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A COMPACT SQUARE LOOP DUAL-MODE BANDPASS FILTER WITH WIDE STOP-BAND

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Abstract—A new dual-mode microstrip bandpass filter with wide stop-band is presented using the square loop resonator with tree-shaped patches attached to the four inner corners of the loop. The mode splitting is realized by introducing a small cut locating at a 45° offset from its two orthogonal modes. It is shown that the dual-mode filter has a wide stop-band including the first spurious resonance frequency. The center frequency can be tuned. Moreover, the proposed filter has a smaller size compared with conventional dual-mode bandpass filters at the same central frequency.

1. INTRODUCTION

Microstrip filters have found wide applications in many RF/microwave circuits and systems. For microwave bandpass filters, compact size and high-performance are highly desirable in wireless communication systems, such as satellite and mobile communication systems [1–5]. Dual-mode resonators have been widely used to realize microwave filters due to their advantages such as small size, low mass, and low loss. Each of dual-mode resonators can be used as a doubly tuned resonant circuit, and therefore the number of resonators required for a n-degree filter is reduced by half, resulting in a compact filter configuration.

The first planar dual-mode filter was presented by Wolff [6]. After that, numerous researchers have proposed various configurations for the dual-mode filters [7–14]. In order to reduce the size of dual-mode filter, authors proposed dual-mode loop [7], slotted patch [8], meander resonators [9], ring [10], open-loop arms dual-mode filter [11], dual-mode filter with capacitive loaded open-loop arms [12], and capacitive

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stepped-impedance resonator [13]. However, some present dual-mode filter configurations occupy still a fairly large circuit area, where the miniaturization is an important factor in wireless communication system. Therefore, it is desirable to develop new types of dual-mode microstrip resonators not only for offering alternative designs, but also for miniaturizing filters. On the other hand, modern wireless communication systems require the bandpass filters having out-of-band spurious rejection performance as well as good in-band performance.

In this paper, a square loop resonator with tree-shape patches attached at the four corners is presented. The new filter structure not only has a smaller size, as compared with the dual-mode microstrip loop [7], cross-slotted patch [8], meander loop resonator [9], ring [10], open-loop arms dual-mode filter [11], and capacitive stepped-impedance resonator [13], but also has a wide upper stop-band, which is very important in wireless communication systems.

2. DUAL-MODE RESONATOR

Figure 1 shows the geometry of the proposed dual-mode microstrip loop resonator. A regular square loop with tree-shape patches attached at the four corners forms the basic element of the resonator. A small triangle cut attached to the dual-mode resonator at a symmetrical

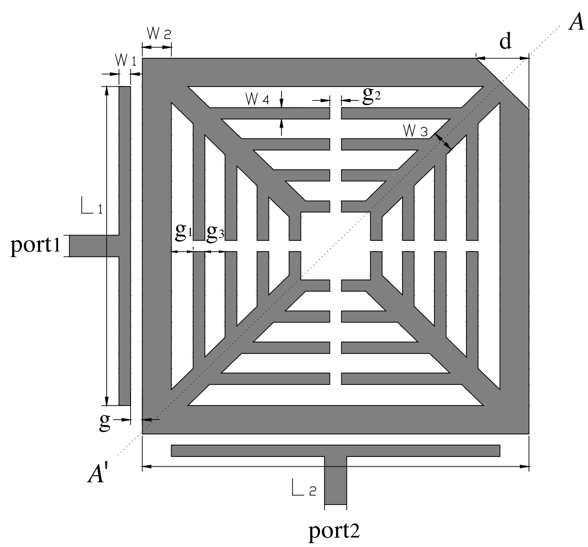

Figure 1. Layout of the proposed dual-mode bandpass filter.

location along the symmetry line $A - A'$, 135° apart from both input and output ports, is employed as an additional perturbation element. There is an electrical length of 90° between input and output ports. The degeneration modes are excited and coupled to each other due to the small triangle cut perturbation.

