

ENHANCED GAIN AND BANDWIDTH OF PATCH ANTENNA USING EBG SUBSTRATES

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ABSTRACT

Microstrip patch antenna becomes very popular day by day because of its ease of analysis and fabrication, low cost, light weight, easy to feed and their attractive radiation characteristics. Although patch antenna has numerous advantages, it has also some drawbacks such as restricted bandwidth, low gain and a potential decrease in radiation pattern. In recent years, attention to use Electromagnetic Band Gap (EBG) substrates to overcome the limitations of patch antenna. In this paper, we propose a rectangular microstrip patch antenna with EBG substrates and compare the performance of the proposed antenna with a conventional patch antenna in the same physical dimension. Due to the presence of the EBG structure in the dielectric substrates, the electromagnetic band gap is created that reduces the surface waves considerably. As a result, the performance of the proposed antenna is better comparing the conventional existing microstrip patch antenna.

KEYWORDS

Microstrip patch antenna, Electromagnetic band gap (EBG) substrates, Gain and Bandwidth.

1. INTRODUCTION

With the drastic demand of wireless communication system and their miniaturization, antenna design becomes more challenging. Recently microstrip patch antennas have been widely used in satellite communications, aerospace, radars, biomedical applications and reflector feeds because of its inherent characteristics such as light weight, low profile, low cost, mechanically robust, compatibility with integrated circuits and very versatile in terms of resonant frequency, polarization, pattern and impedance. In spite of its several advantages, they suffer from drawbacks such as narrow bandwidth, low gain and excitation of surface waves, etc [1-3]. These drawbacks limit their applications in other fields. In order to overcome the limitations of microstrip patch antennas such as narrow bandwidth and low gain, numerous techniques are proposed i.e. for probe fed stacked antenna, microstrip patch antennas on electrically thick substrate, slotted patch antenna and stacked shorted patches have been proposed and investigated [4-5]. These methods have eliminated the bandwidth problem for most applications. But limitations of gain and surface wave excitation still remain. That is why, in recent years there has been considerable effort in the EBG structure for antenna application to suppress the surface wave and overcome the limitations of the antenna. Many works have been done to

improve the performance of the microstrip antennas [6-11]. The EBG structure utilizes the inherent properties of dielectric materials to enhance the microstrip antenna performance. EBG materials are periodic dielectrics that produce pass band and stop band characteristics.

In this paper, we propose a rectangular patch antenna with EBG substrates. The characteristics of EBG depend on the shape, size, symmetry and the material used in their construction. Surface waves are reduced by using EBG substrate which leads to increase the directivity, bandwidth and radiation efficiency [15]. EBG were realized to reduce and eliminate surface waves, which leads to an increase in directivity, bandwidth and radiation efficiency. It is also useful to reduce the side lobes of the radiation pattern and hence radiation pattern front-to-back ratio and overall antenna efficiency are improved. Our proposed antenna gives better performance compare to the conventional rectangular microstrip patch antenna. A substantial gain and bandwidth enhancement has been obtained. The design and simulation have been done by using High Frequency Structure Simulator (HFSS). The remainder of the paper is organized as follows: In section II, a brief description of EBG structure. In section III present the conventional and proposed antenna design and configuration. In section IV present the simulation results and discussion. The conclusion of this paper is provided in section V.

2. ELECTROMAGNETIC BAND GAP SUBSTRATES

The birth of the electromagnetic band gap structure has triggered many novel antenna applications. Electromagnetic band gap structures can be defined as artificial periodic (or sometimes non-periodic) objects that prevent or assist the propagation of electromagnetic waves in a specified band of frequency for all incident angle and polarization state. Two commonly employed features are suppressing unwanted substrate modes and acting as an artificial magnetic ground plane. The main advantage of EBG structure is their ability to suppress the surface wave current. The generation of surface waves degrades the antenna efficiency and radiation pattern. Furthermore, it increases the mutual coupling of the antenna array which causes the blind angle of a scanning array [12-14].

EBG structures are usually realized by periodic arrangement of dielectric materials and metallic conductors. In general, they can be categorized into three groups according to their geometric configuration; (i) three-dimensional volumetric structures, (ii) two-dimensional planar surfaces, and (iii) one-dimensional transmission lines [13]. Two-dimensional planar EBG surfaces again classified into two categories, first one is mushroom like EBG surfaces and another one is uniplanar EBG surfaces.

