

Dual-Band BandPass Filters Using SIRs with Open-Stub Line and Zero-Degree Feed Structure

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Abstract — A novel compact dual-band bandpass filter (DBPF) using SIRs with open-stub line and 0-degree feed structure is presented in this paper. The low-band is obtained by using hairpin type Stepped Impedance Resonators (SIR) split ring through electrical coupling, And by tuning a pair of open-stub lines the high-band is realized too. In order to improve the stop band attenuation, zero-degree feed structure is implemented to introduce three transmission zeros. So the proposed DBPF has high selectivity, and is also simple in design and compact in structure. Finally the proposed filter is designed and fabricated, and the simulation and test results are in good agreement.

Index Terms —dual-band filter, SIR, open-stub line, zero-degree feed structure.

I. INTRODUCTION

With the development of modern wireless communication technology, the frequency spectrum is increasingly crowded. Rapid development of multimodal communication system requires dual-band, even multiband filters [1, 2]. Different communication standards lead to different communication systems. The 2.4 GHz frequency is widely used in Bluetooth, Zigbee, etc. The 3.5 GHz frequency is used in fixed wireless access (FWA) [3]. The SIR microstrip bandpass filter has great advantages for its miniaturization, low cost and high integration [2, 4], so it has been widely used in the field of WLAN communication. Up to now, some methods were used to realize microstrip DBPF, all with obvious drawbacks either in design or realization. One of the straight forward and simple methods is to cascade a wide-bandpass and a bandstop filter with the stop band inserted into the pass band [5]. However this method would yield a larger size with high insertion loss. As a comparatively complicated alternative, DBPF can also be realized through the combination of successive frequency transformations and circuit conversions.[6] This type of DBPF can be designed utilizing $\lambda/2$ SIRs structure [7, 8]; It is difficult to design because the two resonant frequencies of SIRs are not independent. Using stub-loaded resonators, DBPF can be designed too. This method is based on the odd-even mode theory with

shiftable even-mode resonance and almost unchanged fundamental odd-mode resonant when tuning the open stub [9, 10].

Compared with the traditional filters, 0-degree feed structure filters can improve the decay rate of the transition from pass band to stop band, without increase of order number or the introduction of new resonance unit, which ensures a compact design of the filter [11, 12]. The proposed DBPF in this paper is mainly based on $\lambda/2$ SIRs structure and stub-loaded resonators and 0-degree feed structure. In comparison with other filters, the proposed filter distinguishes itself with its simplicity in design, which is realized with compact SIRs and an easily accessible second passband by using the open-stub lines. Both the dual-band filter in [11] and the DBPF in this paper are based on 0-degree feed structure. However, the DBPF in this paper has smaller size due to one pair (rather than two pairs) of SIRs structure and has an easily controllable second resonant band with open-stub lines. So the filter is simple in design and small in size. Finally, the 2.4/3.5GHz microstrip DBPF for short range wireless communication and FWA application is fabricated to verify the proposed design. The measurement of the filter is in good agreement with the simulation.

II. THE DESIGN OF DBPF

The dual-band bandpass filter design process is divided into three steps. The first step is to get basic resonator unit using SIR structure which is detailed in section A. Then, section B demonstrates how hairpin SIR filter with 0-degree feed structure is designed to obtain the low-band passband. The third step is to produce the high-band passband through adding a pair of open-stub lines in section C. Finally, the design parameters of microstrip DBPF using SIRs with open-stub line and 0-degree feed structure are obtained.

A. The basic resonator unit using SIR structure

In this section, SIR split ring is used as the basic resonator unit of the filter. Instead of uniform impedance transmission line resonators, SIRs[13] are used. They

play an even more significant role in miniaturization and harmonics suppression. Half wavelength structure of SIR is shown in Fig. 1.

