Design of a Dual-Mode Dual-Band Bandpass Filter with a Novel Feed Scheme

Ali Kürşad Görür[1], Ayşe Nihan Basmacı[2], and Ceyhun Karpuz[2]

[1]Nevsehir University, Department of Electrical and Electronics Engineering, Turkey
akursadgorur@hotmail.com
[2]Pamukkale University, Department of Electrical and Electronics Engineering, Turkey
nihanbsmc_86@hotmail.com, ckarpuz@pau.edu.tr

Abstract

A novel feed scheme is presented to design a dual-mode dual-band microstrip bandpass filter. The proposed filter has two square loop resonators for both passbands and each resonator are fed by a feedline placed on the upper corners of resonators. Proposed structure allows controlling each passband separately in terms of mode frequencies and transmission zeros. By means of the perturbation elements such as patches or cuts, two degenerate modes can be excited. Also, wideband harmonic suppression can be achieved through this novel feed scheme. Two bandpass filters having elliptical and linear phase frequency responses have been fabricated for experimental verification of the predicted results. Measured results are in good agreement with simulated results.

1. Introduction

According to the recent developments in modern wireless communication systems, RF/microwave devices extensively need bandpass filters having multiple separated frequency bands with dual-mode characteristics. In the literature, multiple frequency bands can be designed by using multiple resonators resonating at different frequencies, stepped impedance resonators (SIR), stacked loop resonators, etc [2-5]. In addition to this, for doubly tuned resonant circuit for each passband, dual-mode resonators are quite important. Exciting two degenerate modes can be achieved by placing a patch or corner-cut element to the symmetry axis of the resonator [7]. To date, many authors have studied on dual-mode resonators and dual-band filters [1-7], but there are fewer studies on dual-mode dual-band microstrip bandpass filters [3-5].

In this paper, a novel feed scheme is proposed for dual-mode dual-band bandpass filter application. So that, input and output ports are located at the top of the resonator and coupled to the resonator from the upper left and right corners. Two separate dual-mode resonators are fed by two separate feedlines. Besides, elliptical and linear phase frequency responses have been obtained in both passbands by means of perturbation patches or cut elements. Another important feature of this work is that harmonics of the first passband has been suppressed without using open loop stubs (OLS) or any loading elements by locating the feedlines as shown in Fig. 1 [5,8]. Center frequencies of the first and second passbands are designed as 1.8 GHz and 2.73 GHz, respectively.

2. Design Procedure

In this study, two dual-mode resonators, resonating at different frequencies, are used to achieve a dual-mode dual-band bandpass filter application. They are located one within the other to remove extra circuit area [5, 8]. Therefore, in order to keep the structure of square loop resonators, an air bridge is used. As can be seen from Fig. 1, feedlines are located on the upper left and upper right corners of each resonator with 180^0 relative to each other [6]. But, by locating the input and output ports with a quarter wavelength, square loop resonators have been gained dual-mode characteristic. In [6], the effect of non-orthogonal input/output feedlines located along a straight line on the frequency response have been investigated and so, adjustable transmission zeros have been obtained.

From Fig. 1, each resonator has its own patch element and they are independent from the other one, so each passband can be controlled separately in terms of mode frequencies and transmission zeros. By changing p_1 and p_2 (depths of perturbation elements), perturbation effect is created and so exciting degenerated modes of the related passband can be achieved. While p_1 and p_2 are in negative position, transmission zeros are occurred on the imaginary axis. So, linear phase characteristic can be obtained. As can be seen from Fig. 1a, widths of perturbation elements are kept at 2.4 mm.

