting from this feature, the resonator can be utilized to design a tri-band bandpass filter (BPF). To verify the proposed approach, a novel compact tri-band BPF is designed and fabricated with microstrip technology for demonstration, indicating good agreement with the theoretical expectation.**

***Index Terms*—Tri-band bandpass filter, square ring short stub loaded resonators, fractional bandwidth.**

I. INTRODUCTION

The rapid development of multiple band operations for wireless communication applications have attracted much attention of many researches, compact tri-band bandpass filter have been studied extensively as a key circuit block in tri-band wireless communication systems [1]–[14]. As shown in the literatures, multi-band bandpass filter (BPF) can be realized in various ways. Stepped impedance resonator (SIR) can be used for achieving the fundamental resonance frequency which is related to the characteristic impedance and electrical length of the resonator [1]–[7]. Although these structures are relatively complicated due to resonant frequencies of SIR are dependent, the three passbands at any desired frequencies can be obtained. Another method for tri-band filter designs is to combine two and three sets of resonators with common input and output ports [8-10]. In [8], *λ/4* and *λ/2* resonators are used to obtain dual- and tri-band responses, having independently controlled center frequencies and bandwidths for the proposed filters. The three desired frequencies can be conveniently controlled by tuning the lengths of open-loaded/half-wavelength resonator [9], open-loaded/quarter-wavelength resonator [10]. However, the disadvantage of these method are that the relatively complex structure can make the design difficult.

Recently, a novel class of compact dual-mode triple-band BPFs based on a single microstrip ring resonator has been presented [11]-[13], the square ring loaded resonator [14]. However, for these structure difficult controllable bandwidths and the selectivity needs to be improved.

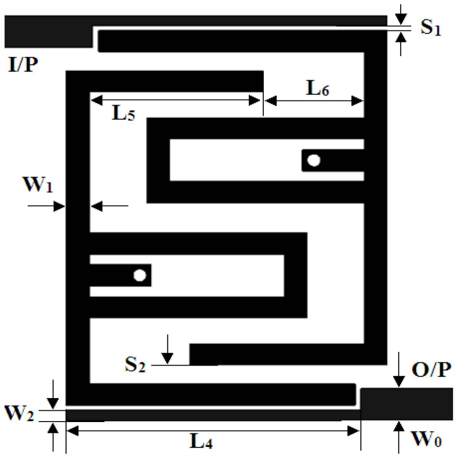

Fig. 1 The layout of proposed tri-band filter

In this letter, a novel compact microstrip tri-band using square ring short stub loaded resonator is presented. The passband frequencies can be conveniently tuned to desired values by controlling the corresponding resonator dimensions.

II. ANALYSIS AND DESIGN OF PROPOSED FILTER

A Characteristic of the Resonators

Fig. 2(a) shows the layout of the square ring short stub loaded resonator. 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 the characteristic impedances of open folder, square ring and short-stub, respectively. The resonator is symmetrical and thus even- and odd-mode analysis can be used. The input impedance for even- and odd-mode can be expressed as

$$Z_{ine} = Z\frac{1/K + jZ\tan\beta L_1}{Z + j\tan\beta L_1/K} \qquad (1)$$

$$K = \frac{j\tan\beta L_3}{Z} + \frac{j\tan\beta L_2 - j(Z/2Z_s)\cot\beta L_s}{Z + (Z^2/2Z_s)\tan\beta L_2\cot\beta L_s} \qquad (2)$$

$$Z_{ino} = \frac{Z + \tan\beta L_1(\cot\beta L_2 + \cot\beta L_3)}{j(\tan\beta L_1 - \cot\beta L_2 - \cot\beta L_3)} \qquad (3)$$

