

PBG Based High Gain Microstrip Stacked Antenna

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Abstract — In this paper, authors have proposed the analysis of a rectangular stacked patch antenna operates at the frequency of 2.4 GHz with a photonic band-gap structure (PBG) and compared its performances with a conventional patch antenna. Due to the presence of the PBG structure in the dielectric substrate, proposed antenna shows a significant reduction in surface wave levels than a conventional patch antenna. As a result, the gain of the proposed antenna is found to be improved by 3.2 dB.

Keywords — Rectangular Patch Antenna, Stacked Patch Antenna, PBG and Gain.

I. INTRODUCTION

Microstrip antennas have a rapid growth of its importance in the field of wireless communication due to ease of fabrication, versatility of possible geometries, low-profile, conformal and robust planer structure. A wide range of radiation patterns can be achieved with such types of antennas [1].

Recently microstrip patch antennas have been widely used in satellite communications, aerospace, radars, biomedical applications and reflector feeds because of its inherent characteristics [2-3]. In order to overcome the limitations of microstrip patch antennas such as narrow bandwidth and low gain, numerous techniques, probe fed stacked antennas, microstrip patch antennas on electrically thick substrate, slotted patch antenna and stacked shorted patches have been proposed and investigated by researchers [4-5]. Above mention technique eliminates the bandwidth problem but limitation of gain and surface wave's excitation are still effective. In recent years there has been considerable effort in the photonic-band gap (PBG) structure for antenna application to suppress the surface wave and overcome the limitations of the antenna such as gain and bandwidth. The number research works have been done to improve the performances of the microstrip antennas [6-10]. Previously researchers have realized that reduction and elimination of surface waves, leads to an increase in directivity, bandwidth and radiation efficiency of antennas [11-13]. It is also useful to reduce the side lobes of the radiation pattern and hence overall improvement of radiation pattern front-to back ratio and antenna efficiency. But microstrip stacked patch antenna on PBG substrate have gained very less attention of researchers till now, though it is the best way to enhanced the performance of patch antennas. Therefore, a stacked patch antenna at $f = 2.4$ GHz using PBG substrate has been designed and the performance of the proposed antenna is compared with a conventional patch antenna in the same physical specifications. The design and simulation have been done by using Ansoft HFSS (High Frequency Structure Simulator). The characteristics of PBG depend on the shape, size, symmetry and the material used in their designing. The proposed antenna gives better performance compare to the conventional stacked antenna.

II. PHOTONIC BAND-GAP STRUCTURE

Photonic band gap (PBG) structures are periodic arrangements of metallic inclusions, dielectric or sometimes combination of both. Most important features of the PBG substrates are forbidden in certain frequency region and however in other region it allows the electromagnetic waves propagation. The periodicity of these structures may be in one, two or three dimensions. These periodic arrangements of structures give rise to stop and pass band in electromagnetic transmission spectrum along the direction of periodicity. Consequently, the RF fields of the frequencies in stop band are strongly reflected while the frequencies in the pass-band propagate almost with very less attenuation. They can be categorized into three-dimensional volumetric structures, two-dimensional planar surfaces, and one-dimensional transmission lines according to their volumetric structures. The PBG structures have potential application in microwave, millimeter-wave and infrared devices such as antennas, couplers, waveguides, filters, resonators, planar reflectors, integrated circuits etc. [6-12].

III. DESIGN SPECIFICATION

The basic geometry of the proposed stacked antenna is shown in Fig 1 (a and b), the antenna is designed on FR4 substrate of thickness 1.6 mm and relative permittivity 4.4. The antenna plate is fed by standard coaxial of 50 at feeding location on the patch. This type of feeding scheme can be placed at any desired location inside the patch in order to match with the desire input impedance and has low spurious radiation. Stacking patches on top of each other is utilized to enhance the bandwidth of a microstrip patch antenna. For a single rectangular microstrip patch antenna of dimension $L \times W$, the lowest order resonant frequency f_0 can be accurately predicted from the following equation; For a given resonance frequency f_0 , the effective length is given by as:

$$L_{eff} = \frac{c}{2 f_0 \sqrt{\epsilon_{reff}}} \dots\dots\dots (1)$$

$$f_0 = \frac{c}{2(L + 2\Delta L)\sqrt{\epsilon_{reff}}} \dots\dots\dots (2)$$

L = Length of the patch extension

ϵ_{reff} = Effective dielectric constant

For a rectangular microstrip patch antenna, the resonance frequency for any TM_{nm} mode is given by [14]:

$$f_0 = \frac{c}{2\sqrt{\epsilon_{reff}}} \left[\left(\frac{m}{L} \right)^2 + \left(\frac{n}{L} \right)^2 \right]^{\frac{1}{2}} \dots\dots\dots (3)$$

