Progress In Electromagnetics Research C, Vol. 1, 55–61, 2008

STUDY ON TWO COMPACT CPW-FED BANDPASS FILTERS USING DUAL-MODE PATCH RESONATOR

J. Wang, H. Zhang, L.-X. Ma, and H.-Y. Xu

Radar Engineering Department
Missile Institute of Air Force Engineering University
Sanyuan, Shaanxi 713800, China

Abstract—Two compact CPW-fed band-pass filters using dual-mode resonator are proposed and studied — one resonator with two unequal corner-cut elements located at two diagonal corners of a conventional micro-strip patch and the other with unequal crossed slots at the center of a conventional micro-strip patch. In this paper, adjusting the length of corner-cut element and the crossed slot are mainly studied. By use of HFSS, the simulation results are given and analyzed. The simulation results show that the pass-band of the filter(a) may be adjusted over the bandwidth range from 4.9% to 16%, and the pass-band of the filter(b) may be adjusted over the bandwidth range from 5.4% to 8.2%, and filter(b) with cross-slot has smaller size than filter(a) with corner-cut to meet the same application demand. According to the simulation results, to design a filter which works at 1.65 GHz, the configuration of filter(b) is adopted owning to smaller size. finally, filter(b) with len1 = 20.2 mm and len2 = 20.4 mm is fabricated and measured, which has a minimum insertion loss of 2.48 dB in its pass-band.

1. INTRODUCTION

A planar dual-mode filter was proposed in the early 1970's by Wolff [1] and it has recently gained interest in the design of low cost and high-quality filters and multiplexers for a new generation of satellite and wireless communication systems. Consequently, dual-mode micro-strip filters have been widely used in wireless communication system because of their advantages in applications requiring high-quality narrow-band microwave band-pass filters with features such as small size, low mass, and low loss. Thus far, various dual-mode resonators are tried and investigated, such as rectangular-, annular- and triangular-ring, that is also feasible for planar resonators, such as rectangular-, circularand triangular-planar resonators [2–7]. However, all the resonators have a fatal disadvantage that is high power loss including conductor loss, dielectric loss and radiation loss. In order to decrease radiation loss that is induced by the surface wave and by the currents on the patch, there are two kinds of techniques. One technique is to use EBG structure that will obstruct the surface wave, however, the EBG structure is not used owing to its larger size, higher cost and more difficult in fabricating, and the other technique is to etch some slots to change the direction of current, which will realize compacter filter and lower radiation loss [8–10].

It is familiar that the filter is fed by CPW structure. The characteristic impedance of CPW is mainly affected by the width of the middle signal line and the gap between signal line and ground, and almost not affected by the height of the substrate, and consequently, CPW structure can realize wider impedance bandwidth than that of traditional micro-strip, and also has the advantage of low radiation loss, low disperse and ease to match [11, 12].

In this paper, the second technique is used and this new filter uses a patch resonator etched by a pair of crossed slots. In Section 2, the working principle of dual-mode filter is described and two CPW-fed band-pass filters are proposed. In Section 3, the simulation results of two filters are got and analyzed, consequently, filter(b) which has smaller size than filter(a) is fabricated, the measurement results show good agreement with the simulation results. Finally, conclusions are given in Section 4.

2. DESCRIPTION OF THE FILTER

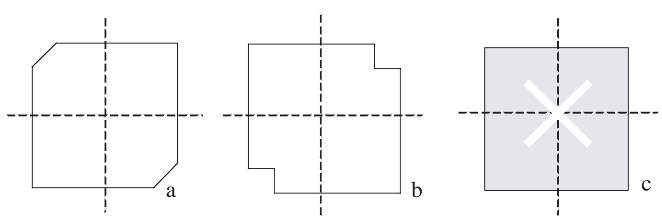

Figure 1. Sketch of the dual-mode resonators.