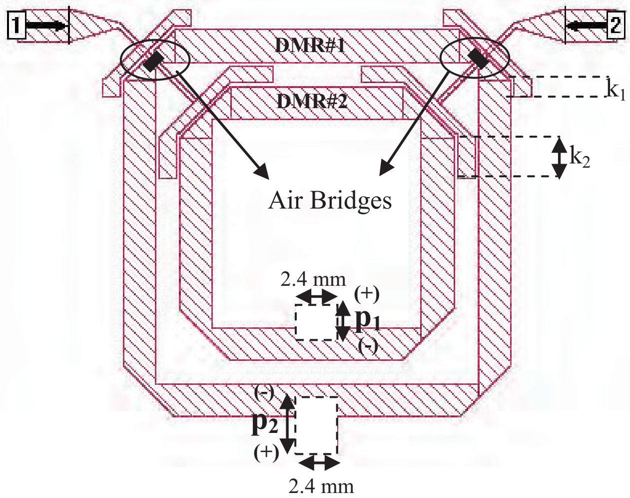

Fig. 1. Proposed Filter Structure

3. Dual-Mode Dual-Band Bandpass Filter Design

A dual-mode dual-band microstrip bandpass filter has been designed using dual-mode square loop resonators. Proposed structure has compactness, because one resonator has been located within the other. Both resonators are fed by two feedlines from their upper left and right corners with a quarter wavelength. As can be seen from Fig. 1, DMR#1 has larger size than DMR#2, so that it is resonating at lower frequencies according to the relation between wavelength and frequency, λ=c/f. Each resonator has its own perturbation elements, as a patch or cut element, and two degenerated modes of each passband can be excited through these perturbation elements. Depths of perturbation elements are defined as p_1 and p_2 for the first and second passbands, respectively. While they are in the negative position, transmission zeros are occurred on the imaginary frequencies, otherwise they are occurred on the real frequencies. As is well known, by increasing p_1 and p_2 in the positive or negative direction, without changing the width of perturbation patches, location of transmission zeros and mode frequencies can be changed.

Dimensions of only one edge of DMR#1 and DMR#2 are 22.6 mm and 16 mm, respectively and two feedlines locating inside and outside of DMR#1 have different dimensions as given in Fig. 1a. In addition, perturbation elements have equal width and changes in p_1 and p_2 on the negative and positive way affect mode frequencies for linear or elliptical phase frequency responses in both passbands. Three different frequency responses corresponding to different perturbation dimensions can be seen in Fig. 2. In Fig. 2a, transmission zeros are occurred on the imaginary frequencies, therefore both passbands have linear phase characteristics. Mode frequencies in each passband can be controlled separately by means of different cut elements. For the first passband mode splitting begins while p_1 is -1.2 mm. For the second passband in Fig. 2a, mode splitting occurs at -0.7 mm. Return loss levels can also be adjusted by changing p_1 and p_2. As can be seen from Fig. 2a, only one passband is changing holding the other one. Elliptical frequency response is investigated in Fig. 2b. In this case, two transmission zeros for each passband are on the real frequency axis and they can be controlled by means of patch element. Increment in p_2 causes that the transmission zeros are moving away from each other. Again, degenerated modes can be excited due to the change in p_2. For the first passband, when p_1 is 2 mm, mode splitting occurs and as shown in Fig. 2b, while p_1 is increasing, mode frequencies are moving away from each other. As can be seen, lower mode frequency is shifting to much lower frequencies, but, higher mode frequency is remaining almost the same, so that bandwidth is widening with increasing p_1. For the second passband, mode splitting begins to occur when p_2 is 1 mm. Effects of changes in mode frequencies are same with the first passband because of the same resonator configuration.

Fig. 3 shows coupling coefficient and mode frequencies with respect to perturbation depths for each passband. According to the formula $k=(f_2^2 - f_1^2)/(f_2^2 - f_1^2)$, while mode frequencies are moving away from each other, coupling coefficient will increase. Negative perturbation depths represent cut elements as mentioned before. Besides, in the absence of any perturbation element, there will be no transmission as known from [1]. As can be seen from Fig. 3, even-mode excitation is observed at lower mode frequencies because of their wider mobility.

