PBG-Excited Split-Mode Resonator Bandpass Filter

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***Abstract*—Photonic bandgap structure is used as a design parameter for the fundamental passband in a split-mode microstrip square resonator. A defect in the PBG cells under the resonator, allows coupling between the two degenerate modes. A filter is designed at 2.2 GHz with good agreement between simulated and measured results.**

***Index Terms*—Filter, PBG, split-mode resonator.**

I. Introduction

VARIOUS photonic bandgap (PBG) structures for microwave integrated circuits have been introduced extensively over the last few years [1]–[6]. However, most of the applications are limited to providing deep and wide stopband for circuits and surface-wave suppression. PBG has been used to prevent excitation of higher-order modes of microstrip antennas [4]. PBG structure has also been used in filter designs to reject higher order passbands, due to its inherent stopband behavior [5]. Harmonic termination for power amplifier using PBG has also been demonstrated [6]. In the area of split-mode filter, extensive work has been made using ring and rectangular microstrip resonator [7]–[9]. Some tuning element is introduced on the circuit plane to allow coupling of the two degenerate modes. At times, the introduction of the tuning elements results in a significant shift in resonant frequency, as compared to the unperturbed resonator [9]. This makes design difficult and tedious. However, size is reduced.

In this paper, PBG is used to excite the space-orthogonal degenerate mode of a square microstrip resonator. As a result, there is coupling between the two orthogonal modes. It is important to stress here that a uniform PBG structure does not result in a split in the modes. A defect PBG cell underneath the patch resonator is needed to allow cross coupling. Also, inherent in the PBG's stopband behavior, the higher order passbands are rejected. A filter at 2.2 GHz using this phenomenon will be demonstrated.

II. Resonator Structures

Fig. 1(a) shows a square microstrip resonator of size 800 mils$\times$800 mils on a substrate 25 mil thick with $\varepsilon_r = 10.2$. Fig. 1(b) shows the same resonator with PBG structure on the ground plane. The PBG cell is a square etched off on the ground plane, with size 150 mils$\times$ 150 mils. The PBG cut-off frequency is expected to be twice that of the fundamental resonant frequency of the resonator. Hence, it is natural to expect that the resonant frequency of the resonator in Fig. 1(b) to be close to that of Fig. 1(a). Simulation using full-wave *IE3D* shows that being the case. The unperturbed resonator has a simulated resonant frequency of 2.295 GHz. Due to the presence of PBG, the effective dielectric electric constant is slightly higher than that

