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A SIMPLE METHOD TO DESIGN A COMPACT AND HIGH PERFORMANCE DUAL-BAND BANDPASS FILTER FOR GSM AND WLAN

C.-Y. Hung

Department of Electronics Engineering and Computer Science
Tung-Fang Institute of Technology
No. 110, Tung-Fung Road, Hunei Shiang, Kaohsiung 829, Taiwan

R.-Y. Yang

Department of Materials Engineering
National Ping-Tung University of Science and Technology
No. 1, Syuefu Rd., Neipu Township, Pingtung 91201, Taiwan

Y.-L. Lin

General Education Center
Wenzao Ursuline College of Languages
Mitsu 1st Road, Kaohsiung 807, Taiwan

Abstract—This paper proposes a novel compact dual-band bandpass filter (BPF) using four spiral resonators for application in GSM and IEEE 802.11b WLANs for the first time. Since the two passbands can be tuned individually, the filter has more design freedoms. The symmetry coupling structure is realized to achieve a isolation higher than 30 dB between the lower and higher passbands. The full-wave simulator IE3D is used to design the spiral resonators and calculate the coupling coefficients of the basic coupling structures. The designed BPF is fabricated and measured. Good agreement between the simulated and measured results verifies our design concept.

Corresponding author: R.-Y. Yang (ryyang@mail.npust.edu.tw).

1. INTRODUCTION

In recent year, there has been a growing interest in the wireless communication applications operating in multi-band, especially in the developed global system for mobile communications (GSM) or wireless local area networks (WLANs) [1, 2]. Therefore, the high performance dual-band bandpass filters (BPFs) in different systems have become attractive and key components. A number of publications have provided a variety of solutions to the realization of dual-band BPFs [3–7]. The challenges to circuit designers when designing dual-band BPFs are to achieve the compact size and high dual-passband performance simultaneously [5–7]. The dual-band BPF was proposed by cascading shunt stubs and shunt serial resonators. However, it has a drawback of a large circuit size [3, 4]. Stepped impedance resonator (SIR) can be used for controlling the multi-resonance modes which are related to the electrical length and impedance ratio of the resonator. Therefore, the first and second passbands of the SIR can be tuned to shift the desired passband positions. However, poor passband selectivity and design complexity are the problematic issues of these dual-band BPFs based on the SIRs [5–7]. For multi-services in communication system, a dual-band BPF centered at 1.8 GHz for GSM system and 2.4 GHz for WLAN system will be needed. However, there has been no paper for the systems at 1.8 GHz and 2.4 GHz till now. Moreover, to design the dual-band filter with such frequency bands is a little difficult since these two bands are close, and a high isolation between the two bands is needed.

In this paper, we propose a novel and simple method to obtain a compact dual-band BPF using spiral resonators centered at 1.8 GHz for GSM system and 2.4 GHz for WLAN system. It is shown that the designed dual-band BPF can generate two passbands located at any two desired frequencies with high passband selectivity through the arrangement of spiral resonators. In additional, it is found that the arrangement of the four spiral resonators forms a symmetry coupling circuit, which can reduce interference between the first and second passbands and increase design freedom for individual passband design. The designed dual-band BPF is fabricated and measured. Good agreement exists between the experimental results of the fabricated filter and the simulation ones.

2. DESIGN OF COUPLING STRUCTURE

Figure 1 depicts the schematic of the proposed dual-band BPF using spiral resonators. In this paper, a RT/Duroid 5880 substrate, with a relative dielectric constant of 2.2, a loss tangent of 0.001 and a thickness of 0.787 mm, is used for the simulation and practical fabrication. The dual-band BPF mainly consists of four half-guided-wavelength ($\lambda_g/2$) resonators with a high-impedance line around 115 Ω and two parallel coupling input/output (I/O) ports at the two sides. The reason to use 115 Ω to realize the microstrip line is that if a microstrip line with a lower impedance value is used, a bending effect would be easily produced, thus causing a distortion result, and if a microstrip line with a higher impedance value is used, the microstrip line is difficult to be fabricated. The two shorter spiral resonators (R_3 and R_4) placed on the lower side of the BPF are used to obtain the higher passband of 2.4 GHz, and the two longer spiral resonators (R_1 and R_2) located on the higher side of the BPF are used to obtain the lower passband of 1.8 GHz. Unlike the conventional design of I/O ports which are only attached to the resonators (R_1/R_2) or the resonators (R_3/R_4), the proposed I/O ports have coupling lines to transmit energy into the resonators centered at different bands simultaneously, as shown in Fig. 1. Moreover, since the resonators R_1 and R_3 (R_2 and R_4) form a symmetry coupling structure, the coupling effect between the shorter and longer spiral resonators is low [8]. Therefore, such a symmetry coupling structure provides an independent design for lower and higher passbands. Therefore, we only need to discuss the coupling effect between the spiral resonators R_1/R_2 and R_3/R_4, without discussing the coupling effect between the spiral resonators R_1/R_3 or R_2/R_4. The coupling between the spiral resonators can be specified by the two dominant resonant frequencies, which are split off from the resonance condition due to electromagnetic coupling. Therefore, the simulated coupling coefficient $K_{i,i+1}$ can be calculated as [6]