According to the model described in [14], where the top and bottom of the cavity are perfect electric walls and the remaining sides are perfect magnetic walls, the electromagnetic fields inside the loop cavity can be expanded in terms TM^z (where z is perpendicular to the ground plane). Although each arm of proposed resonator attaches tree-shape patch, two fundamental degenerate modes correspond to TM^z_{100} and TM^z_{010} modes in a square patch resonator, as described in [9]. Fig. 2 shows the simulated electric field patterns using electromagnetic simulation tool Ansoft's HFSS. The excited resonant mode is corresponding to the TM^z_{100} mode in square loop resonator when port 1 is excited, which is named mode-1. It can be seen from this pattern that two zeros are located at the left-lower and the right-upper corners. If the excitation port is changed to port 2, the field pattern is rotated by 90° for the associated degenerate mode, which corresponds to the TM^z_{010} in a square loop resonator, named mode-2. When $d \neq 0$, no matter what the excitation port is, both the degenerate modes are excited and coupled to each other, which causes resonance frequency splitting. The degree of coupling depends on d, which in turn controls the mode splitting. To observe the mode splitting, the dual-mode resonator has been simulated using the electromagnetic simulation tool Ansoft's HFSS with different perturbation size d. Fig. 3 shows the simulated split resonance frequencies of two modes of the loop resonator with different perturbation sizes. As can be seen from Fig. 3

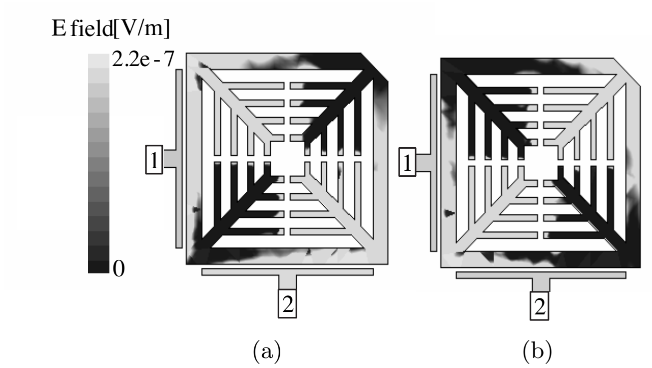

Figure 2. Simulated electric field patterns of the proposed dual-mode filter. (a) Mode-1 (1.57 GHz), (b) Mode-2 (1.59 GHz).

that the split between two modes increases as the perturbation size d increases. Without the perturbation ($d = 0$), neither splitting of the resonance frequency nor passband response has been observed.

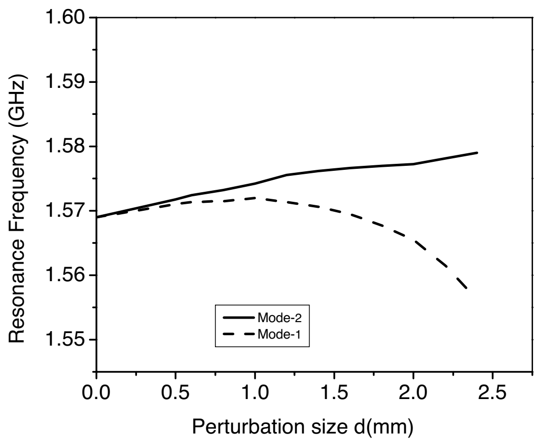

Figure 3. Two resonance frequencies of degenerate modes versus the perturbation size d.

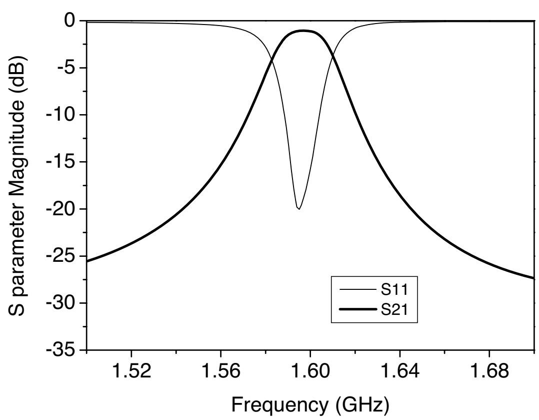

Figure 4. Simulated S parameters with $L_1 = 11.3\,\text{mm}$, $L_2 = 13.3\,\text{mm}$, $w_1 = 0.4\,\text{mm}$, $w_2 = 1.0\,\text{mm}$, $w_3 = 0.8\,\text{mm}$, $w_4 = 0.4\,\text{mm}$, $d = 1.8\,\text{mm}$, $g_1 = 0.83\,\text{mm}$, $g_2 = 0.4\,\text{mm}$, $g_3 = 0.7\,\text{mm}$, $g = 0.3\,\text{mm}$, $\varepsilon_r = 10.8$, and $h = 1.27\,\text{mm}$.