For the mushroom like EBG surfaces, a band gap is observed between the frequency 7GHz and 11GHz. On the other hand, for the uniplanar EBG surfaces a band gap is observed the frequency from 13GHz to 14.6GHz. In this paper, mushroom like EBG surface is used in order to design patch antenna on EBG substrates because the mushroom like EBG surface has a lower frequency band gap and a wider bandwidth than the uniplanar EBG surface.

A two dimensional mushroom like EBG structure is shown in Figure 1. Design of patch antenna mushroom like EBG structures are preferable because light weight, low fabrication cost. There are four main parameters affecting the performance of mushroom like EBG structures. The parameters are like this: rectangle width w , gap width g , substrates thickness h and substrates permittivity ϵ_r . Also, the vertical vias radius r has a trival effect because it is very thin compared to the operating wavelength. The parameters that are affecting the performance of EBG structures are directly dependent on the operating wavelength of the patch antenna [8]. The parameters are varying with operating wavelength as like this that the rectangle width, w varies from $0.04\lambda_{12 \text{ GHz}}$ to $0.20\lambda_{12 \text{ GHz}}$, gap width varies from $0.01\lambda_{12 \text{ GHz}}$ to $0.12\lambda_{12 \text{ GHz}}$ and the substrate thickness, h varies from $0.01\lambda_{12 \text{ GHz}}$ to $0.09\lambda_{12 \text{ GHz}}$. Here, $\lambda_{12 \text{ GHz}}$ means the wavelength between medium 1 and 2 i.e. the free space and the guiding device and GHz means the wavelength respect to the GHz range frequency.

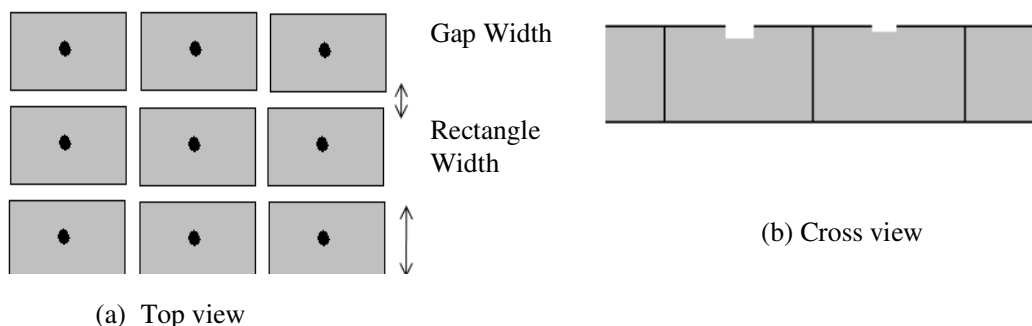


Figure 1 Two dimensional mushrooms like EBG surfaces: (a) Top view (b) Cross view

3. ANTENNA DESIGN AND CONFIGURATION

In order to identify and verify the improvement of the performance of microstrip antenna on EBG substrates, designed a conventional antenna and the proposed antenna. The width of the rectangular patch antenna is usually chosen to be larger than the length of the patch, L to get higher bandwidth. The antenna is designed to operate at frequency 10GHz. In this paper, we use neltec dielectric material as patch substrates whose dielectric constant is 2.45. The antenna is excited by a microstrip transmission line feed. The point of excitation is adjustable to control the impedance match between feed and antenna, polarization, mode of operation and excitation frequency. To design patch antenna lower dielectric constant is used because in case of lower dielectric constant of the substrates, surface wave losses are more severe and dielectric and conductor losses are less severe. By using EBG structures, surface wave loss can be reduced easily. Table1 shows the important parameters for the geometrical configuration of the patch antenna.

Table1 Geometrical configuration of the patch antenna

Antenna Part	Parameter	Value
Patch	Length	8.8mm
	Width	11.4mm
Patch Substrates (NeltecN×9245) (IM)(tm)	Dielectric constant	2.45
	Height	0.787mm
	Dielectric loss tangent	0.01
EBG Substrates	Rectangle Width	$0.10\lambda_{12\text{ GHz}}$
	Gap Width	$0.02\lambda_{12\text{ GHz}}$
	Substrates thickness	$0.04\lambda_{12\text{ GHz}}$
Operating Frequency		10GHz

4. SIMULATION RESULTS AND DISCUSSIONS

Now a days, it is a common practice to evaluate the system performances through computer simulation before the real time implementation. A simulator “Ansoft HFSS” based on finite-element method (FEM) has been used to calculate return loss, impedance bandwidth, radiation pattern and gains. This simulator also helps to reduce the fabrication cost because only the antenna with the best performance would be fabricated. Figure 2 shows the simulated results of the return loss of the conventional antenna and the proposed antenna.