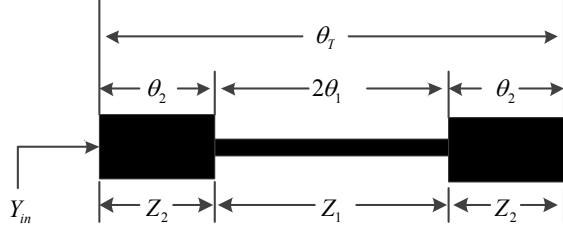


Fig. 1 The general structure of $\lambda_g/2$ SIR

It can be seen in Fig. 1 that the $\lambda_g/2$ SIR is symmetric and has two different characteristic impedances of Z_1 and Z_2 . And the corresponding two electrical lengths are θ_1 and θ_2 , respectively. For simplicity, let $\theta_1=\theta_2=\theta$ in practice. The admittance of the resonator at the open end, Y_{in} is given as follows: [12]

$$Y_{in} = j \frac{1}{Z_2} \frac{2(1+R_Z)(R_Z - \tan^2 \theta) \tan \theta}{R_Z - 2(1+R_Z + R_Z^2) \tan^2 \theta + R_Z \tan^4 \theta} \quad (1)$$

Where the impedance ratio $R_Z=Z_2/Z_1$. The resonance condition can be obtained from the following equation:

$$Y_{in} = 0 \quad (2)$$

It is now readily to calculate the resonant frequency corresponding to the length value. The resonant frequency is set as f_0 corresponding to an electrical length of θ_0 . Letting first spurious resonant frequency of $\lambda_g/2$ SIR be f_{s1} corresponding to θ_{s1} , we can obtain

$$\frac{f_{s1}}{f_0} = \frac{\theta_{s1}}{\theta_0} = \frac{\pi}{2 \arctan(\sqrt{R_Z})} \quad (3)$$

Even the fundamental resonance frequency is settled, the impedance ratio can be adjusted to control other resonant response positions, which explains why SIR can be used for harmonic suppression.

B. Hairpin SIR Filter with zero-degree feed structure

Hairpin resonator is a kind of improved filter structure of half wavelength coupled structure, while SIR hairpin resonator structure is more compact than the traditional

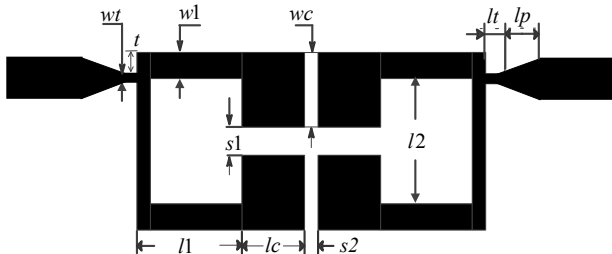


Fig. 2 The electric coupling feeding structure of SIR split ring (a) Non 0-degree feed structure

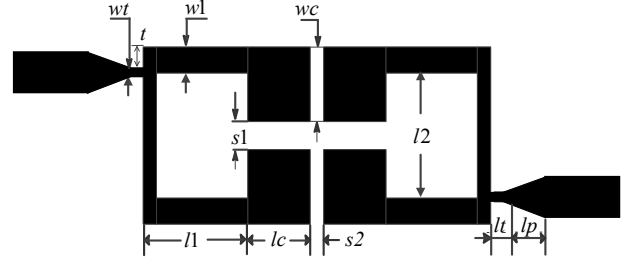


Fig. 2 The electric coupling feeding structure of SIR split ring (b) 0-degree feed structure

hairpin resonator, so the latter is preferred.

Fig.2 shows two feed structures of hairpin type microstrip SIR split ring, one (Fig.2 (a)) is non 0-degree feed structure; the other (Fig. 2(b)) is 0-degree feed structure.

The EM software IE3D has been taken to optimize the filters. The substrate thickness is 1 mm with a dielectric constant of 2.65. Other dimensions are as follows:

$w1=1.1\text{mm}$, $wc=4.35\text{mm}$, $l1=5.2\text{mm}$, $l2=9.1\text{mm}$, $ls=13.2\text{mm}$, $t=0.85\text{mm}$, $wt=0.5\text{mm}$, $lt=1\text{mm}$, $s1=0.4\text{mm}$, $s2=0.3\text{mm}$. The simulated S parameters of the two different feed structures are shown in Fig.3.

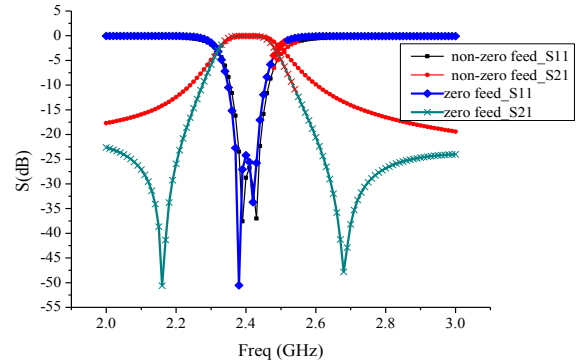


Fig.3 Simulated frequency responses of the non-zero degree and zero degree structures

The center frequencies of the filters are both at 2.4GHz, the return loss are both below 25dB. However, the zero degree structure has produced two transmission zeros at 2.12GHz and 2.67 GHz, respectively, so the stopband rejection is greatly increased.