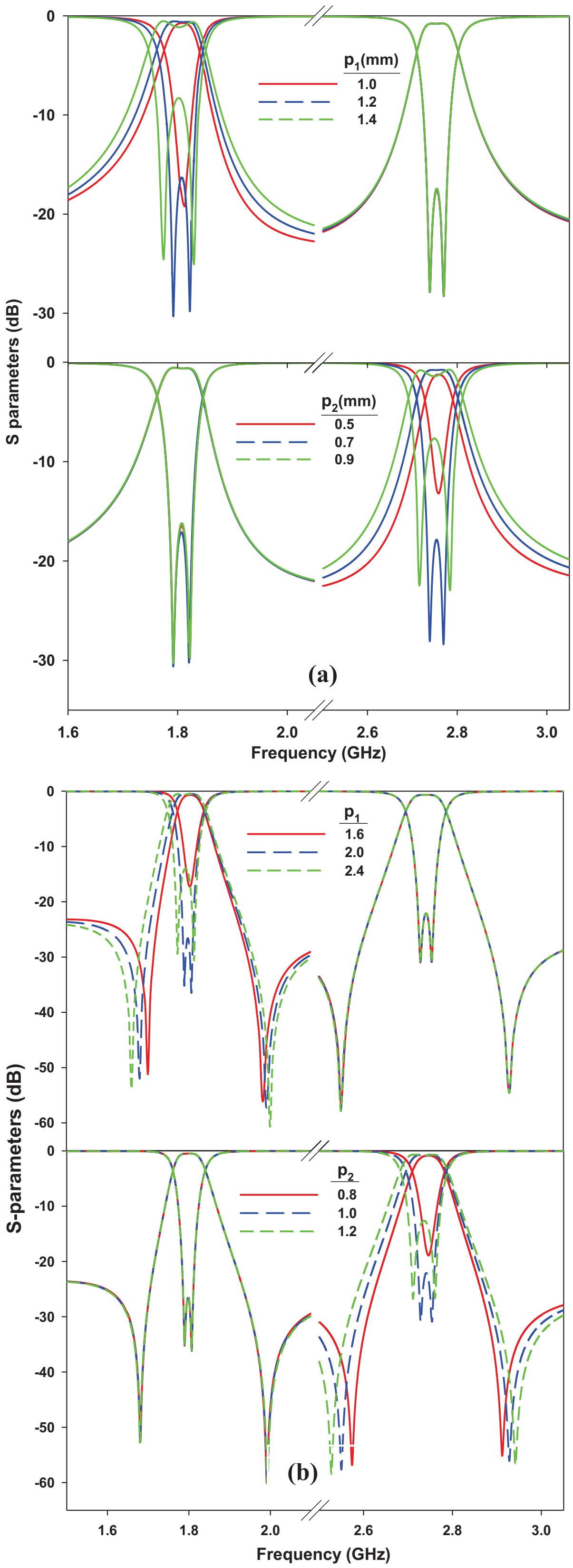

Fig. 2. Effect of perturbation dimensions on the frequency responses **a.** for linear phase frequency response **b.** for elliptical phase frequency response

