Novel 2-D Photonic Bandgap Structure for Microstrip Lines

Vesna Radisic, *Student Member, IEEE*, Yongxi Qian, *Member, IEEE*, Roberto Coccioli, *Member, IEEE*, and Tatsuo Itoh, *Life Fellow, IEEE*

***Abstract*— A new two-dimensional (2-D) photonic bandgap (PBG) structure for microstrip lines is proposed, in which a periodic 2-D pattern consisting of circles is etched in the ground plane of microstrip line. No drilling through the substrate is required. Three PBG circuits were fabricated with different circle radii to determine the optimum dimensions, as well as a PBG circuit with the compensated right-angle microstrip bend. Measurements show that deep and wide stopbands can be achieved using this method.**

***Index Terms*—Filter, photonic bandgap (PBG).**

I. Introduction

Photonic bandgap (PBG) structures are periodic structures in which propagation of certain bands of frequencies is prohibited [1]. Original PBG research was done in the optical region [2], but PBG properties are scalable and applicable to a wide range of frequencies. Recently, there has been an increasing interest in microwave and millimeter-wave applications of PBG structures. In the microwave region, PBG structures have been used to improve radiation pattern of antennas [3], increase the output power and efficiency of power amplifiers [4] as well as with the design of reflectors [5], broad-band absorbers, and frequency selective surfaces.

PBG structure can be achieved by using metallic, dielectric, ferromagnetic, or ferroelectric implants. Dielectric PBG structures have been used for microstrip circuits [3], [6]. These require drilling of a periodic pattern through the substrate. In this letter, we propose a new PBG structure that requires only partial etching of the ground plane, which is compatible with monolithic circuit technology. The experimental results of this newly proposed structure show wider and deeper stopbands than previous designs using the dielectric hole approach [6].

II. PBG Design and Measurements

The PBG structure selected is a two-dimensional (2-D) square lattice with circles etched in the ground plane of a 50-Ω microstrip line, as shown in Fig. 1. The substrate used is RT/Duroid 6010 with dielectric constant of 10.5 and 25 mil thick. The period a was kept constant to 200 mil and the circle radius was varied. Only three rows of cells are necessary because the fields in the microstrip line are concentrated near the line. A conductor width of 27 mil was used, corresponding to 50-Ω line for conventional microstrip.

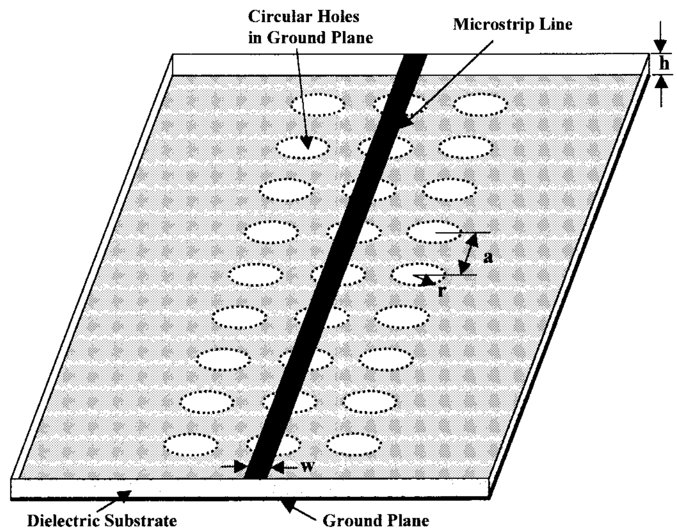

Fig. 1. Three-dimensional view of the proposed PBG structure. The square lattice circles are etched in the ground plane of a microstrip line.

In order to investigate the stopband effect of the newly proposed PBG structure, three circuits were fabricated with circles of different radii. Measured results for reflection (S_{11}) and transmission (S_{21}) for all three circuits are shown in Fig. 2(a)–(c). In all three cases the stopband is about 11 GHz. In general, the stopband center frequency f_0 is a function of the period of the structure [1]. In particular, the guided wavelength at f_0 is twice the period a. Unfortunately, the propagation constant is not easily determined for the structure shown in Fig. 1, and full-wave analysis is necessary to accurately characterize PBG structure. However, for small values of r/a the stopband center frequency can be assessed by using the propagation constant of the unperturbed microstrip. Based on previous research, depth and bandwidth of the stopband depend on the circle radius and number of periods [7]. The number of periods is kept constant for all circuits.

For smaller circle radii the stopband is very small, as shown in Fig. 2(a). In the limiting case $r \to 0$ (or $r/a \to 0$) there is no stopband, and the structure is a standard microstrip line. As the circle radius is increased the stopband becomes

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The authors are with the Department of Electrical Engineering, University of California at Los Angeles, Los Angeles, CA 90095 USA.