The dual-mode filter and single-fed circularly polarized radiating antenna share a common operating principle in that a perturbation element is added usually at a certain position of a resonator in order to slightly degrade its geometrical symmetry. In this way, the two degenerate modes with physical orthogonality can electrically be coupled with each other. Fig. 2 is the corresponding equivalent circuits of the dual-mode filter. By detuning the proper perturbation segments, the resonated frequency is separated between mode I and mode II. As for the filter, the coupling principle between two modes is the same like the coupling principle between two resonators. and therefore, two-level filter that is designed by use of two resonators can be realized by use of only one dual-mode resonator [13].

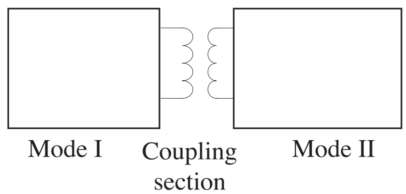

Figure 2. Equivalent circuits of the dual-mode filter.

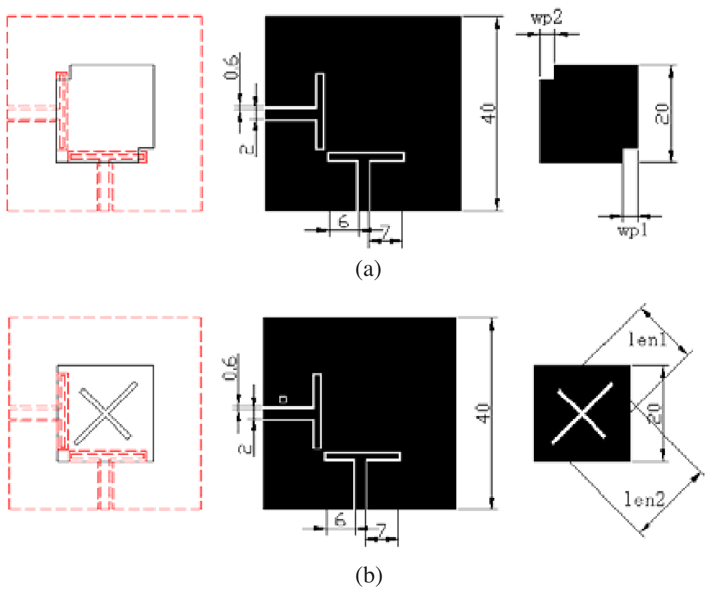

Figure 3. Schematics of two CPW-fed dual-mode band-pass filters: (a) corner-cut patch resonator, (b) cross-slotted patch resonator.

Figure 3 depicts the geometrical sketch of a dual-mode band-pass filter on the basis of a conventional micro-strip patch resonator incorporating the perturbation element, which is simply a pair of corner cuts at its diagonal plane A-B. The dimensions of the filter are shown in the Fig. 3. In the literature [14], the results about the filter performance varied with the geometric dimensions are given, but it supposes that wp1 is equal to wp2. In this paper, by optimizing wp1 and wp2 respectively, the new geometrical sketch is given.

The geometrical sketch of the CPW-fed section shown by the dashed line is on one side of the substrate and the patch resonator shown by solid line is on the other side of the substrate.

On the basis of the same CPW-fed section, the patch resonator etched by a pair of crossed slots is used. If two slots are equal, the resonator will work in the single mode, but if not, the resonator will work in the dual-mode.

3. SIMULATION AND EXPERIMENTAL RESULTS

Two filters are etched on a thin (1.0-mm thick) substrate, $\varepsilon_r = 10.0$, according to the parameters shown in the Fig. 3. The feeding configurations and the sizes of two filters are the same, but only the configurations of two dual-mode patch resonators are different. The numerical results is got by HFSS.