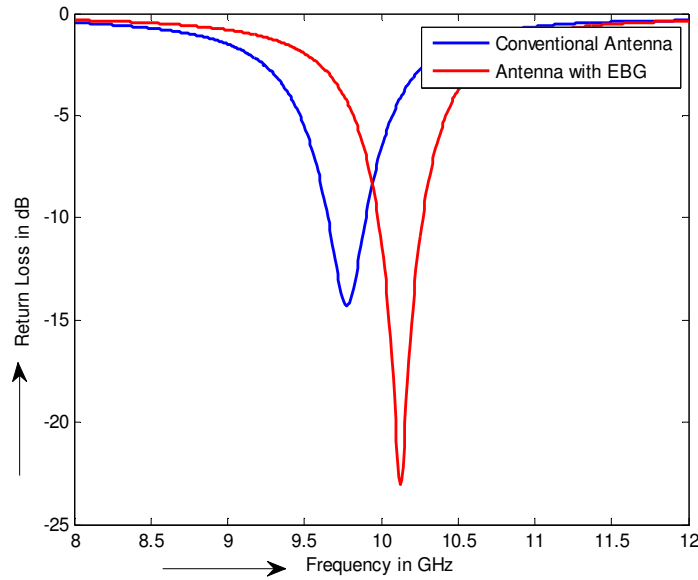


Figure 2 Return losses of the conventional patch antenna and antenna with EBG

It is seen from the Figure 2, the return loss for the conventional patch antenna is -14.5dB at 9.79GHz and for the proposed patch antenna is -23dB at 10.12GHz . A negative value for return loss shows that this antenna had not many losses while transmitting the signals. According to theoretical design, the minimum loss has been observed at 10GHz . But from simulation results we have observed that the minimum loss get at 9.79GHz for conventional antenna and 10.12GHz for the proposed antenna. Thus the return loss of the proposed microstrip patch antenna is 58.6% less compared to the conventional microstrip patch antenna. From the same Figure 2, the antenna bandwidth can be calculated. At the point of return loss -10dB , the bandwidth (BW) and the relative bandwidth (RBW) are 240MHz and 5.43% for conventional patch antenna but at same point of return loss the bandwidth (BW) and the relative bandwidth (RBW) of the proposed antenna are 330MHz and 7.33% . Therefore, the bandwidth of the proposed antenna is 37.5% more than the conventional antenna.

The simulated results for gain that are obtained from conventional antenna and the proposed antenna on EBG substrates are shown in Figure 3 and Figure 4.

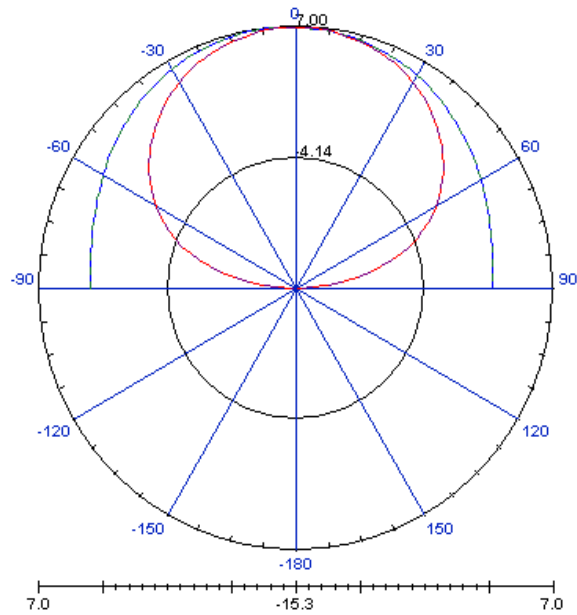


Figure 3 Gain of the conventional rectangular patch antenna.