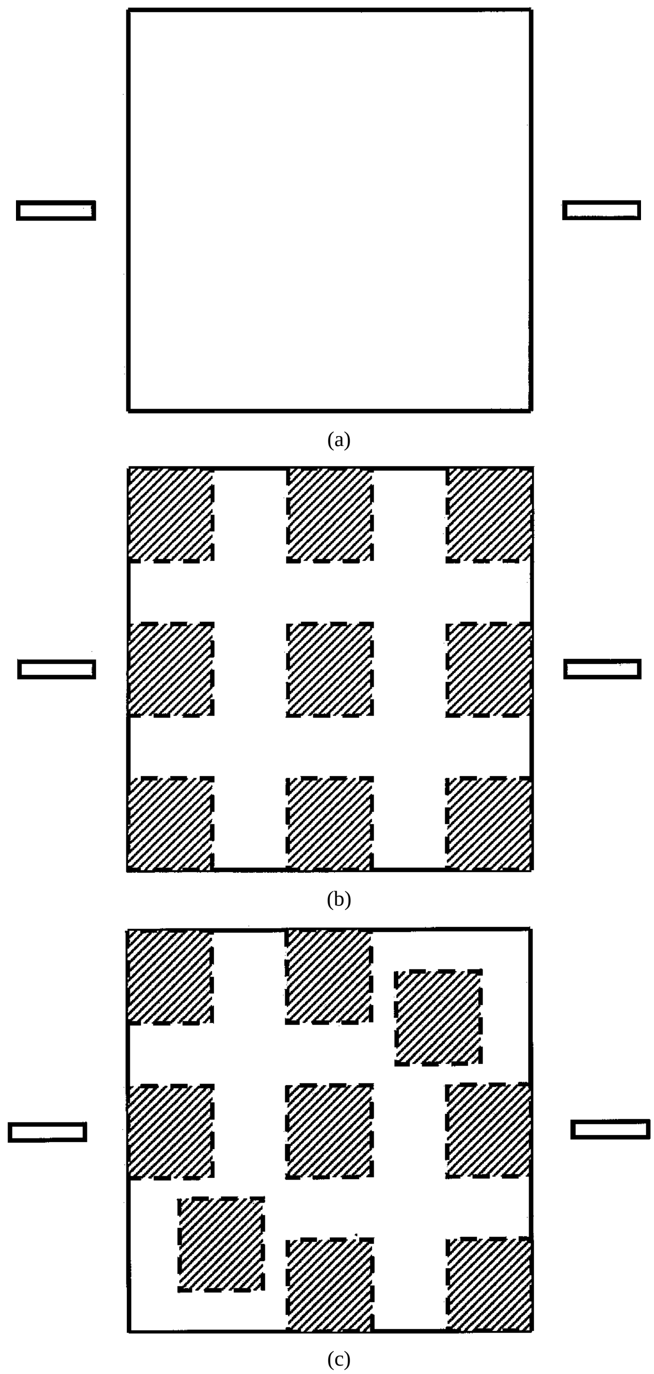

Fig. 1. (a) Microstrip resonator, (b) uniform PBG square microstrip resonator, and (c) defect PBG square microstrip resonator.

Manuscript received March 30, 2001; revised July 2, 2001. The review of this letter was arranged by Associate Editor Dr. Arvind Sharma.

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Publisher Item Identifier S 1531-1309(01)08083-7.

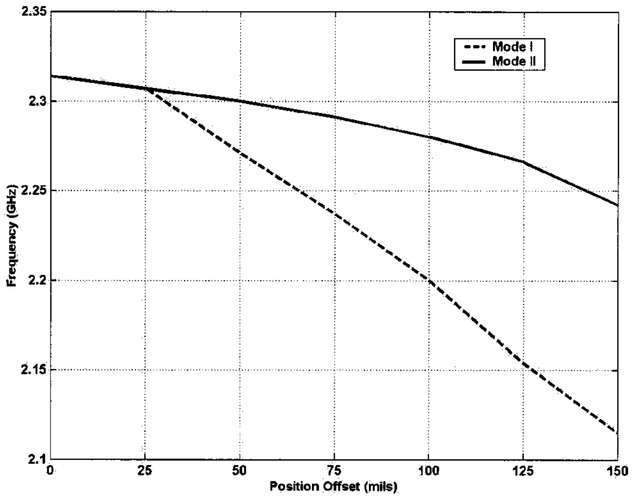

Fig. 2. Simulated change in resonant frequency of the split modes with different position offset of the defect PBG.

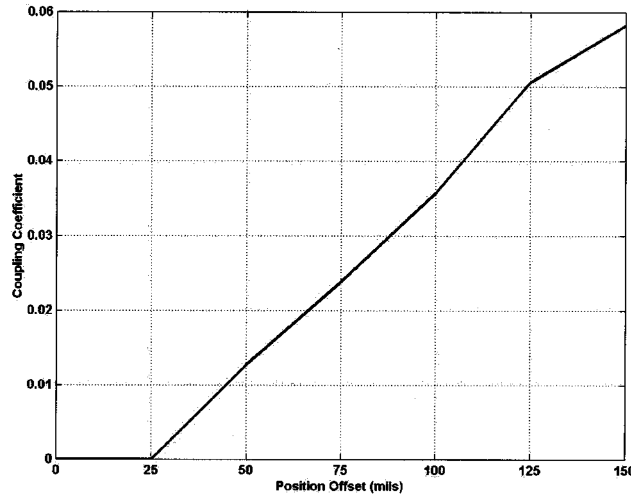

Fig. 3. Simulated coupling coefficient with different position offset of the defect PBG.

of unperturbed microstrip. The simulated resonant frequency of the PBG microstrip resonator is 2.315 GHz.

Fig. 1(c) shows the same resonator in Fig. 1(b) with some offset in the position of the diagonal cells in the plane A-A'. Using PBG terminology, this offset is a defect in the PBG lattice. By offsetting the position, the current on the patch is forced to flow with a strong component orthogonal to its unperturbed mode. This orthogonal current is supported by the orthogonal degenerate mode at the same frequency. The amount of position offset determines the amount of the cross coupling. Hence, an increase in position offset results in an increase in the coupling. Offset is made along axis A-A' to maintain symmetry about the same axis. This results in two additional zeros on both sides of the band edges [10].

As the coupling affects these two modes differently, there is a split in the resonant frequencies for these modes. To observe the split mode, a resonator shown in Fig. 1(c), is simulated using *IE3D* with different offset defect PBG. The ports are opposite each other and coupled to the resonator by a 10 mil gap. The substrate used is 25 mil thick with $\varepsilon_{\mathrm{r}} = 10.2$. The substrate is chosen to reduce radiation loss. Fig. 2 shows the simulated split resonant frequencies of these two modes (I and II) of the resonator with different offsets. The position offset in the x- and y-axes are of the same amount. It can be seen that as the offset increases, the split between the modes becomes more pronounced. The effect of the defect PBG is greater on Mode I, as compared to the Mode II [9]. Using the relationship between the split in resonant frequency of these two modes and the coupling [11], the coupling coefficient between the two modes can be computed as shown in Fig. 3.