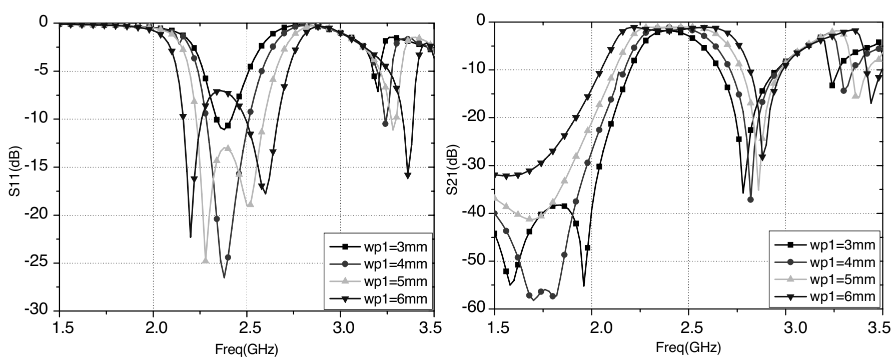

Figure 4. Simulation results of filter(a).

When wp1 is constant (3 mm), wp2 varies from 3 mm to 6 mm. the s parameters of the filter(a) are given in Fig. 4. From the results, when wp2 is 3 mm, the peak of the S11 is single, and f_1 is almost equal to f_2. Along with wp2 increasing, the difference between f_1 and f_2 enlarges and a two-peak S11 parameter is carried out. While wp2 varies from 3 mm to 6 mm, the bandwidth of filter enlarges. According to the demand of application, wp2 can be different value from 3 mm to 6 mm.

When len2 is constant (20.4 mm), len1 varies from 20.0 mm to 21.0 mm. the s parameters of the filter(b) are given in Fig. 5. From

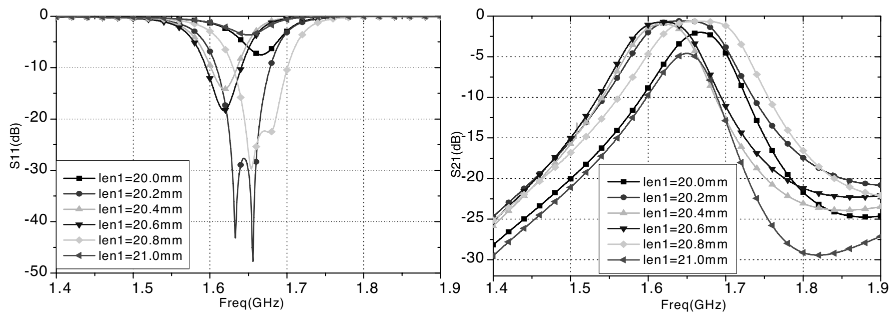

Figure 5. Simulation results of filter(b).

the results, when len1 is 20.4 mm, the peak of the S11 is single, f_1 is almost equal to f_2. Along with len1 deviating from len2, the difference between f_1 and f_2 enlarges, and a two-peak S11 parameter is shown. The more len1 deviates from len2, the higher the main frequency is and the wider the filter bandwidth is. To meet the demand of engineering application, different len1 can be adopted according to numerical results.

As far as two filters' configurations are concerned, in order to meet the same demand, the size of filter(b) can be much smaller than that of filter(a). In this paper, considering the volume and cost, the compact filter(b) is fabricated in the 206 institute of CWI Group which has len1 = 20.2 mm and len2 = 20.4.

From the above numerical results, filter(b) with len1 = 20.2 mm and len2 = 20.4 mm is fabricated in the 206 institute of CWI Group.

Figure 6 shows the measurement results of filter(b). there are

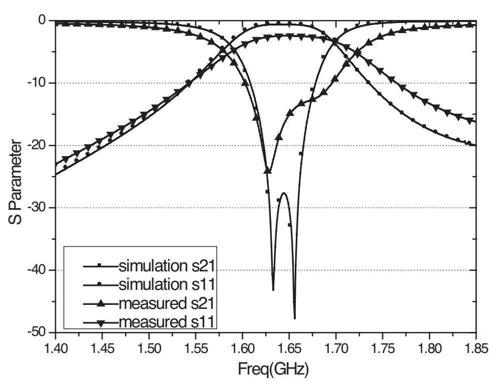

Figure 6. Simulation results and measurement results of filter(b) with len2 = 20.4 mm and len1 = 20.2 mm.

some deviation between numerical results and measurement results, due to dielectric loss, conductor loss and configuration error. But at changing tendency, those validated that the measurement results are good agreement with the numerical results.