For a multilayer rectangular patch antenna, the resonance frequency of the upper patch is [15-17]

$$f_0 = \frac{c}{2(L_2 = 2\Delta L_2)\sqrt{\epsilon_{\text{reff}2}}} \dots\dots\dots (4)$$

Where L_2 is the length and $\epsilon_{\text{reff}2}$ is the effective dielectric constant of upper patch and given by [15-17]

$$\epsilon_{\text{reff}2} = \frac{(\epsilon_{r2} + 1)}{2} + \frac{(\epsilon_{r2} - 1)}{2} \left(1 + \frac{10.0 \sum_{i=1}^n h_i}{L_2} \right)^{-1/2} \dots\dots\dots (5)$$

$$\Delta L_2 = 0.412 \sum_{i=1}^n h_i \left[\frac{(\epsilon_{\text{reff}2} + 0.3)}{(\epsilon_{\text{reff}2} - 0.258)} \right] \left[\frac{\frac{W}{\sum_{i=1}^n h_i} + 0.264}{\frac{W}{\sum_{i=1}^n h_i} + 0.813} \right] \dots\dots\dots (6)$$

Where h_i represents the dielectric thickness between the plates. In similar way authors have calculated the resonance frequency of the lower patch to design stacked patch antenna. Design parameters of the proposed antenna are given in Table.1.

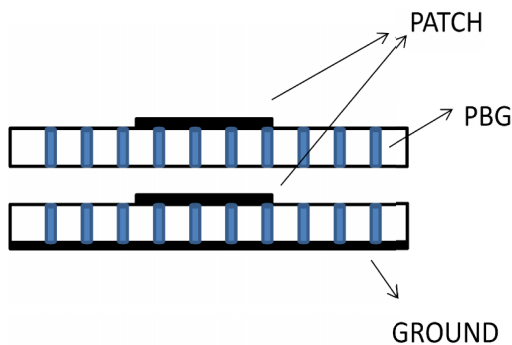


Fig.1.(a) Stacked Patch antenna with PBG structure

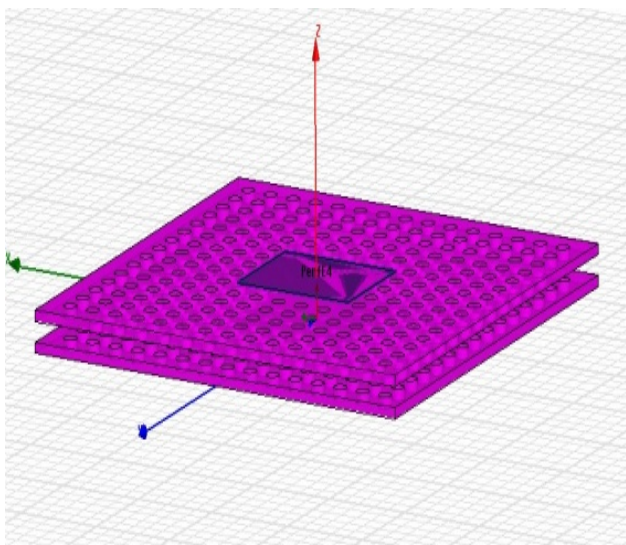


Fig.1. (b) Stacked antenna with PBG structure on HFSS

IV. SIMULATION & RESULTS

Fig.1 shows a schematic diagram of a probe-fed stacked patch configuration, where a rectangular shaped patch is etched on a grounded substrate and fed by a microstrip transmission line. However another patch antenna is mounted on a second laminate with no ground plane and is placed directly above the driven patch.

In order to analyze the performances of the proposed antenna, the Ansoft HFSS is used which calculate return loss, VSWR, radiation patterns and gain. HFSS (High Frequency Structure Simulator) is based on Finite Element Method (FEM) a high performance full wave electromagnetic (EM) field simulator that takes advantage of the familiar Microsoft Windows graphical user interface. The simulation results show gain enhancement at the operating frequency of 2.4 GHz.

