A Modified Microstrip Circular Patch Resonator Filter

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***Abstract*—Circular holes are etched off of a microstrip disk resonator. This results in a reduction of 30% in size. By offsetting the positions of some of these holes, degenerate orthogonal mode is excited, resulting in a split-mode bandpass filter. This filter can be considered as a lattice-type structure. A filter with a bandwidth of 8% centered at 2.0 GHz was designed. The measured insertion loss is 0.6 dB.**

***Index Terms*—Circular patch, filter, lattice structure, split mode.**

I. Introduction

MICROWAVE resonators are widely employed in a myriad of applications such as filters, oscillators, and tuned amplifiers. There is a strong interest in the wireless communication community to miniaturize such resonators. In [1], triangular stubs are used to achieve miniaturization by exploiting the slow-wave effect. This approach is also adopted in [2], whereby slow-wave, open-loop resonators are employed. It has been shown that a resonator with dual degenerate modes can also be designed as a filter [3]–[5]. In [4], it has been demonstrated that a square microstrip resonator can also exhibit filter characteristics by etching periodic structures on the ground plane underneath with some defects.

In this paper, a filter will be designed by etching four circular holes off of the microstrip disk resonator instead. This allows ease of assembly and packaging. It is also expected that the modified resonator will exhibit a lower resonant frequency, as compared to the conventional disk resonator of the same size. Filter response is achieved by offsetting the positions of some of these holes. The coupling level with respect to the amount of offset will be characterized. A commercial EM simulator (*IE3D*) is used to simulate the filter response. A 2.0 GHz filter will be designed and measured.

II. Disk Resonator

The resonant frequency of a microstrip disk resonator, as shown in Fig. 1(a), can be readily approximated using perfect magnetic walls at $r = a$. The dominant mode resonant frequency is given by

$$f_{110} = \frac{1.841 c_0}{2\pi a \sqrt{\varepsilon_r}}. \tag{1}$$

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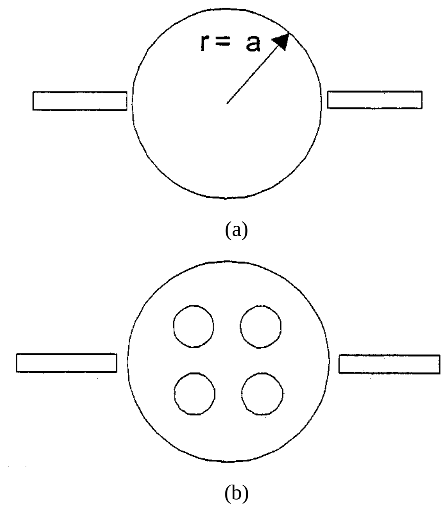

Fig. 1. (a) Microstrip disk resonator; (b) modified disk resonator with four etched holes.

For a 2.4 GHz resonator using RT6010 with a dielectric constant of 10.2 and thickness 25 mils, the radius a of the circular patch is computed to be 11.47 mm. The resonator is then analyzed using EM. The simulated resonant frequency is 2.39 GHz, showing good agreement with the closed-form equation.

In Fig. 1(b), four circular holes each of radius 3.3 mm were etched off the patch at positions $r = 6.47$ mm, $\phi = 45°$, 135°, 225°, and 315°. There is still symmetry in the layout. The structure is then simulated using *IE3D*. Through simulation, it has been observed that the hole-size affects the dominant mode frequency. A larger hole-size will result in a lower dominant frequency. In our design, the dominant frequency was shifted from 2.4 GHz to 2.0 GHz.

The result is then compared against the experimental result, which is shown in Fig. 2. Both results are in good agreement. Miniaturization is achieved, resulting in about 30% savings of real estate and hence a more compact packaging.

III. Filter Design and Measurement

As the modified resonator maintains symmetry, it supports dual degenerate modes. Hence, adopting the same approach in [4], the filter is designed, as shown in Fig. 3.

There is symmetry along axis AA'. Initially, the holes are located at $r = 6.47$ mm to create a resonant structure at 2 GHz. An offset in the position of the holes along axis AA' will cause the other degenerate mode to be excited. Hence, the amount of offset along AA' will determine the amount of coupling to the

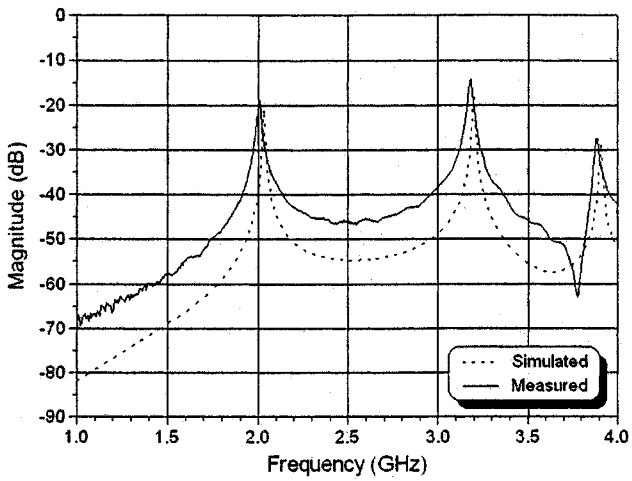

Fig. 2. Simulated and measured results of the modified resonator.