C. Hairpin Dual-Band Pass Filter Using SIRs with Open-Stub Line Based on 0 Degree Feed Structure

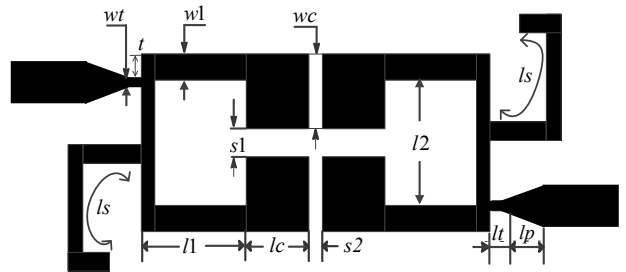


Fig.4 The structure of proposed DBPF

On the basis of the design of section B, by adding a pair of open-stub lines, the second passband is produced, so the DBPF using SIRs can be realized. The structure of DBPF is shown in Fig. 4.

The properties with varying stub length are verified by the simulated curves shown in Fig. 5.

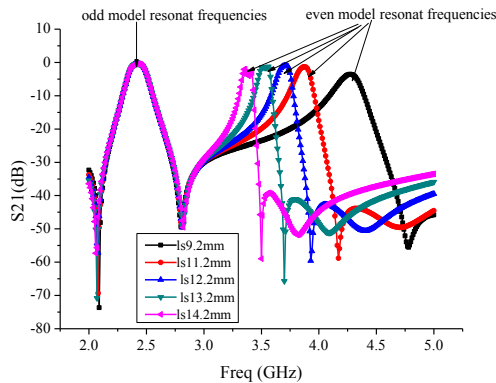


Fig.5 Resonant properties of the microstrip stub-loaded resonator with different stub lengths

The odd-mode resonant frequencies are not affected by the open stubs; the low-band center frequency is mainly determined by the hairpin type SIRs. While the high-band center frequency, corresponding to the resonant frequency of the even-mode, is easily varied by changing the stub length L_s .

When the length of the open stubs is 13.2mm, the high-band center frequency is found to be 3.5GHz. The main parameters of the DBPF are the same as that in Fig. 2 (b) in section B. The width of the open stub is 1.1mm, and the open stub is bent to minimize circuit board size. Finally, the proposed DBPF is fabricated, and the photo is shown in Fig. 6.

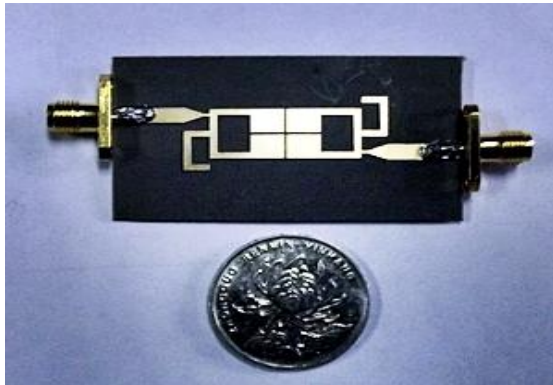


Fig.6 The photo of the proposed DBPF

As can be observed from Fig. 7, although the measured S parameters are slightly worse than the simulated one, and the high-band passband is a little offsetting, the agreement between simulated and measurement results is still good. The measured dual passbands are at 2.42 and 3.6GHz with insertion losses of 1.1dB and 3.16dB and the fractional frequency bandwidths of about 5.8% and

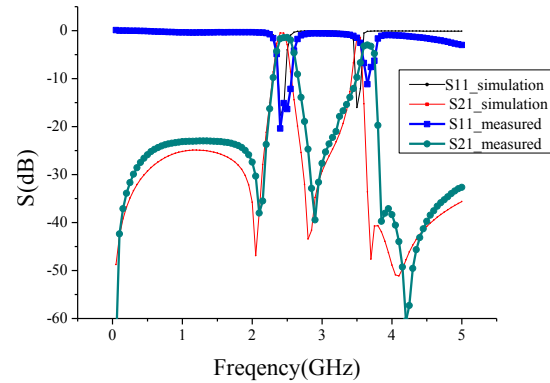


Fig.7 Simulated and measured results of the proposed DBPF

3.6%, respectively. And both the simulated and the measured return losses within the low-band passband are better than 15dB, while the measured return losses within the high-band passband is about 10dB, which is less than the simulated one. Three transmission zeros are realized with more than 35 dB attenuations. The measured insertion loss is mainly due to the conductor loss, and frequency deviation can be attributed to the possible tolerance of fabrication. Thus, the proposed novel DBPF can meet the 2.4 GHz and 3.5GHz wireless communication requirements.