$$K_{i,i+1} = \frac{f_H^2 - f_L^2}{f_H^2 + f_L^2} \tag{1}$$

where f_H is the higher of the two resonant frequencies, and f_L is the lower one. It is noted that $K_{i,i+1}$ ($i = 1$ and 3) is applied by separating two resonators at a time, and K_{12} and K_{34} are also subjected to an offset S_1 and S_2, as shown in Fig. 2. We used 3D full-wave simulator IE3D [9] to design the coupled spiral resonators and determine the resonant frequencies of each coupling structure. The optimum design conditions of S_1 and S_2 for 1.8 and 2.4 GHz are set as 0.5 mm and 0.9 mm, respectively.

To further demonstrate the design concept, Figs. 3(a) and (b) show the simulation current distribution and coupling paths operated at 1.8 and 2.4 GHz for the dual-band BPF. It is clearly observed that more current distribution is located on the spiral resonators R_1 and

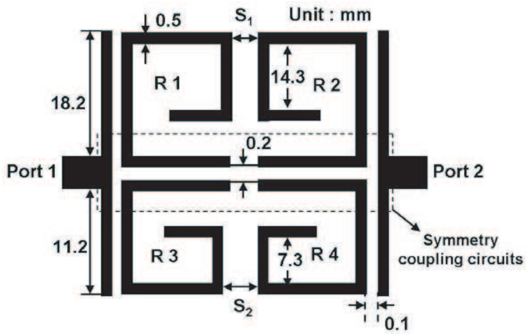

Figure 1. Practical layout of the designed dual-band BPF designed on a 0.787-mm-thick substrate with a dielectric constant of 2.2.

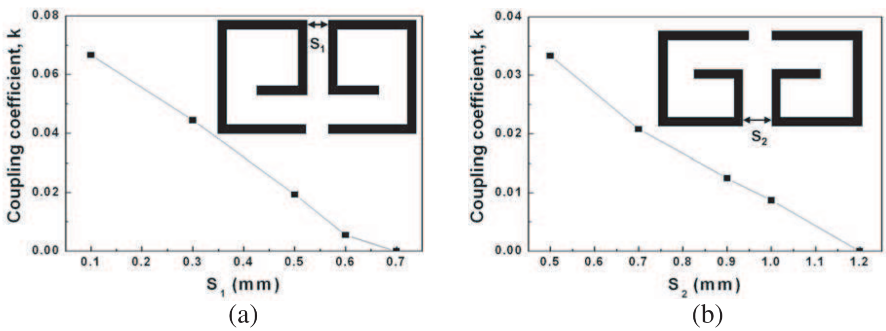

Figure 2. The calculated coupling coefficients K_{12} (for resonators R_1 and R_2 at 1.8 GHz and K_{34} (for resonators R_1 and R_2 for 2.4 GHz) with different (a) spacing S_1 and (b) spacing S_2 between the resonators.

R_2 at 1.8 GHz, and maximum current distribution occurs at the spiral resonators R_3 and R_4 at 2.4 GHz. It is also noted that the current distribution gives direct insight to understand the direction of the coupling paths and thus to make easy optimum design of proposed dual-band BPF structure.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Based on the above design guide, the designed dual-band BPF was fabricated by using the printed circuit technology. The coupling I/O ports are designed for 50 Ω. Photograph of the fabricated dual-band BPF is shown in Figure 4. The whole size of the fabricated filter is 25.3 mm × 31.8 mm, i.e., approximately $0.2\lambda_g$ by $0.25\lambda_g$, where λ_g is the

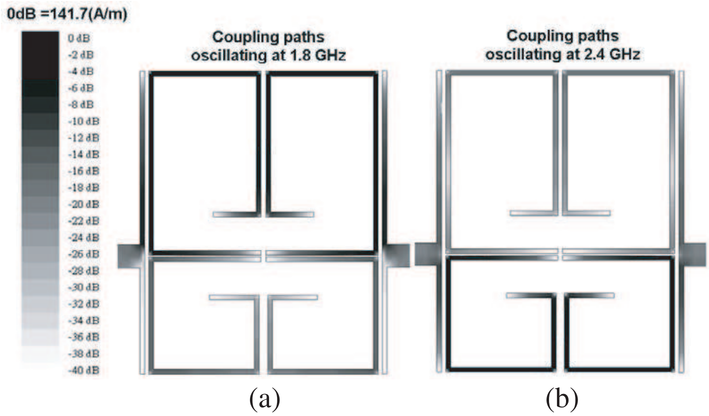

Figure 3. Simulated current distribution and coupling paths oscillating of dual-band BPF at (a) 1.8 GHz and (b) 2.4 GHz.