4. CONCLUSION

Two compact CPW-fed band-pass filters using dual-mode patch resonator have been proposed. The patch resonator of filter(a) is a traditional patch with two corner-cut elements, and that of filter(b) is a traditional patch with two crossed slots. Two filters are simulated and studied. Some rules are gotten that filter(b) is more smaller filter(a) on the premise of the same working frequency and filter(b) has lower radiation loss than filter(b). Finally, filter(b) with len2 = 20.4 mm and len1 = 20.2 mm is fabricated, the measurement results show a good agreement with the simulation results.

ACKNOWLEDGMENT

This work has been supported by National High Technology Development Program (863) of China under contracts 2003AA005044. The authors also thank the 206 Institute of CWI Group for fabrication and measurement supports.

REFERENCES

1. Wolff, I., "Microstrip bandpass filter using degenerate modes of a microstrip ring resonator," *Electron. Lett.*, Vol. 8, No. 12, 302–303, June 1972.
2. Matsuo, M., H. Yabuki, and M. Makimoto, "Dual-mode stepped impedance ring resonator for bandpass filter applications," *IEEE Trans. Microwave Theory Tech.*, Vol. 49, 1235–1240, July 2001.
3. Hong, J.-S. and S. Li, "Dual-mode microstrip triangular patch resonators and filters," *IEEE MTT-S Int. Microwave Symp. Dig.*, 1901–1904, 2003.
4. Waegel, K. H. and R. Bauer, "Slot coupled dual-mode patch filters," *Electron. Lett.*, Vol. 32, No. 10, 878–879, May 1996.
5. Zhao, L.-P., X. Zhai, B. Wu, et al., "Novel design of dual-mode bandpass filter using rectangle structure," *Progress In Electromagnetics Research B*, Vol. 3, 131–141, 2008.

6. Wu, G.-L., W. Mu, X.-W. Dai, et al., "Design of novel dual-band bandpass filter with microstrip meander-loop resonator and CSRR DGS," *Progress In Electromagnetics Research*, PIER 78, 17–24, 2008.
7. Wang, Y.-X., B.-Z. Wang, and J. P. Wang, "A compact square loop dual-mode bandpass filter with wide stop-band," *Progress In Electromagnetics Research*, PIER 77, 67–73, 2007.
8. Zhu, L., P.-M. Wecowski, and K. Wu, "New planar dual-mode filter using cross-slotted patch resonator for simultaneous size and loss reduction," *IEEE Trans. Microwave Theory Tech.*, Vol. 47, 650–654, May 1999.
9. Chen, Z.-X., X.-W. Dai, and C.-H. Liang, "Novel dual-mode dual-band bandpass filter using double square-loop structure," *Progress In Electromagnetics Research*, PIER 77, 409–416, 2007.
10. Zhao, L.-P., X.-W. Dai, Z.-X. Chen, et al., "Novel design of dual-mode dual-band bandpass filter with triangular resonators," *Progress In Electromagnetics Research*, PIER 77, 417–424, 2007.
11. Huang, X. D. and C. H. Cheng, "A novel coplanar-waveguide bandpass filter using a dual-mode square-ring resonator," *IEEE Trans. Microw. Wireless Compon. Lett.*, Vol. 16, No. 1, 13–15, Jan. 2006
12. Zhang, X. Y. and Q. Xue, "Novel dual-mode dual-band filters using coplanar-waveguide-fed ring resonators," *IEEE Trans. Microwave Theory Tech.*, Vol. 55, 2183–2190, October 2007.
13. Garg, R., P. Bhartai, I. Bahl, et al., *Microstrip Antenna Design Handbook*, 493–500, Artech House, Boston London, 2000, www.artechhouse.com.
14. Hu, H. L. and C. H. Cheng, "A cpw bandpass filter using a dual-mode square patch resonator," *Journal of Microwaves*, Vol. 23, No. 2, 59–62, April 2007 (in Chinese).