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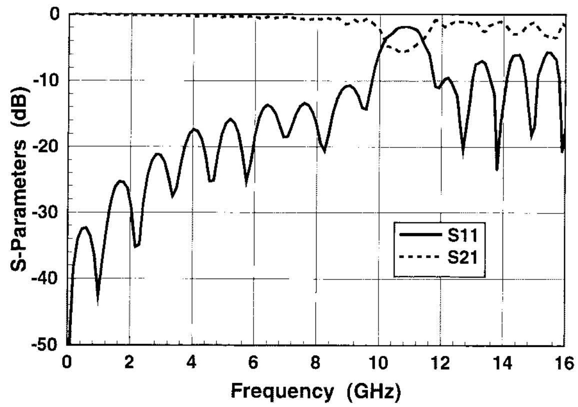
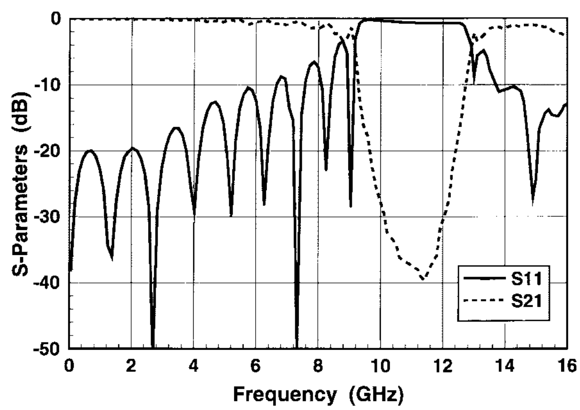
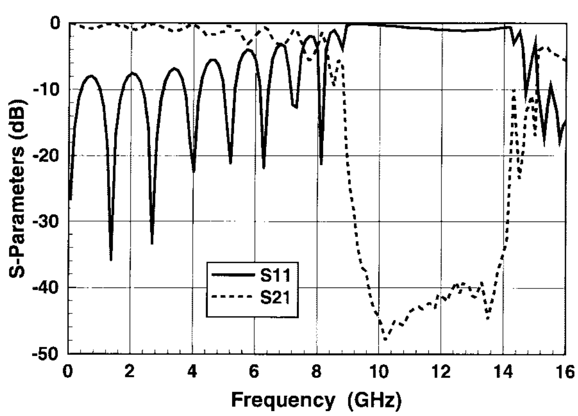


(a)



(b)

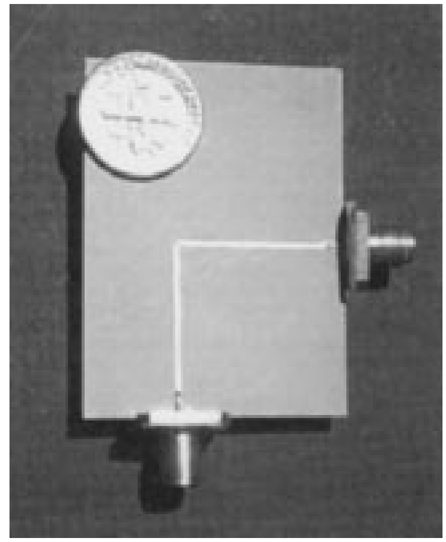


(c)

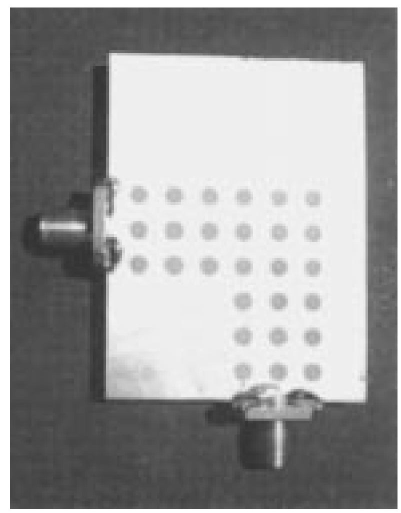
Fig. 2. Measured S-parameters for the PBG microstrip transmission line. The ground plane has a square lattice with 3 × 9 etched circles. The hole radius is (a) $r = 25$ mil, (b) $r = 50$ mil, and (c) $r = 90$ mil. The period is 200 mil for all cases.

more distinctive. A tradeoff is that for very large r/a factor the ripple in the passband is also increased, as shown in Fig. 2(c). Fig. 2(b) shows the S-parameters for an optimized PBG structure $(r/a = 0.25)$, with significant stopband depth and small passband ripple in S_{11}. Addition of the reflected and transmitted power with the metal and dielectric losses shows a low radiation level from the ground plane.

Another important design issue is the ability to bend the microstrip line to increase circuit design flexibility. Fig. 3 shows a photograph of a compensated right-angle microstrip bend with circle radius of 50 mil and period $a = 200$ mil.



(a)



(b)

Fig. 3. Photograph of (a) top and (b) bottom sides of the compensated right-angle microstrip bend on the PBG structure with circle radius $r = 50$ mil and period $a = 200$ mil.

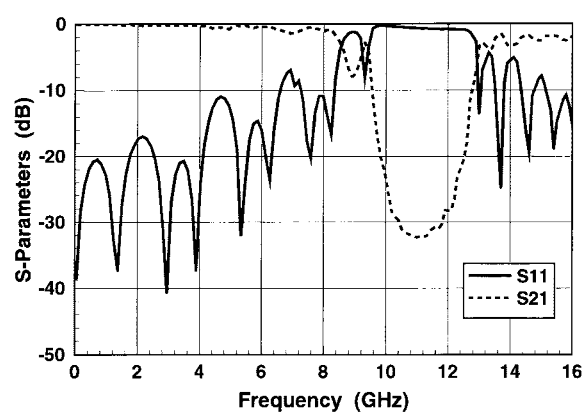


Fig. 4. Measured S-parameters for the compensated right-angle microstrip bend, as shown in Fig. 3.

The etched circles on the ground plane follow the right-angle bend. The S-parameters for the PBG bend are shown in Fig. 4. The stopband is slightly reduced compared to straight line, but shows almost identical PBG properties, as seen in Fig. 2(b). As demonstrated in [6] finite-difference time-domain (FDTD) can be expected to analyze this periodic structure quite accurately.

III. Conclusions

We proposed a novel 2-D PBG structure which is compatible with microstrip circuits, based on etching a 2-D periodic pattern on microstrip ground plane. The newly proposed structure is simpler to fabricate and has been shown to achieve larger stopbands than the method based on drilling holes through the dielectric substrate. Possible applications include filters, frequency-selective surfaces, and efficient antenna structures.

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