3. DUAL-MODE BANDPASS FILTER

The proposed dual-mode bandpass filter was fabricated on an RT/Duroid substrate having a thickness of 1.27 mm and a relative dielectric constant of 10.8. After an optimal design process, the structure parameters of the proposed dual-mode filter are chosen as follows (refer to Fig. 1): $L_1 = 11.3\,\text{mm}$, $L_2 = 13.3\,\text{mm}$, $w_1 = 0.4\,\text{mm}$, $w_2 = 1.0\,\text{mm}$, $w_3 = 0.8\,\text{mm}$, $w_4 = 0.4\,\text{mm}$, $d = 1.8\,\text{mm}$, $g_1 = 0.83\,\text{mm}$, $g_2 = 0.4\,\text{mm}$, $g_3 = 0.7\,\text{mm}$, and $g = 0.3\,\text{mm}$. Fig. 4 shows its simulated frequency responses. The simulated passband width is about 1.5% at the central frequency of 1.59 GHz. The simulated minimum insertion loss is -1.06 dB. The return loss is better than 20 dB within the passband. Fig. 5 shows a wide range frequency response. It can be seen that the proposed filter exhibits a wide stopband with a rejection better than 20 dB up to 3.85 GHz. Compared with the wide stopband of the dual-mode microstrip filter with open-loop arms [11], the proposed dual-mode filter has an advantage that the central frequency can be adjusted by changing the lengths and spaces of these tree-shape patches. Moreover, the dual-mode filter has a compact size of $13.3 \times 13.3\,\text{mm}^2$, with a size reduction of about 56% as compared with the dual-mode microstrip loop [7], cross-slotted patch [8], and ring [10]. Also, the size reduction is about 31% against the meander loop resonator filter [9]. Although the size of the proposed filter is a litter bit larger than dual-mode filter with capacitive loaded open-loop arms [12], it has a wider stopband, and the structure is relatively simpler. In reference [13], to demonstrate

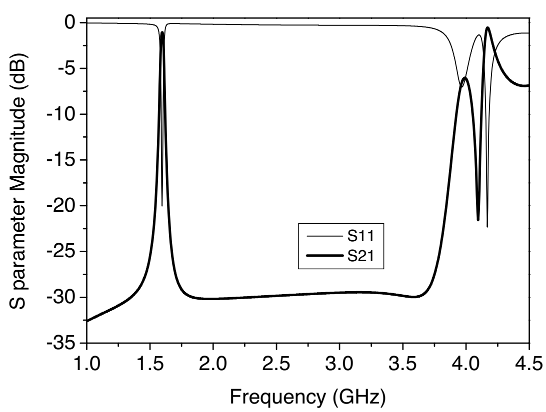

Figure 5. Wide range frequency performances of the proposed microstrip bandpass filter.

the frequency-tuning advantage, four varactors are used to replace the loading capacitance in the four corners of the resonator. When the filter operates at the center frequency of about 1.59 GHz with the bias voltage of diode 15 V, the size is $31 \times 31\,\mathrm{mm}^2$. We also use the same substrate RO4003 [13] to design the filter, but adopt the structure in Fig. 1. The simulated results show that the size is about $20 \times 20\,\mathrm{mm}^2$. It is apparent that the size is greatly reduced by using our proposed structure compared with that given in [13].

4. CONCLUSION

A new dual-mode microstrip square loop resonator with tree-shape patches attached at the four corners has been proposed. A dual-mode bandpass filter with 1.5% bandwidth at the central frequency of 1.59 GHz has been designed to demonstrate the application of the proposed loop resonator for designing compact microstrip filters. The proposed filter has a wide stop-band. It also has a size reduction of about 56% with respect to the dual-mode microstrip loop, cross-slotted patch, ring, and about 31%, and 58% size reduction against the meander loop filter and capacitive stepped-impedance resonator at the same center frequency.

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