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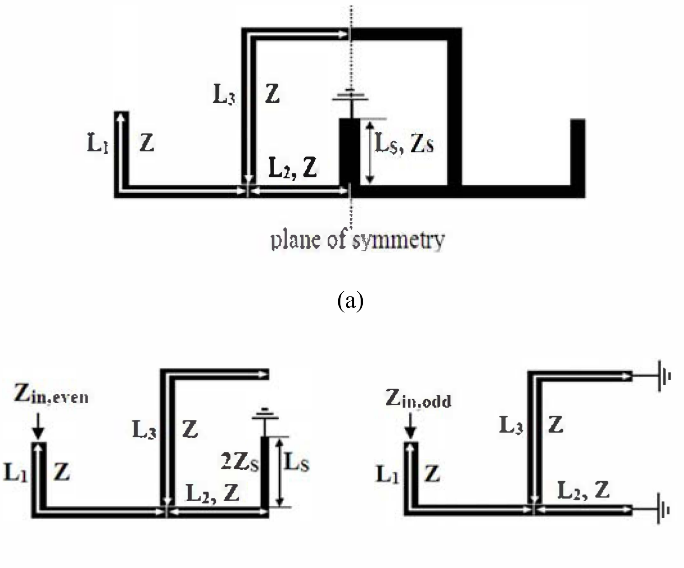


(a)

(b) (c)

Fig. 2 (a) Layout of square ring short stub loaded resonators. (b) Even-mode equivalent circuit. (c) Odd-mode equivalent circuit.

Where β is the propagation constant, and it is equal for even-mode and odd-mode.

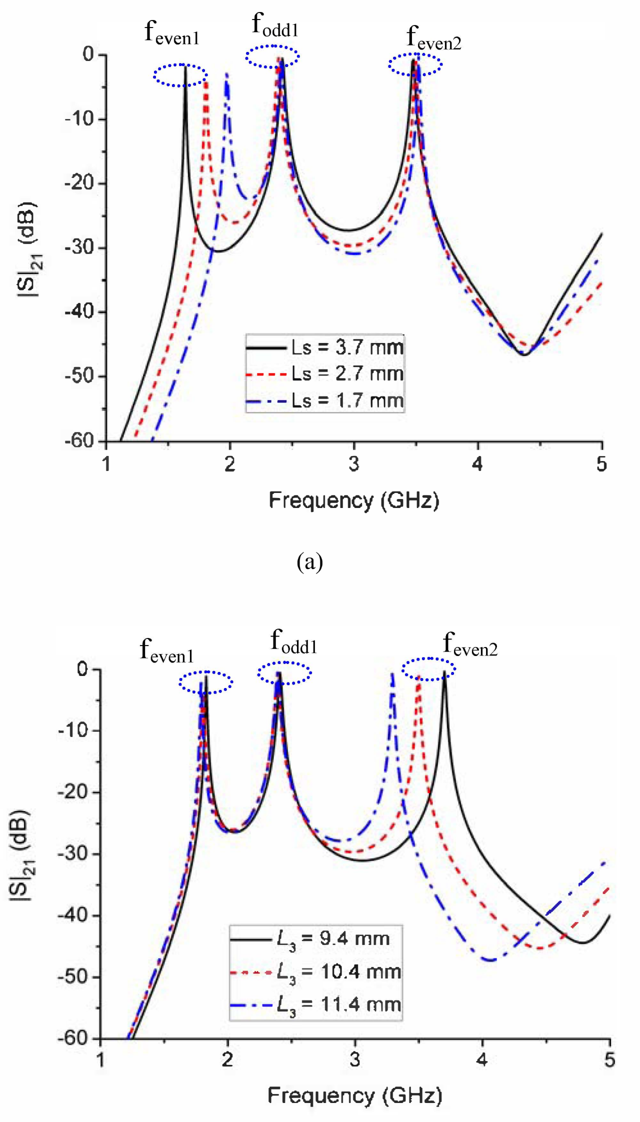
Furthermore, the specific effects of the main parameters of the proposed resonators can be fully demonstrated in Fig. 3. In Fig. 3(a), by changing the short-stub length L_s, the first passband frequency f_{even1} can be shifted within a wide range, meanwhile, when the f_{odd1} is fixed, the f_{even2} varies a little. In addition, Fig. 3(b) shows the simulated insertion loss of the filter in cases of different length L_3, the third passband f_{even2} can be shifted within a wide range, when f_{even1} and f_{odd1} are fixed. So in the filter design, to obtain desired passband frequencies, f_{odd1} can be determined by adjusting the length of the L_1 and L_2 then f_{even1} can be controlled simply by tuning the length of L_s, and f_{even2} can be determined by adjusting the length of L_3.