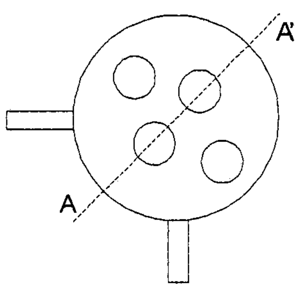

Fig. 3. Proposed filter with offset etched holes along AA'.

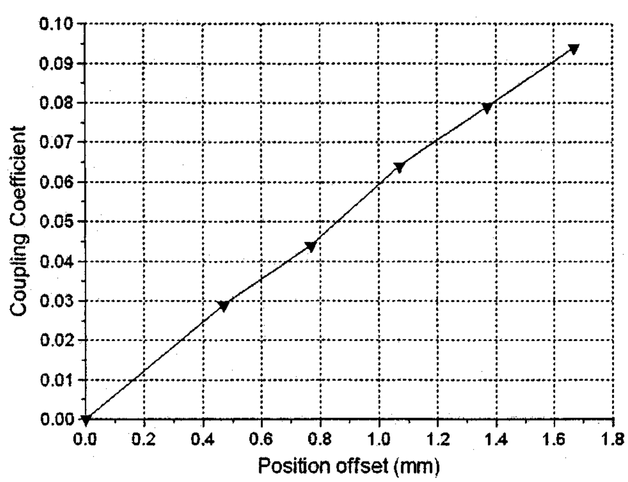

Fig. 4. Simulated coupling coefficients for different offsets along AA'.

other mode. This affects the bandwidth as well as its passband performance.

To characterize this coupling between the two modes, various position offsets along AA' are simulated. The two EM-simulated split mode resonant frequencies are then noted for computation of the coefficient of coupling [5]. Fig. 4 shows the coupling coefficient with respect to the position offsets.

A disk resonator of resonance frequency 2.4 GHz is first selected. Knowing that the etched holes will cause a 17% reduction in the resonant frequency, a filter is then designed at 2.0 GHz with a coupling coefficient of 0.094 and bandwidth of 10%. The filter is simulated using *IE3D* with an offset of 1.67 mm.

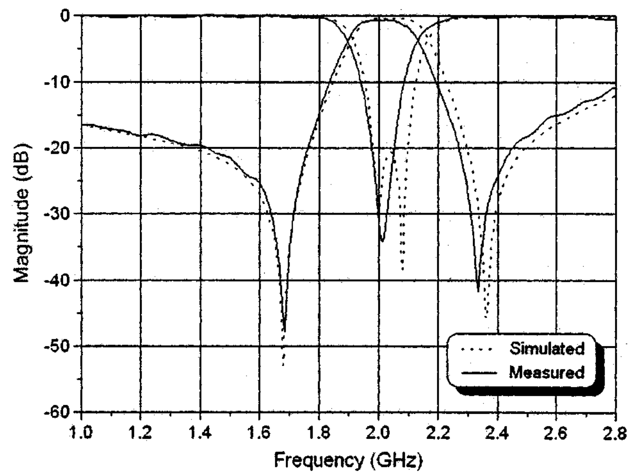

Fig. 5. Measured and simulated results of bandpass filter.

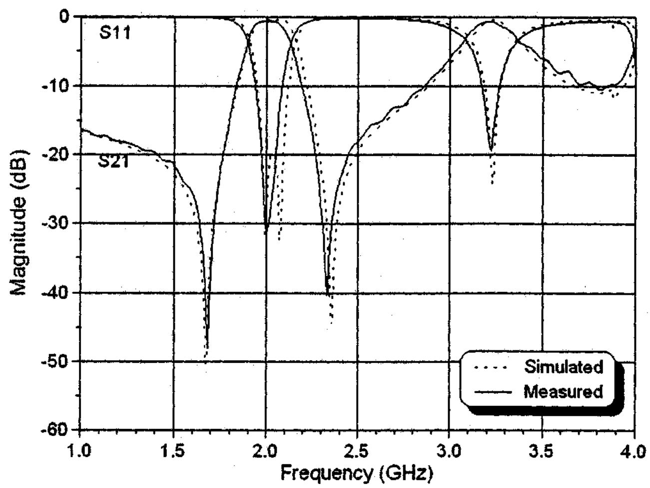

Fig. 6. Out-of-band response of bandpass filter.

Simulation of this filter shows an insertion loss of 0.37 dB and a return loss of 27 dB at 2 GHz. Due to the symmetry along AA', two additional zeros are observed on both sides of the passband. The filter is fabricated on substrate $er = 10.2$ and thickness 25 mils. The simulated and measured results are shown in Fig. 5. The resonant frequency is observed to be at 2.01 GHz and the measured insertion loss is 0.614 dB with a return loss of 30 dB. The measured bandwidth is about 8%.

The out-of-band response is also measured and shown in Fig. 6. A second passband was observed at 3.25 GHz, which is not harmonically related to the fundamental frequency. The simulated result is also shown in Fig. 6 for comparison. Both results are in good agreement.

IV. Conclusion

Circular holes are etched off the conductor surface of a microstrip disk resonator, and this has proven to reduce the fundamental resonant frequency. The size of each hole actually determines the amount of reduction whereas their relative position has minimal effect on it. A dual mode bandpass filter is also designed by taking advantage of the existing structure and offsetting the circular holes along the diagonal axis of symmetry.

A filter designed at 2.0 GHz shows good agreement between simulated and measured results.

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