Isolation Enhancement of Anisotropic UC-PBG Microstrip Diplexer Patch Antenna

Y. Hao and C. G. Paini

***Abstract*—Anisotropic characteristics of uniplanar compact photonic bandgap (UC-PBG) structure is studied and applied for the first time into the design of microstrip diplexer patch antennas to enhance the isolation between transmitting (Tx) and receiveing (Rx) ports. Theoretical results indicate that the isolation is improved and measurement results are compared with simulation data and good agreement is reported.**

***Index Terms*—Diplexer antenna, microstrip, photonic bandgap.**

I. Introduction

PHOTONIC bandgap (PBG) structures originating from optics have been extensively applied in the microwave region and for this application are now referred as electromagnetic bandgap (EBG) by some other researchers [1]. The application of PBGs at microwave frequencies includes the suppression of surface waves [2], the construction of approximated perfect magnetic conducting (PMC) planes [3] and antenna gain enhancement [4]. More recently, the anisotropic characteristics of PBG structures have been studied [5]–[7] and applied to the design of microstrip diplexer antennas [6], [7] and diplexer filters [8].

Dual frequency–dual polarization antennas are often required for frequency reuse to enhance communication system capacities. Rectangular patch antennas provide inherent isolation (about 20 dB) between orthogonal edges and they can be used for transmit and receiver channels on linear orthogonal polarization [6]. However, such poor isolation prohibits the direct integration of microstrip diplexer antennas with active microwave components to form transceivers. Conventionally, a low insertion loss bandpass filter is used before low noise amplification in the receiving path. Such filters are very difficult to fabricate at millimeter wave frequencies and only recent micromachining techniques have made the manufacturing possible.

In this letter, the anisotropic characteristics of PBG structures are further investigated and applied to the design of a dual linear polarized diplexer microstrip antenna with enhanced receiving/transmitting (Rx/Tx) isolation. Various PBG structures are studied and applied into the antenna design. The simulation is performed by commercial EM software packages and it is validated by measured results.

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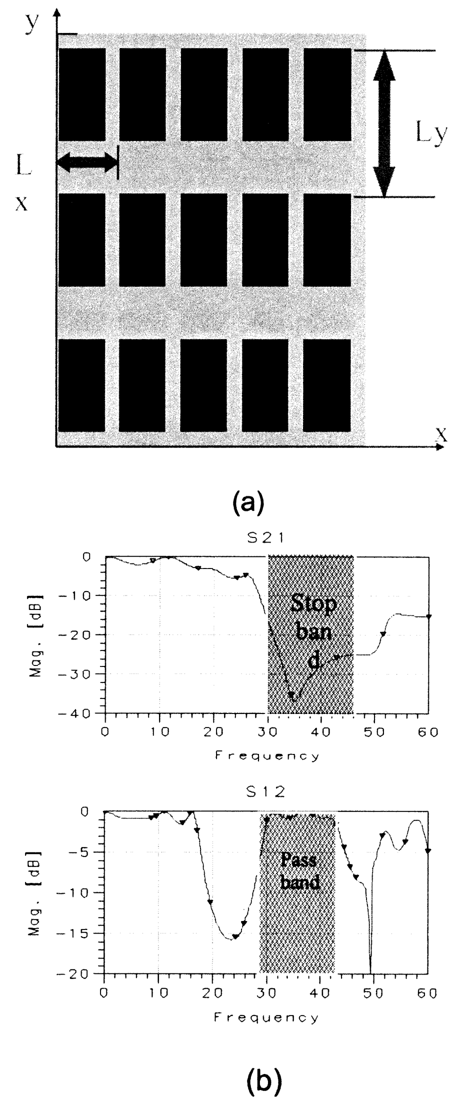


Fig. 1. (a) An anisotropic UC-PBG pattern. (b) Frequency response of 2-D PBG along x direction (above). Frequency response of 2-D PBG along y direction (bottom).

II. Anisotropic Characteristics of 2-D UC-PBG Structure

The Uniplanar Compact (UC) PBG introduced by Caloz *et al.* [5] has the advantage in ease of fabrication, and most UC-PBGs have been designed by etching a periodic pattern on the ground plane. In this letter, a novel 2-D UC-PBG structure shown in Fig. 1(a) has two different periods in the x and y direction respectively. The proposed UC-PBG structure exhibits different central stopband frequencies [Fig. 1(b)] when electromagnetic waves propagate along the two orthogonal edges of the proposed PBG substrate. Such PBG structures also allow wave propagation over a certain frequency band, acting as bandpass filters [Fig. 1(b)]. The central stopband frequency can be approximated by

$$f_{C_i} \approx \frac{C}{4L_i}, \qquad i = x \text{ or } y \tag{1}$$

where c is speed of light and L_i is the given period [Fig. 1(a)].