B. Tri-band bandpass filter design

Fig. 1 shows the layout of the proposed tri-band filter. This is a two-order microstrip square ring short stub loaded resonator filter, which are coupled in a pseudo-interdigital format. The resonance frequencies for the tri-band BPF was designed to locate at 1.8/2.4/3.5 GHz for GSM (1.8 GHz), WLAN (2.4 GHz) and WiMAX (3.5 GHz) applications.

A prototype of filter is fabricated of filter on a substrate with relative permittivity $\varepsilon_r = 4.4$ and $h = 0.8$ mm with size of 14 mm × 19 mm. The prototype photograph is shown in Figure 5.4. After optimization using Ansoft HFSS 10.0, the dimensions for this tri-band bandpass filter are determined as follows: $W_0 = 1.5$ mm, $W_1 = 1$ mm, $W_2 = 0.48$ mm, $L_1 = 15.9$ mm, $L_2 = 1.5$ mm, $L_3 = 10.5$ mm, $L_4 = 12.62$ mm, $L_5 = 7.8$ mm, $L_6 = 4.2$ mm, $L_s = 2.2$ mm, $S_1 = 0.22$ mm, $S_2 = 0.9$ mm, $d = 0.6$ mm.

In this case, the filter is designed with characteristic impedances $Z = Z_s$.



(a)

(b)

Fig. 3 Simulated insertion loss of resonator under the weak coupling with different (a) L_s and (b) L_3.

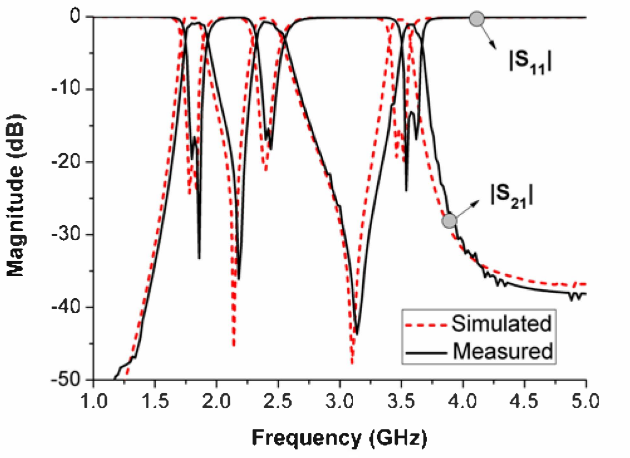


Fig. 4 Measured and simulated results of the tri-band bandpass filter.

Fig. 5 Photograph of the fabricated tri-band bandpass filter.

III. MEASURED RESULTS AND DISCUSSIONS

A prototype is fabricated to demonstrate the design strategies, the photograph as shown in Fig. 5. The measurement is accomplished using Agilent 8753ES network analyzer. For comparison, the measured results and simulation results are shown together in Fig. 4. The measured 3-dB fractional bandwidth for the three passbands (1.8, 2.4 and 3.5 GHz) are found to be 1.72-1.88 GHz (8.88%), 2.29–2.51 GHz (9.16%), and 3.49–3.65 GHz (4.48%), respectively. The measured minimum insertion losses including the loss from SMA connectors are 1.1, 1.1, and 1.5 dB, while the return losses are greater than 16.5, 15 and 14 dB, respectively.

In addition, the measured and simulation results at the first and second passbands are in good agreement. However, the discrepancy can be observed at the third passband, which might be due to the unexpected tolerance of fabrication and implementation.