III. CONCLUSION

A novel compact dual-band bandpass filter (DBPF) with high selectivity is proposed. The basic resonator unit is SIR split ring, the low-band passband is obtained through the SIRs electric coupling. By adding open-stub lines, the high-band passband is easy to generate and adjust almost without influence to the low-band passband. In order to further improve the selectivity, 0-degree feed structure is applied to introduce three transmission zeros. Finally, it is observed that there is a good agreement between the simulated and measured results. So the proposed novel DBPF using SIRs with open-stub lines and 0-degree feed structure not only has high selectivity, but also is compact in size, and easy to realize. It can meet the 2.4 GHz and 3.5 GHz wireless communication requirements such as short range wireless communication in WLAN and FWA application.

REFERENCES

- [1] I. C. Hunter, L. Billonet, B. Jarry, P. Guillon, "Microwave Filters-Applications and Technology," IEEE Trans. Microw. Theory Tech., vol. 50, no. 3, pp. 794-805, 2002.
- [2] G. Matthaei, L. Young and E. M. T. Jones, Microwave Filter, Impedance-Matching Networks, and Coupling Structures, Norwood, MA: Artech House, 1980.
- [3] F. R. Chang, W. L. Chen, S. C. Chang, et al., "A Dual-band RF Transceiver for Multi-standard WLAN Applications," IEEE Trans. Microw. Theory Tech., vol. 53, no. 3, pp. 1048-1055, Mar. 2005.

- [4] J.-S. Hong, M. J. Lancaster, *Microstrip Filters for RF/Microwave Applications*, Wiley, New York, 2001.
- [5] L. C. Tsai and C. W. Hsue, "Dual-band bandpass filters using equal-length coupled serial-shunted lines and Z-transform technique," *IEEE Trans. Microw. Theory Tech.*, vol. 52, no. 4, pp. 1111–1117, 2004.
- [6] X. Guan, Z. Ma, P. Cai, G. Li, et al., "Synthesis of dual-band bandpass filters using successive frequency transformations and circuit conversions", *IEEE Microwave and Wireless Component Letters*, vol. 16, no. 3, pp. 110-112, 2006.
- [7] C.-Y. Chen, C.-Y. Hsu, H.-R. Chuang, "Design of Miniature Planar Dual-Band Filter Using Dual-Feeding Structures and Embedded Resonators," *IEEE Microwave and Wireless Components Letters*, vol. 16, no. 12, pp. 669 - 671, 2006.
- [8] J.-S. Gao, H.-H. Hu, Z.-Y. Xiao, "A Novel Compact Dual-Band Bandpass Filter Using SIRs with Open-Stub Line," *2008 China-Japan Joint Microwave Conference*, pp. 464 - 466, 2008.
- [9] J.-X. Chen, T.-Y. Yum, et al., "Dual-Mode Dual-Band Bandpass Filter Using Stacked-Loop Structure. *IEEE Microwave and Wireless Components Letters*, vol. 16, no. 9, pp. 502-504, 2006.
- [10] X.-Y. Zhang, J.-X. Chen, Q. Xue, et al., "Dual-Band Bandpass Filters Using Stub-Loaded Resonators," *IEEE Microwave and Wireless Components Letters*, vol. 17, no. 8, pp. 583-585, 2007.
- [11] W. Xue, C.-H. Liang, X.-W. Dai and J.-W. Fan, "Design of miniature planar dual-band filter with 0-degree feed structures," *Progress in Electromagnetics Research, PIER* 77, pp 493-499, 2007.
- [12] J. W. Fan, C. H. Liang and B. Wu, "Dual-band filter using equal-length split-ring resonators and zero-degree feed structure," *Microwave and Optical Technology Letters*, vol. 50, no. 4, pp. 1098-1101, 2008.
- [13] M. Makimoto, S. Yamashita, *Microwave Resonators and Filters for Wireless Communication Theory, Design and Application*. Berlin: Springer, 2001.