Such PBG structures demonstrate different attenuation characteristics along different wave propagation directions and they are referred as anisotropic PBGs by Caloz [5]. Clearly enhanced isolation can be achieved if a PBG structure can be found to reject Tx signal but let Rx signal pass at the receiving path, and vice versa at transmitting path [6], [7].

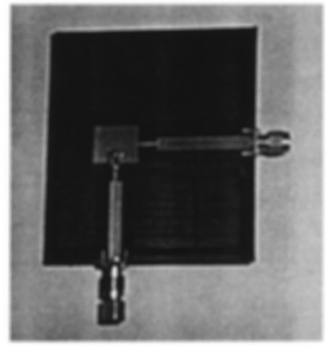
III. Conventional Microstrip Diplexer Antenna Design

The diplexer-antenna element can be designed using a PC based program called "Patch9" [9]. Both resonant lengths are calculated and the simulated data of antenna return loss is in a HP/ADS (HP/EESOF) compatible file (a file with the extension *.S1P* is created). To match the antenna impedance well, a two-section quarter-wavelength transformer is used. This configuration also helps to increase the isolation between Tx/Rx channels and reduce antenna cross polarization. The antenna is fabricated on RT/Duroid with substrate thickness 1.524 mm, dielectric constant 3. The dimensions of the rectangular patch are 16.25 mm and 13.71 mm for resonant operation at 5.2 and 6.0 GHz, respectively. The 50 Ω transmission line width is 4.2 mm. The widths of the impedance transformers are 0.6 mm for receiving path (5.2 GHz), and 0.75 mm for transmitting path (6.0 GHz). Their lengths are 7.63 mm for transmitting path, and 8.19 mm for receiving path, respectively.

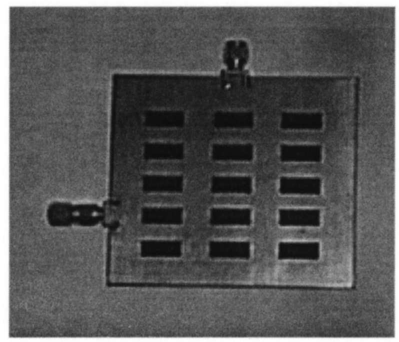
Fig. 2(a) shows the final antenna prototype and the simulation are performed using HP/Momentum (HP/EESOF). The simulated results are shown in Fig. 4 with the return losses for both frequencies and the isolation between Rx and Tx channels.

IV. Design of Novel Microstrip Diplexer Antenna With Anisotropic PBG Structure

The design of microstrip diplexer antenna with anisotropic PBG structure is based on equation (1). The periods can be calculated once the antenna operating frequencies are defined. In our case, these frequencies are 5.2 and 6.0 GHz. At receiving port, the forbidden band central frequency is set to be 6.0 GHz and, when applying (1), the period is given as about 12.5 mm. The length of printed slot resonators for PBG structure is set to be about half of a guided wavelength on microstrip substrate. At the receiving port, it is about 14.6 mm. At the transmitting port, the forbidden bandgap central frequency is determined by the receiving channel frequency, and it should be 5.2 GHz in this case. However, considering the effect of adding PBG structure on the microstrip ground plane, the effective permittivity is reduced and hence the receiving channel frequency shifts down. In this case, the receiving frequency is about 3.1 GHz (Fig. 3), and it gives the period of the PBG along the transmitting channel



(a)



(b)

Fig. 2. (a) Conventional microstrip diplexer antenna prototype. (b) Prototype of anisotropic UC-PBG microstrip diplexer antenna (ground plane).

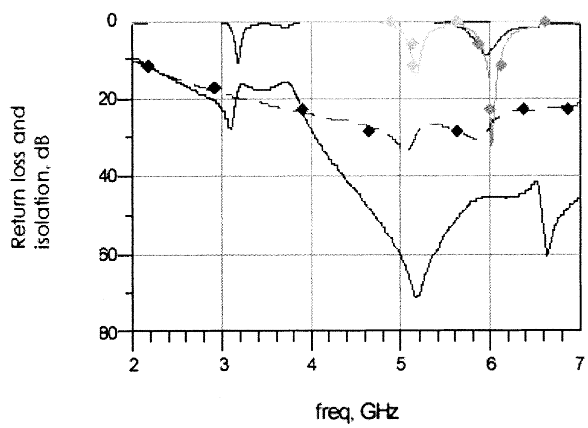


Fig. 3. Simulated antenna frequency responses using HP/Momentum (HP/EESOF). (Solid line: anisotropic UC-PBG diplexer antenna, solid line with diamonds: conventional diplexer antenna).

of about 25.6 mm. The slot width of slots is set to be about 3.8 mm following the above proposed design rule. On the top of substrate lays a conventional microstrip diplexer antenna. For simplicity and comparison, dimensions of the antenna remains unchanged and it is the same as the conventional diplexer antenna discussed above. Therefore, only the ground-plane prototype of the proposed novel anisotropic PBG antenna is shown in Fig. 2(b). It can be seen that the anisotropic characteristics of the PBG are provided by the inherent anisotropy of the rectangular slots with the different periods along two orthogonal directions used by transmitting and receiving channels of the diplexer antenna.

