Defected Ground Structure Coupled Miniaturized Dual-Mode Square Patch Bandpass Filter

***Yatendra Kumar Singh**, Abdulla P, Ajay Chakrabarty*

Department of Electronics and Electrical Communication Engineering, Indian Institute of Technology, Kharagpur – 721 302, India. Phone: +91-9932573239, Fax: +91-3222-255303, emails: yatendra@ece.iitkgp.ernet.in, abdulla@ece.iitkgp.ernet.in, bassein@ece.iitgkp.ernet.in

Abstract

This paper presents design of a defected ground structure coupled miniaturized dual-mode bandpass filter realized using a square patch. Two slots orthogonal to each other are cut on the patch to increase the path length of the fundamental mode while keeping the second mode current path almost unaffected. An inclined aperture cut on the ground plane right beneath the center of the patch is used to couple the two degenerate modes of the patch. The measured filter has a 3 dB fractional bandwidth of 21.7 % at 1.29 GHz. It's 58% smaller than a square patch filter.

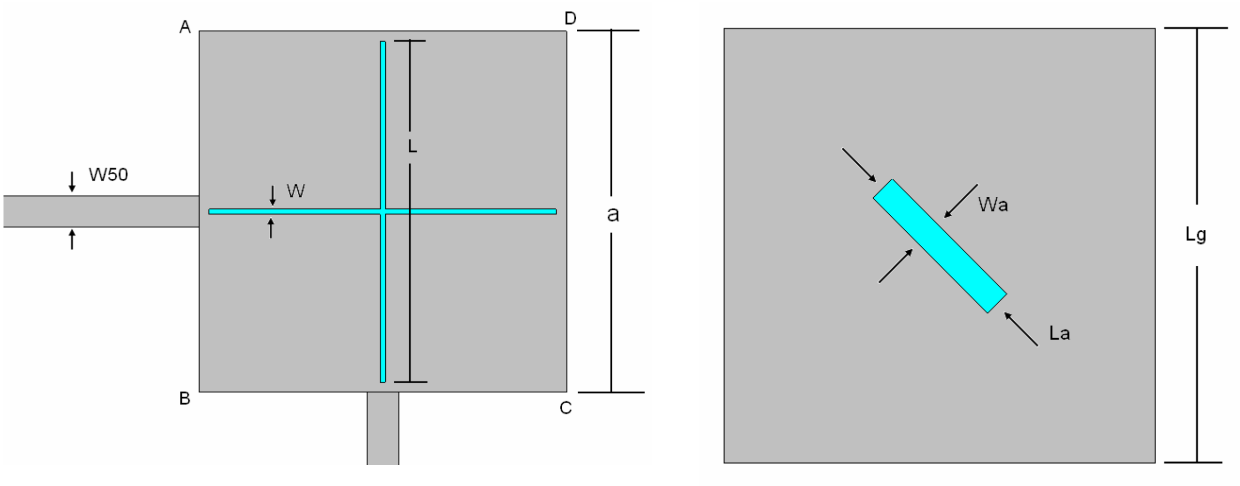
1. Introduction

Dual-mode bandpass filters have received considerable research interest since Wolff published work on dual-mode ring bandpass filter in 1972 [1]. They have become popular because space required by dual mode filters is half of that required by single-mode filters. Both ring and patch geometries have been used to design the dual-mode bandpass filters [2-9]. It has been possible to miniaturize the filters based on both the geometries. The ring based filters have been miniaturized either by meandering [2] or by loading the ring [3, 4]. To miniaturize the patch bandpass filters, patches are defected either by cutting slots or by digging holes [5-8]. In all the dual-mode bandpass filters, coupling between the degenerate modes of the resonator has been provided by creating a perturbation element in the resonator at a symmetric location relative to the two orthogonal feeds. The perturbation elements have been either a cut on the patch or an additional small patch added to the ring. In [9], a dual-mode bandpass patch filter excited by a photonic band gap (PBG) structure is reported. A defect is introduced in the PBG to increase the coupling between the degenerate modes of the square patch. The patch, however, is left intact.

In this paper, we report the design of a dual-mode bandpass filter realized using a square patch. The patch has two orthogonal slots created on it to reduce the resonance frequency of the fundamental mode. A novel idea of an aperture on the ground plane right below the patch has been used to introduce the coupling between the two degenerate modes of the resonator.