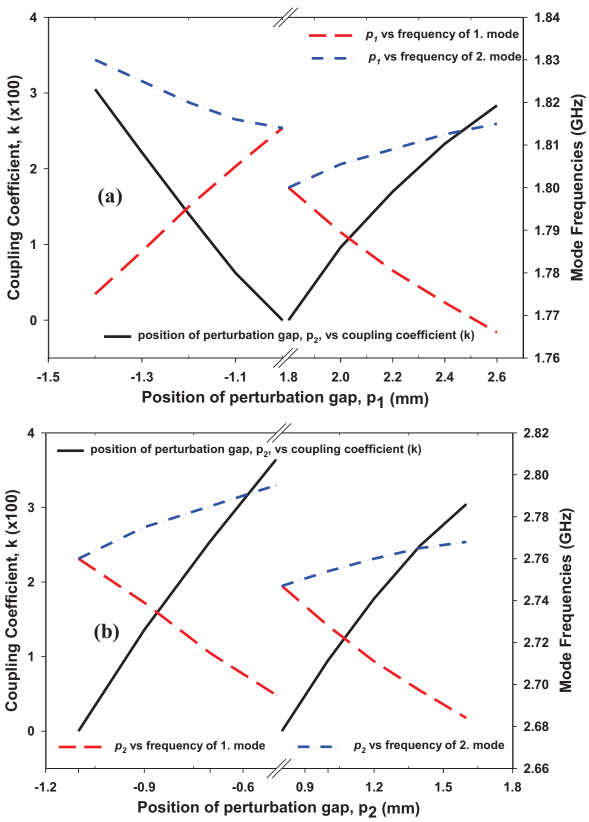

Fig. 3. Coupling coefficient and mode frequencies with respect to perturbation positions **a.** p_1 **b.** p_2

Simulated surface charge distributions of designed dual-mode dual-band bandpass filter has been shown in Fig. 4. For the charge distribution of elliptical filter, p_1 and p_2 are given as 2 mm and 1 mm, respectively. For the first passband, mode frequencies have been obtained at 1.789 GHz and 1.811 GHz. In the second passband, mode frequencies have been obtained at 2.728 GHz and 2.754 GHz. As can be seen from Fig. 4a, charge distribution for the even mode frequency has been observed on the upper edges of resonators for both passbands and for the odd mode frequencies bottom edges of resonators have much more charge distribution. For linear phase filter, mode frequencies for the first and second passbands have been obtained at 1.792 GHz, 1.820 GHz and 2.739 GHz, 2.77 GHz, respectively. In this case, p_1 and p_2 are 0.7 mm and 1.2 mm, respectively. Charge distributions show opposite behavior according to elliptical filter. For the even mode frequencies for each passband, charge distribution is more intense on the bottom edges of resonators and for the odd mode frequencies, charge distribution can be observed on upper edges. It is also seen that, charge distribution for a mode frequency can be observed at only one resonator by means of the design configuration.

4. Experimental Results

Designed dual-mode dual-band bandpass filters have been fabricated on an RT/Duroid substrate having a thickness of 1.27 mm and a relative dielectric constant of 6.15. Fabricated filters have been measured with an HP8720C Vector Network Analyzer. All simulations have been realized by a full wave EM

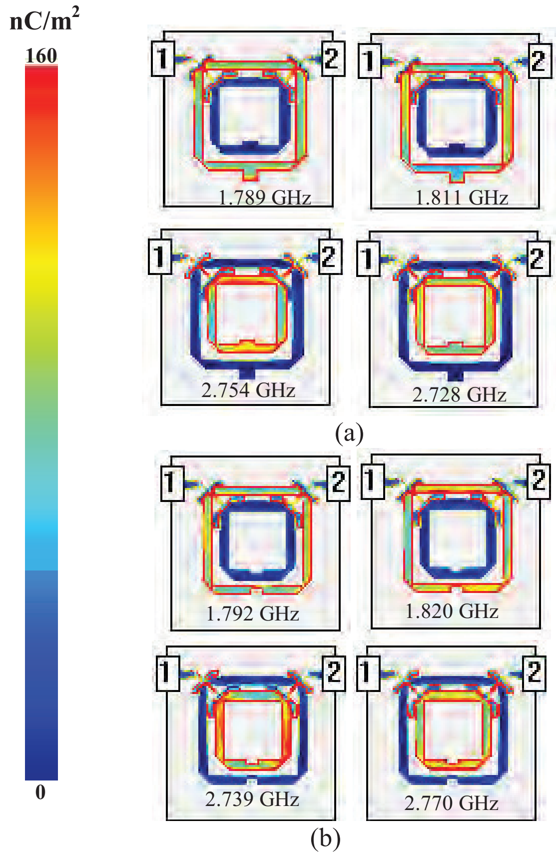

Fig. 4. Charge distributions at mode frequencies for the filter having **a.** an elliptical phase **b.** a linear phase

