Abstract

This paper presents a microstrip patch antenna using a photonic band gap (PBG) structure for attaining higher bandwidth. The photonic periodic structure was considered as cross shaped, placed on the ground plane. The simulation results from HFSS Ansoft design showed that surface waves can be suppressed by the periodic structure due to the influence of its forbidden band. As a result, the bandwidth of the proposed antenna was 6.7% higher than the conventional antenna. Moreover, the values of gain and directivity of antenna were more by adding PBG in comparison with the values of the antenna alone.
Keywords
Microstrip Antenna, HFSS, PBG.

Introduction

In recent years, there has been a prompt growth in using microstrip antennas in different applications such as array antennas, cellular phones, wireless communications and other communication systems, due to its advantages such as low cost, low profile planar configuration, low weight and capability [1]. A microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate and a ground plane on the other side. So, the design of the patch and substrate directly affects the antenna results. The propagating waves are submitted to refraction effects due to the dielectric characteristics of that material. The resonant frequency of the antenna is continuing to propagate in its interior. A part of those waves are just emitted or received and the remaining part is stored in the antenna [2]. Because of this energy stored, widespread to all the frequencies, such a process generates surface waves (surface currents) on the ground plane of the antenna. In the array antenna, the patch antenna operates as a resonator besides the future radiator. So, the harmonic components might produce the problems in this case [3].

Recently, several techniques have been proposed for overcoming the problem of surface waves. One of the effective methods which suits for the millimetre structures is to use photonic band gap structures. The idea of these structures was proposed by Yablonovich for the first time [4]. Using photonic band gap structures has become attractive for engineers and researchers working on antennas, electromagnetic and microwaves. The usages of these materials are redounded to preventing from the propagation modes of these antennas in the Forbidden frequency band. Suppressing the surface waves in the desired frequencies depends on the PBG structure associated with the antenna substrate.

These structures are used for improving the characteristics of the microstrip patch antennas and resonator antennas. Photonic band gap materials or Electromagnetic Band Gap (EBG) are periodic dielectrics which can suppress the propagation of the surface waves in certain frequency bands [5]. In [6], types of substrates with PBG structures probed. Researchers using the PBG in the structure of the microstrip patch antennas can improve their radiation pattern, decrease side lobe levels and back lobe levels and increase their gain [7]. Also, improvement of the antenna characteristics using PBG was reported in [8].
Furthermore, in [9], the radiation directivity of the patch antenna was improved using PBG cover.

In this paper, a photonic band gap periodic structure is used which is cross shaped in the ground plane of the microstrip patch antenna. The simulated results show that characteristics such as the bandwidth, gain and directivity of the antenna are improved by adding the PBG structure.

**Antenna Design**

Figure 1 shows the conventional antenna. To achieve a higher bandwidth, the PBG structures are used in the ground plane. The geometry of the photonic crystal antenna is shown in Figure 2. The periodic structure is considered by periodic cross’s holes in the ground plane. Figures 2a and b demonstrate the top and side views. A unit cell of the PBG structure used in the proposed configuration is illustrated in Figure 3.

In this paper, the dimension of the patch and the width of the feed line are considered 4.3 mm x 4.3 mm and 0.3 mm, respectively. The FR-4 substrate’s dimension is: 10 mm x 9 mm x 0.32 mm and the relative permittivity is 4.4 (Figure 1). All the parameters of the antenna substrate are shown in Table 1.
Results and Discussion

The simulated return loss characteristic of the conventional antenna and PBG antenna using HFSS Ansoft are shown in Figures 4 and 5 respectively. As discovered by the figures, the proposed structure improved the bandwidth so that the bandwidth of the conventional and Proposed antenna is 5.9% and 12.6%, respectively. In addition, Figures 6 and 7 illustrate the graph of the gain in both structures.

The preceding simulated results proved that the PBG antenna gain is en-
Figure 4: Return Loss ($S_{11}$) of the Conventional Antenna

Table 1: FR-4 Substrate Properties

<table>
<thead>
<tr>
<th>Properties</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permittivity, $\epsilon$</td>
<td>4.4</td>
</tr>
<tr>
<td>Loss Tangent</td>
<td>0.02</td>
</tr>
<tr>
<td>Substrate Length</td>
<td>10 mm</td>
</tr>
<tr>
<td>Substrate Width</td>
<td>9 mm</td>
</tr>
<tr>
<td>Substrate Height</td>
<td>0.32 mm</td>
</tr>
</tbody>
</table>

enhanced in comparison with the patch antenna used alone. The directivity radiation pattern of the conventional antenna and proposed antenna are shown in Figure 8a and 8b separately. As a result for the PBG structure, a 1 dB increase is achieved in directivity as compared with the non-PBG antenna structure. Besides, the main lobe of the proposed antenna come to be sharper for $\phi = 90^\circ$.

Conclusion

Since the surface wave has a robust effect on the conventional microstrip antenna structure, the effects of such a phenomenon should be overwhelmed;
subsequently an increase in the antenna performance would be observable. In this paper, a photonic band gap structure was used in the ground plane of the microstrip antenna. Consequently, the results proved that the surface waves were suppressed in a certain frequency band, thus the bandwidth, gain and the values of the directivity increased from 5.9% to 12.6%, 0.42 dB to 2.47 dB and 3 dB to 4 dB, respectively. Hence, the performance of the microstrip antenna can be increased using simple PBG structures.
Figure 7: Gain of the PBG Antenna

Figure 8: Directivity radiation pattern (a) conventional antenna, (b) proposed antenna at 8 GHz

References


References


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