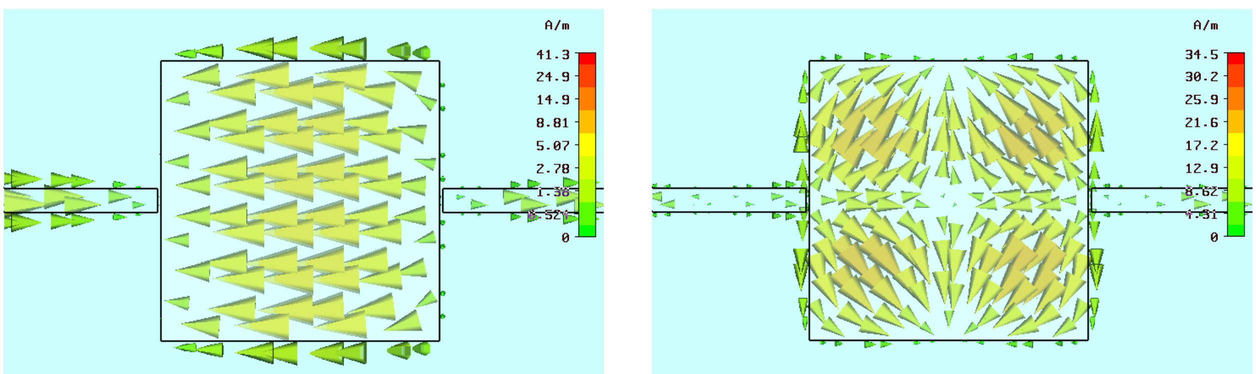
2. Filter Configuration

Fig. 1(a) shows a square patch of dimension 36 mm × 36 mm with two orthogonal slots on an FR4 substrate of thickness 1.5875 mm, dielectric constant of 4.3 and loss tangent of 0.01. Fig. 1(b) shows defected ground structure (DGS) beneath the patch. The dimension of the aperture on the ground plane is 5 mm × 30 mm. The slots on the patch have been oriented either parallel or perpendicular to the patch edges. This type of orientation increases the fundamental current path length while keeping the second higher order mode current path length almost unaffected [5]. This results in wide harmonic separation. Slots oriented along diagonal of a square patch bring down the resonance frequencies of both the fundamental and second order harmonic [6, 7]. From Fig. 2(a) and Fig. 2(b), the effect of slot orientation on the resonance frequencies can be easily explained. To couple the two degenerate modes of the slotted patch resonator, an inclined aperture is cut on the ground plane right underneath the slotted patch. The aperture is oriented along diagonal AC of the patch. This orientation gives rise to two attenuation poles, which do not exist if the aperture is directed along diagonal BD.



(a) (b)

Fig. 1 Final configuration of the proposed filter: (a) the patch resonator with crossed slots, (b) ground plane with inclined coupling aperture.

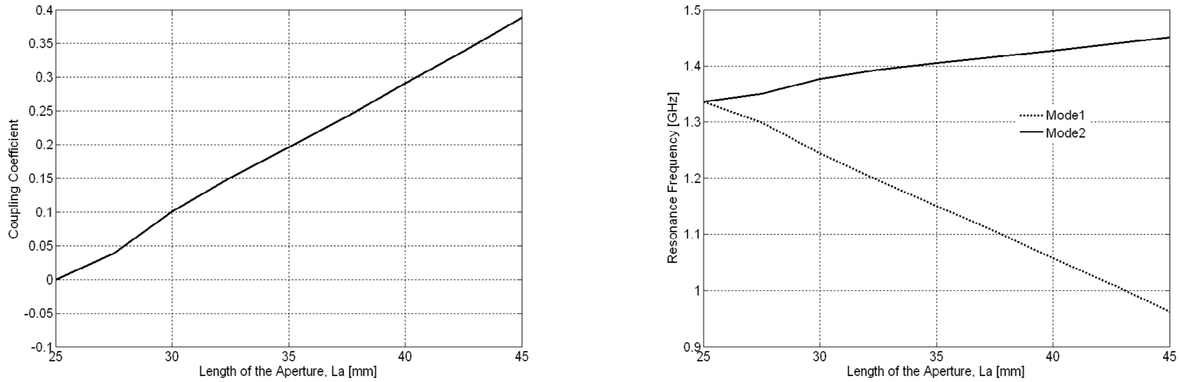


(a) (b)

Fig. 2 Simulated current distribution on a square patch without any slot: (a) the fundamental mode current, (b) the second higher order mode current.

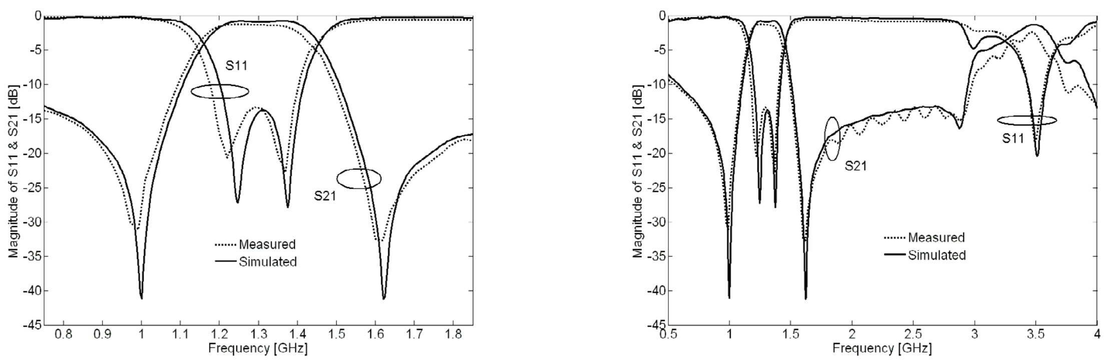
3. DGS Coupled Miniaturized Dual-Mode Patch Filter