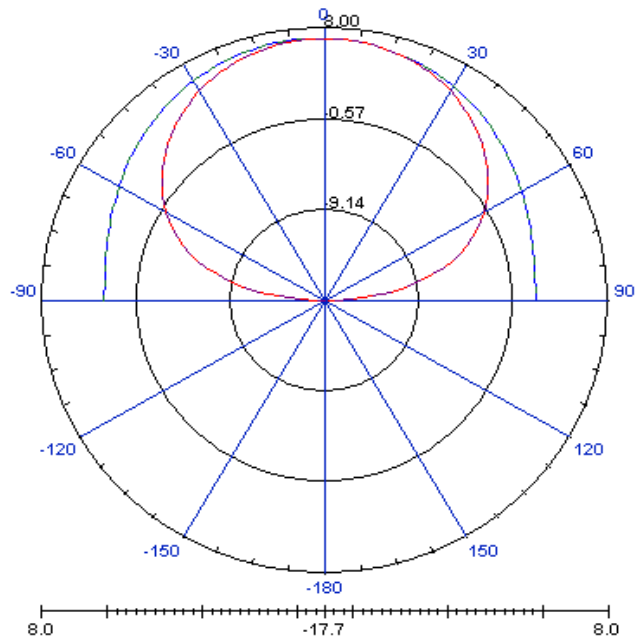


Figure 4 Gain of the rectangular patch antenna with EBG

From the simulated results, it is shown that the gain of the conventional antenna and the proposed antenna is 22.3dB and 25.7dB. So, the gain of the proposed patch antenna on EBG substrates is 15.2% more than the conventional patch antenna.

The Figure 5 and Figure 6 shows the simulated directivity of the conventional antenna and the proposed antenna.

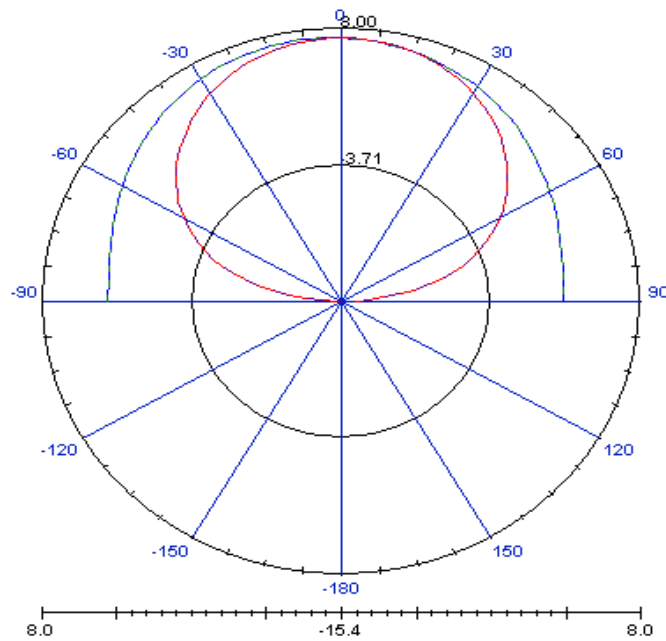


Figure 5 Directivity of the conventional rectangular patch antenna.

From the Figure 5 and Figure 6, the directivity for the conventional patch antenna and the proposed patch antenna are 23.4dBi and 25.5dBi. Thus, the directivity of the proposed antenna is also enhanced of 8.97% than the conventional antenna.

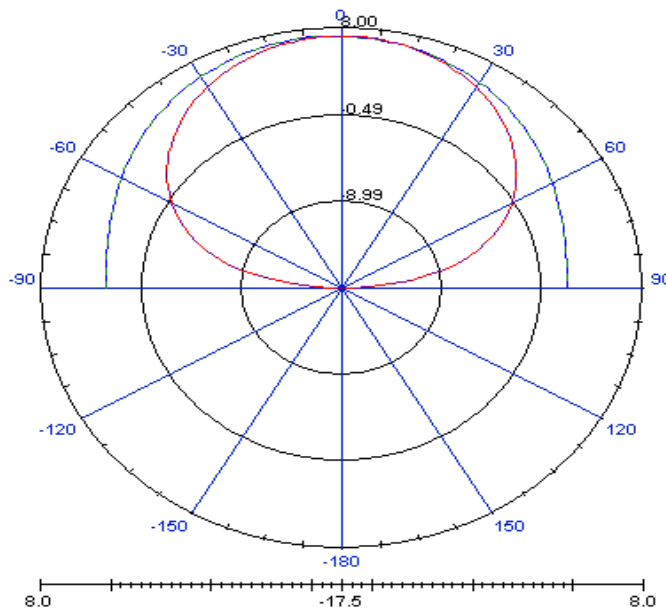


Figure 6 Directivity of the rectangular patch antenna with EBG

5. CONCLUSION

The patch antenna mostly used in modern mobile communication. The goals of this paper are to design conventional patch antenna and the patch antenna on EBG substrates with same physical dimensions that can operate at 10GHz and study the performance of microstrip antenna when EBG structure added on it. From the simulated results, it is seen that the performance is better of a patch antenna that is designed on EBG substrates than the conventional patch antenna. In future, our targets are to real time implementation of the proposed antenna and also design another microstrip patch antenna with EBG substrates that can operate at higher frequency.

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