III. Bandpass Filter

To demonstrate the use of PBG to excite orthogonal degenerate mode in split-mode filter, a square microstrip resonator of size 800 mils $\times$ 800 mils on a substrate 25 mil thick with $\varepsilon_{\mathrm{r}} = 10.2$ is fabricated. The filter is designed and simulated using *IE3D*. The position offset used is 150 mils in both x- and y-axes. It is found that direct tapping of the resonator yields

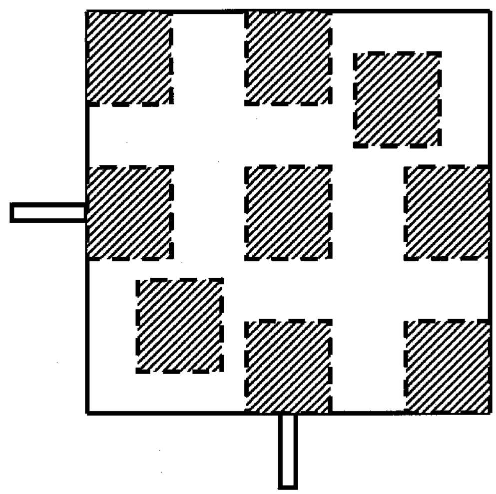

Fig. 4. PBG-excited split-mode microstrip filter.

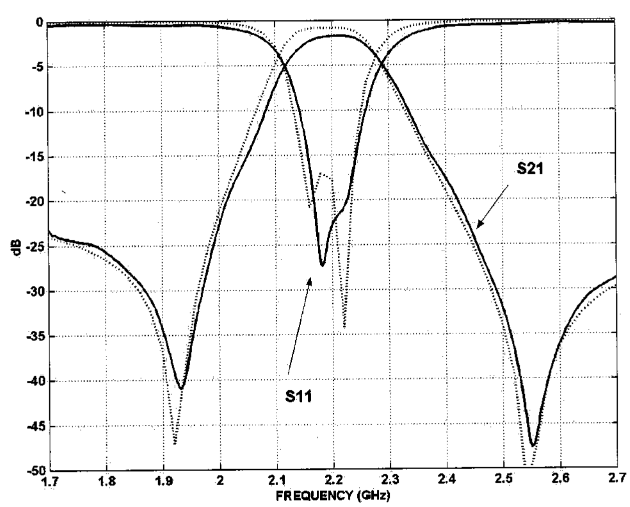

Fig. 5. Simulated (dotted line) and measured (bold line) responses of the filter.

good input/output match. Hence, the ports are connected to the middle of the edges as shown in Fig. 4. Fig. 5 shows the measured and simulated responses of the filter. The simulated band-

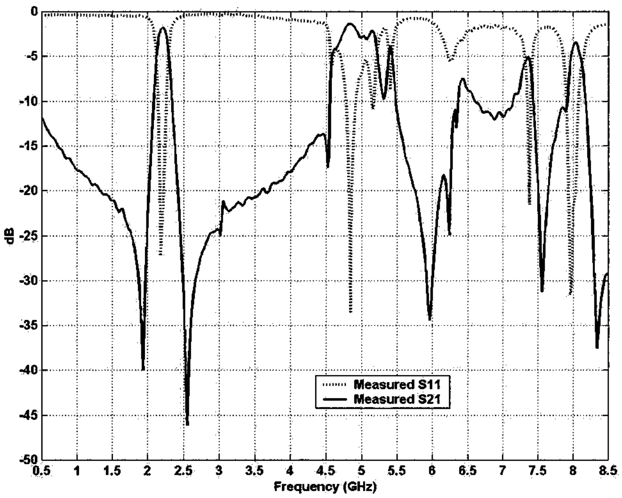

Fig. 6. Measured wideband response of the PBG-excited microstrip filter.

width is about 4.5%, while the measured bandwidth is about 3.5%. The measured insertion loss is 2 dB with return loss better than 15 dB. Due to its symmetry, two additional zeros are found at both sides of the band edges. The simulated and measured results are in good agreement.

Fig. 6 shows the measured wideband response of the filter. The second passband is at 4.6 GHz, which is not harmonically related. It is also important to note that when PBG cells are also made available underneath the input/output microstrip lines, the higher order passbands are also rejected.

IV. Conclusion

A defect PBG underneath a microstrip square resonator can effect cross coupling between the two degenerate space-orthogonal modes. This defect is a position offset in the PBG cells. The PBG does not affect the resonant frequency of the resonator significantly, as compared to an unperturbed microstrip resonator. A filter at 2.2 GHz is designed using this perturbation. Measured and simulated results are in good agreement.

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