The proposed filter was designed and simulated using CST-Microwave Studio 2006 [10] on an FR4 substrate of thickness 1.5875 mm. The final configuration of the filter is shown in Fig. 1. The values of the various parameters shown in Fig 1 and used in the final filter configuration are: a = 36 mm, L = 34 mm, W = 0.5 mm, W50 = 3.1 mm, La = 30 mm and Wa = 5 mm, length of the ground, Lg = 80 mm. Fig. 3(a) shows the variation of the coupling coefficient and Fig. 3(b) shows variation of the resonance frequency the two degenerate modes of the slotted patch with the variation in the length of the aperture for its fixed width of 5 mm. Fig 4(a) shows the measured and simulated results of the filter near the passband and Fig 4(b) shows the broadband results. The proposed filter has a 3 dB simulation fractional bandwidth of 21.8% and measured bandwidth of 21.7% at center frequency of 1.29GHz. The minimum simulated and measured passband insertion losses are 0.81 dB and 1.27 dB respectively. The simulated and measured return losses are better than 13.76 dB and 13.30 dB respectively. Filter has two measured attenuation poles of dip better than 31 dB at 0.993 GHz and 1.62 GHz. The second measured passband occurs at 3.47 GHz, which is 2.7 times of the fundamental passband center frequency of 1.29 GHz. The filter is 58% smaller compared to a square patch filter. The fabricated filter is shown in Fig. 5(a) and Fig. 5(b).



(a) (b)

Fig. 3 For an inclined ground aperture of width 5 mm, effect of its length on: (a) coupling between the two degenerate modes, (b) on the resonance frequencies of the two modes.



(a) (b)

Fig. 4 Measured and simulated frequency response of the proposed filter: (a) narrow band response, (b) wideband response.

(a) (b)

Fig. 5 Fabricated filter: (a) top side, (b) bottom side

4. Conclusion

This paper presents a design of a DGS coupled dual-mode bandpass filter using a square patch resonator. Two orthogonal slots are created on the square patch to reduce the fundamental resonance frequency while keeping the second mode resonance location almost unchanged. This results in a wide harmonic separation with the second passband occurring at 2.7 times that of the fundamental frequency. An inclined aperture is created on the ground plane to increase the coupling between the two orthogonal modes of the patch. The aperture is oriented in such a direction that it gives rise to two attenuation poles of dip more than 31dB on either side of the passband resulting in sharp cutoff.

5. References

1. I. Wolff, "Microstrip Bandpass Filter Using Degenerate Modes of a Microstrip Ring Resonator," *Electron. Lett.*, vol. 8, no. 12, June 1972, pp. 163-164.

2. J. S. Hong and M. J. Lancaster, "Microstrip bandpass filter using degenerate modes of a novel meander loop resonator," *IEEE Microwave Guided Wave Lett.*, vol. 5, Nov. 1995, pp. 371-372.

3. A. Gorur, C. Karpuz, and M. Akpinar, "A reduced-size dual-mode Bandpass filter with capacitively loaded open-loop arms," *IEEE Microw. Wireless Compon. Lett*., vol. 13, no. 9, Sept. 2003, pp. 385-387.

4. A. Gorur, "Description of coupling between degenerate modes of a dual-mode microstrip loop resonator using a novel perturbation arrangement and its dual-mode Bandpass filter application," *IEEE Trans. Microw. Theory Tech.*, vol. 52. no. 2, Feb 2004, pp. 671-677.

5. Wen-Hua Tu, and Kai Chang, "Miniaturized dual-mode Bandpass filter with harmonic control," *IEEE Microw. Wireless Compon. Lett.*, vol. 15, no. 12, Dec. 2005, pp. 838-840.

6. L. Zhu, B. C. Tan, and S. J. Quek, "Miniaturized dual-mode Bandpass filter using inductively loaded cross-slotted patch resonator," *IEEE Microw. Wireless Compon. Lett.*, vol. 15, no. 1, Jan. 2005, pp. 22–24.

7. L. Zhu, Pierre-Marie Wecowski, and K. Wu, "New planar dual-mode filter using cross-slotted patch resonator for simultaneous size and loss reduction," *IEEE Trans. Microw. Theory Tech.*, vol. 47, no. 5, May 1999, pp. 650–654.

8. B. T. Tan, S. T. Chew, M. S. Leong, and B. L. Ooi, "A modified microstrip circular patch resonator filter," *IEEE Microw. Wireless Compon Lett.*, vol. 12, no. 7, Jul. 2002, pp. 252–254.

9. S. T. Chew and T. Itoh, "PBG-excited split-mode resonator Bandpass filter," *IEEE Microw. Wireless Compon. Lett.*, vol. 11, no. 9, Sept. 2001, pp. 364–366.

10. *Computer Simulation Technology, GmbH,* CST Microwave Studio 2006, Oct. 2005.