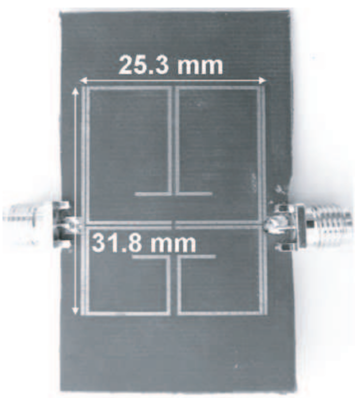

Figure 4. Photograph of the fabricated dual-band BPF.

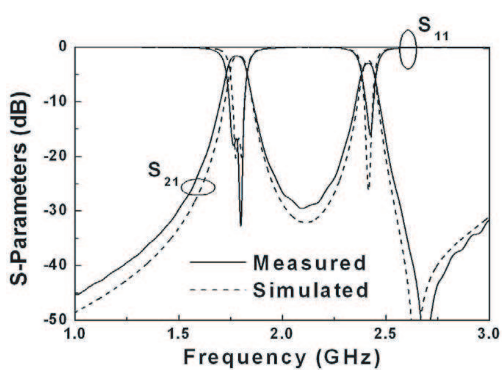

Figure 5. Simulated and measured frequency response of the designed dual-band BPF.

guided wavelength at the 1.8 GHz. The measured frequency response of the proposed dual-band BPF was characterized in an HP 8510C network analyzer (VNA).

Figure 5 shows the simulated and measured results of designed dual-band BPF. The measured insertion losses are less than 1.6 dB and 2.5 dB, and return losses are greater than 18 dB and 16 dB for 1.8 GHz and 2.4 GHz, respectively. In general, the loss tangent of the material increases when the operating frequency increases, thus the insertion loss would increase slightly with increasing frequency. The measured fractional bandwidths (defined as 3 dB bandwidth over the center frequency) are 5.6% and 3% for 1.8 GHz and 2.4 GHz, respectively. The symmetry coupling structure produces low coupling effect to reduce interference between lower passband of 1.8 GHz and higher passband of 2.4 GHz. Therefore, the isolation between the two passbands is greater than 30 dB rejection. It is verified that the symmetry coupling structure between four spiral resonators can reduce interference between the first and second passbands, thus increasing the design freedom for individual passband. The difference between the simulated and measured results might be due to the fabricated error and can be improved by more careful fabrication. The proposed dual-band BPF also has the advantages of small size, low insertion losses, ease of design, narrow bandwidths and high isolation for GSM and WLAN and multi-use communication applications.

4. CONCLUSION

A novel and simple method to design a compact dual-band BPF centered at 1.8 GHz for GSM system and 2.4 GHz for WLAN system by using four spiral resonators has been presented. In this study, it is found that the interference between the first and second passbands can be reduced, due to the use of symmetry coupling structure among four spiral resonators. The high isolation between the first and second passbands can be also obtained by using the symmetry coupling structure. The compactness in circuit size makes the proposed design of the dual-band BPF attractive for further developments and applications in modern radio systems.

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REFERENCES

1. Helhel, S., S. Ozen, and H. Goksu, "Investigation of GSM signal variation depending weather conditions," *Progress In Electromagnetics Research B*, Vol. 1, 147–157, 2008.
2. Papantoniou, V. P. and T. D. Xenos, "Development and electromagnetic characterization of adaptable open-architecture WLAN

systems," *Progress In Electromagnetics Research*, PIER 91, 229–242, 2009.

3. Jang, G. and S. Kahng, "Design of a dual-band metamaterial bandpass filter using order resonance," *Progress In Electromagnetics Research C*, Vol. 12, 149–162, 2010.
4. Liu, Y. and W. Dou, "A dual-band filter realized by alternately connecting the main transmission-line with shunt stubs and shunt serial resonators," *IEEE Microw. Wireless Compon. Lett.*, Vol. 19, 296–299, 2009.
5. Weng, M. H., H. W. Wu, and Y. K. Su, "Compact and low loss dual-band bandpass filter using pseudo-interdigital stepped impedance resonators for WLANs," *IEEE Microw. Wireless Compon. Lett.*, Vol. 17, 187–190, 2007.
6. Weng, M. H., S. K. Liu, H. W. Wu, and C. H. Hung, "A dual-band bandpass filter having wide and narrow bands simultaneously using multilayered stepped impedance resonators," *Progress In Electromagnetics Research Letters*, Vol. 13, 139–147, 2010.
7. Lin, W. J., C. S. Chang, J. Y. Li, D. B. Lin, L. S. Chen, and M. P. Houng, "A new approach of dual-band filters by stepped impedance simplified cascaded quadruplet resonators with slot coupling," *Progress In Electromagnetics Research Letters*, Vol. 9, 19–28, 2009.
8. Pozar, D. M., *Microwave Engineering*, 2nd edition, John Wiley & Sons, Inc., New York, 1998.
9. Zeland Software, Inc., IE3D Simulator, 1997.