IV. CONCLUSION

A new method to design tri-band filters is used to the square ring short stub loaded resonators is presented. The centre frequencies of the three passbands can be conveniently controlled to the desired values by controlling the corresponding resonator dimensions. A novel compact tri-band bandpass filter for GSM (1.8 GHz), WLAN (2.4 GHz) and WiMAX (3.5 GHz) applications is designed. Good agreement is observed between the experiments and theoretical analysis, indicating the validity of the proposed design strategies.

REFERENCES

[1] Q. X. Chu and X. M. Lin, "Advanced triple-band bandpass filter using tri-section SIR," *Electron. Lett.*, vol. 44, no. 4, pp. 295-296, Feb. 2008.

[2] X. M. Lin and Q. X. Chu, "Design of triple-band bandpas filter using tri-section steppedimpedance resonators," in *Proc. Int. Conf. Microw .Millimeter Wave Tech.*, Guilin, China, Apr. 2007, pp. 798-800.

[3] M. Makimoto and S. Yamashita, "Bandpass filters using parallel coupled stripline stepped impedance resonators," *IEEE Trans. Microw.Theory Tech.*, vol. MTT-28, no. 12, pp. 1413–1417, Dec. 1980.

[4] W. Ma and Q. X. Chu, "A novel dual-band step-impedance filter with tunable transmission zeros," *Proc. Asia–Pacific Microw. Conf.*, Su Zhou, pp. 2833-2835,Dec. 2005.

[5] C.-H. Lee, C.-I. G. Hsu, and H.-K. Jhuang, "Design of a new tri-band microstrip BPF using combined quarter-wavelength SIRs," *IEEE Microw.Wireless Compon. Lett.*, vol. 16, no. 11, pp. 594–596, Nov. 2006

[6] C.-I. G. Hsu, C.-H. Lee, and Y.-H. Hsieh, "Tri-band bandpass filter with sharp passband skirts designed using tri-section SIRs," *IEEE Microw.Wireless Compon. Lett.*, vol.18, no.1, pp.19-21, Jan. 2008.

[7] F.C. Chen and Q.X. Chu, "Design of compact tri-band bandpass filter using assembled resonators", *IEEE Trans. Microw. Theory Tech.,* vol. 57, no. 1, pp. 165-171, Jan. 2009

[8] F. C. Chen, Q. X. Chu, and Z. H. Tu, "Design of dual-and tri-band bandpass filter using *λ/4* and *λ/2* resonators," *IEEE . Microw. Optical Tech. Lett.,* vol. 51, no. 3, pp 638-641, March. 2009

[9] X. Y. Zhang, Q. Xue, and B. J. Hu, "Planar tri-band bandpass filter with compact size," *IEEE Microw. Wirel. Compon. Lett.*, vol 20, no 5, pp 262-264, May 2010.

[10] M. T. Doan, W. Q. Che, K. Deng, and W. J. Feng, "Compact Tri-band bandpass filter using stub-loaded resonator and quarter-wavelength resonator," *In Proc. Int. Conf. Microw. China-Japan Joint*, pp 1-4, Apr 2011.

[11] S. Luo, L. Zhu, and S. Sun, "Compact dual-mode triple-band bandpass filters using three pairs of degenerate modes in a ring resonator," *IEEE Trans. Microw. Theory Tech.*, vol 59, pp 1222-1229. 2011.

[12] S. Luo, L. Zhu, "A novel dual-mode dual-band bandpass filter based on a single ring resonator," *IEEE Microw. Wireless Compon. Lett.*, vol. 19, no. 8, pp. 497–499, Aug. 2009.

[13] S. Sun, "A dual-band bandpass filter using a single dual-mode ring resonator," *IEEE Microw. Wireless Compon. Lett.*, vol 21, no 6, pp 298-300, Jun. 2011.

[14] J. Z. Chen, N. Wang, Y. He, and C. H. Liang, "Fourth-order tri-band bandpass filter using square ring loaded resonators," *Electron. Lett.*, vol 47, no 15, pp 858-859, July 2011.