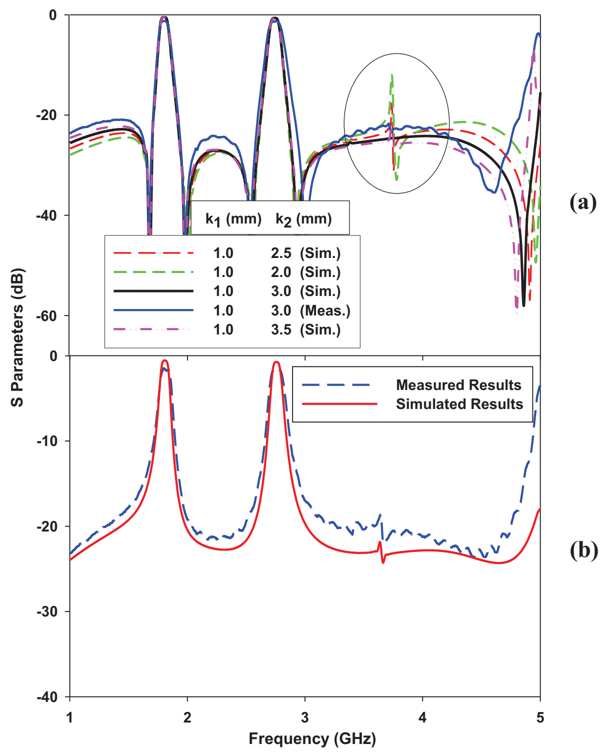

Fig. 5. Wideband frequency response investigation of **a.** elliptical phase filter **b.** linear phase filter

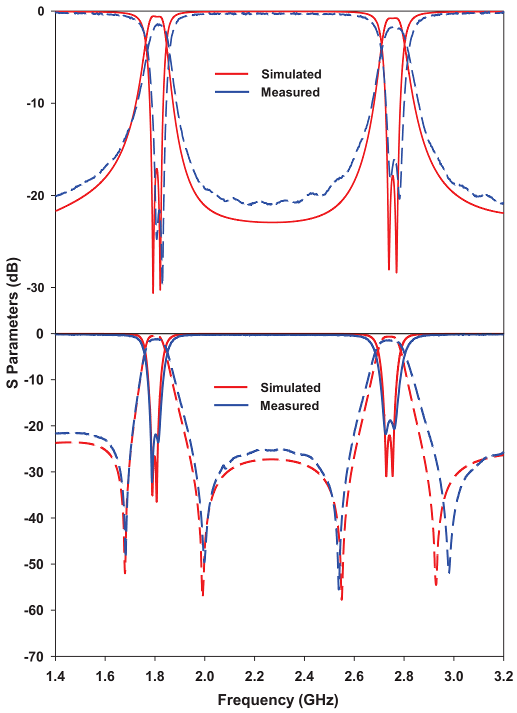

Fig. 6. Simulated and measured results (Dashed lines are for S_{21}, solid lines are for S_{11})

Simulator [9]. Dimensions of the fabricated filters have been shown in Fig. 1 and DMR#1 and DMR#2 have 22.6x22.6 mm^2 and 16x16 mm^2 surface areas, respectively. In Fig. 5, linear phase and elliptical phase wideband simulated and measured results are shown. For both phases, first passband has a harmonic in the vicinity of 3.7 GHz and suppression of this harmonic has been achieved by means of the design configuration. In [5, 8], hairpin resonators and loading stubs have been used for harmonic suppression. Meanwhile, in this work, feedlines are located to act as them. For elliptical phase filter, as can be seen from the Fig. 5a, while k_1 and k_2 are 1.0 mm and 3.0 mm, respectively, harmonic suppression has been achieved completely. Wideband results of linear phase filters have also been investigated in Fig. 5b for k_1 and k_2 are 1.0 and 3.5 mm, respectively.