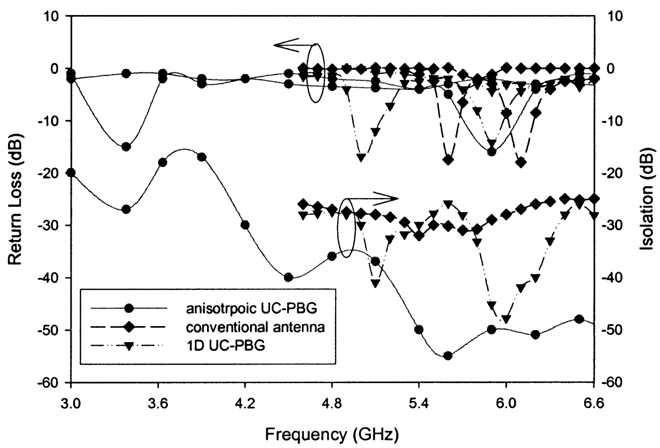


Fig. 4. Comparison of measured return loss and isolation of various antennas.

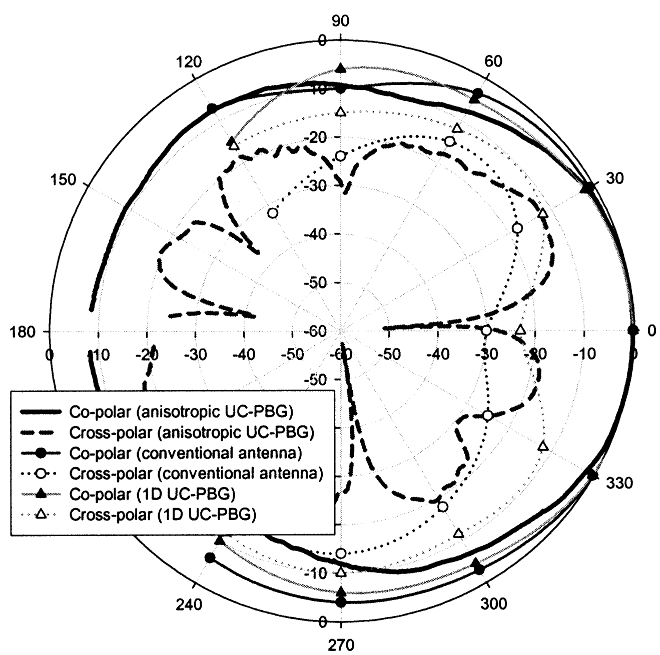


Fig. 5. Comparison of measured radiation patterns of various antennas.

V. Measurement Results and Analysis

Three types of antennas were fabricated and measured to verify the simulation. They are the conventional microstrip diplexer antenna [Fig. 2(a)], antenna with 1-D UC-PBG (a linear array of PBG elements along the receiving channel) on the ground plane and the antenna with anisotropic UC-PBG [Fig. 2(b)]. The return losses and Rx/Tx isolation of the first two types of antennas are measured and compared in Fig. 3. It can be seen that the conventional diplexer antenna resonating at 5.5 and 6.1 GHz respectively has only about -30 dB isolation between Rx/Tx ports, but with the help of the 1-D UC-PBG, the isolation can be improved. It is also evident that the receiving frequency has changed due to the variation of effective dielectric constants caused by periodic slots etched under the antenna feed line at the receiving port on the ground plane. The measurement on the anisotropic UC-PBG diplexer antenna was also performed and the result is shown in Fig. 4. It demonstrates much improved Rx/Tx isolation over a wider frequency range and shows that the shift of resonant frequencies is now at both of Rx and Tx ports when introducing anisotropic PBG on the whole antenna ground plane.

The radiation characteristics of the antenna array within its frequency bandwidth are also investigated. Fig. 5 shows the *E*-plane copolar and cross-polar radiation pattern for conventional diplexer antenna, antenna with 1-D UC-PBG and anisotropic UC-PBG antenna. No significant changes are found in radiation pattern for 1-D UC-PBG antenna. However, higher backward radiation is found in the anisotropic UC-PBG antenna and it is caused by energy leaking from the printed slots on the ground plane. This effect could be eliminated by employing embedded PBG structure with solid ground planes. And it is currently under investigation and will be presented for future publications. All results are measured inside an anechoic chamber.

VI. Conclusion

The anisotropic characteristics of UC-PBG structure were investigated and implemented on a design of microstrip diplexer antennas. It is demonstrated in this letter that some PBG lattices are inherently anisotropic and their constructions with different periods along two orthogonal directions exhibit different forbidden bandgap responses. The self-diplexing antenna on anisotropic UC-PBG ground plane has demonstrated improved isolation, and this concept can lead to the development of direct integration of RF transceiver with planar antennas to realize on-chip antenna front-ends.

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