6. Conclusions

A dual-mode dual-band microstrip bandpass filter with a novel feed scheme has been presented in this paper. Feedlines have been located with a quarter wavelength with respect to each other. By using a perturbation element, elliptical and linear phase frequency responses for both passbands has been obtained. Charge distribution at mode frequencies, coupling coefficient corresponding to perturbation dimensions and wideband frequency response for both passbands has also been investigated. By means of the designed filter configuration, harmonic suppression has been achieved and so, a wide stopband has been obtained until 5 GHz. Designed structure has two controllable passbands and two filter prototypes have been fabricated for experimental verification of the predicted results. Simulated and measured results are in an excellent agreement.

7. References

[1] J. S. Hong and M. J. Lancaster, Microstrip Filters for RF/Microwave Applications, Wiley, New York, 2001.

[2] Tsung-Hui Huang; Han-Jan Chen; Chin-Sheng Chang; Lih-Shan Chen; Yeong-Her Wang; Mau-Phon Houng; , "A novel compact ring dual-mode filter with adjustable second-passband for dual-band applications," *Microwave and Wireless Components Letters, IEEE* , vol.16, no.6, pp. 360- 362, June 2006

[3] Chu-Yu Chen; Cheng-Ying Hsu; , "A simple and effective method for microstrip dual-band filters design," *Microwave and Wireless Components Letters, IEEE* , vol.16, no.5, pp. 246- 248, May 2006

[4] Jian-Xin Chen; Yum, T.Y.; Jia-Lin Li; Quan Xue; , "Dual-Mode Dual-Band Bandpass Filter Using Stacked-Loop Structure," *Microwave and Wireless Components Letters, IEEE* , vol.16, no.9, pp.502-504, Sept. 2006

[5] A. Görür and C. Karpuz,"Compact dual-band bandpass filters using dual-mode resonators", *2007 IEEE MTT-S International Microwave Symposium Digest*, pp.905-908, Jun 3-8, 2007, Honolulu, Hawaii.

[6] Erylmaz, G.M.; Karpuz, C.; Gorur, A.; , "Dual-mode microstrip filters with adjustable transmission zeros," *Microwaves, Antennas & Propagation, IET* , vol.2, no.8, pp.839-847, December 2008

[7] Gorur, A.; , "Description of coupling between degenerate modes of a dual-mode microstrip loop resonator using a novel perturbation arrangement and its dual-mode bandpass filter applications," *Microwave Theory and Techniques, IEEE Transactions on* , vol.52, no.2, pp. 671- 677, Feb. 2004

[8] Karpuz, C., Gorur, A.; , "Dual-mode dual-band microstrip filters," *Microwave Conference, 2009. EuMC 2009. European* , vol., no., pp.105-108, Sept. 29 2009-Oct. 1 2009

[9] EM User's Manual, Sonnet Software, Inc., Liverpool, NY, 2008.

Table 1. Numerical simulated and measured results for elliptical and linear phase filters

	1. Band				2. Band			
	f_0(GHz)	RL(dB)	IL(dB)	FBW(%)	f_0(GHz)	RL(dB)	IL(dB)	FBW(%)
Simulated (Elliptical)	1.797	26.24	0.48	4.4	2.741	-21.29	-0.667	3.3
Measured (Elliptical)	1.802	22.18	1.263	5.26	2.744	-18.8	-1.476	4.3
Simulated (Lineer)	1.805	-17.2	-0.62	4.7	2.753	-17.9	-0.78	3.3
Measured (Lineer)	1.816	-21.7	-1.55	4.9	2.762	-15.8	-1.74	4.1