Table: 1 Parameter of Stacked Patch Antenna

Antenna Part	Parameter	Value
Patch	Length	37.01 mm
	Width	28.2 mm
Patch Substrate	Flame Retardant 4 (FR-4)	
	Dielectric Constant	4.4
	Height	1.6 mm
	Dielectric loss tangent	0.02
PBG Structure	Radius of PBG structure	4 mm
	Distance between each radius	2 mm
	No. of PBG structure in each plane	225
Operating Frequency		2.4 GHz
Length of ground plate (L_g)		140 mm
Width of ground plate (W_g)		120 mm
Feeding Technique		Coaxial feeding

The return loss for the conventional stack patch antenna is -18.55 dB at 2.33 GHz and for the proposed stacked patch antenna it is -21.60 dB at 2.37GHz.

Moreover, VSWR is a measure of how well matched antenna is to the cable impedance. The smaller VSWR, better the antenna is matched to the transmission line and the more power is delivered to the antenna. A perfectly matched antenna would have a VSWR of 1:1. This indicates how much power is reflected back or transferred into a cable. VSWR obtained from the simulation is 1.13 dB which is approximately equals to 1.1:1 as shown in Figure 3. This considers a good value as the level of mismatched is not very high because high VSWR implies that the port is not properly matched.

Figure 4 shows that the input impedance of the antenna at the center frequency 2.4 GHz is 48.98 ;this is very close to the standard value 50 .

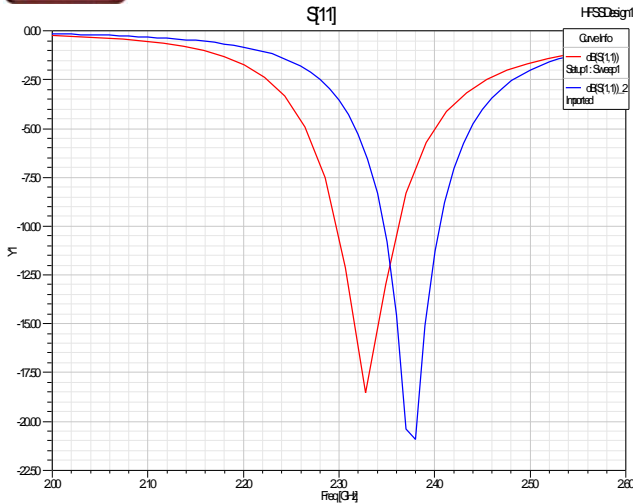


Fig.2. Return loss (S11) of the conventional stacked patch antenna (Red) and PBG based antenna (Blue).

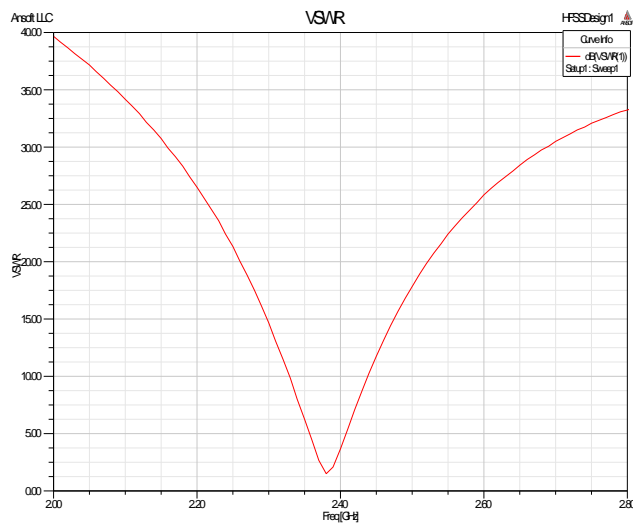


Fig.3. VSWR vs. Frequency of PBG based antenna

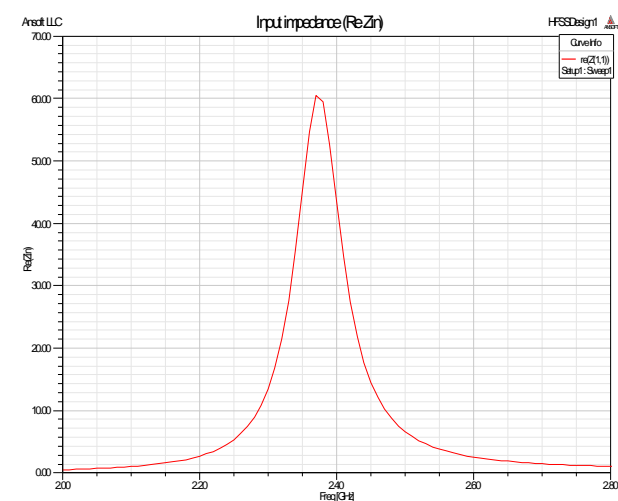


Fig.4. The Input impedance (Re Zin) of PBG based

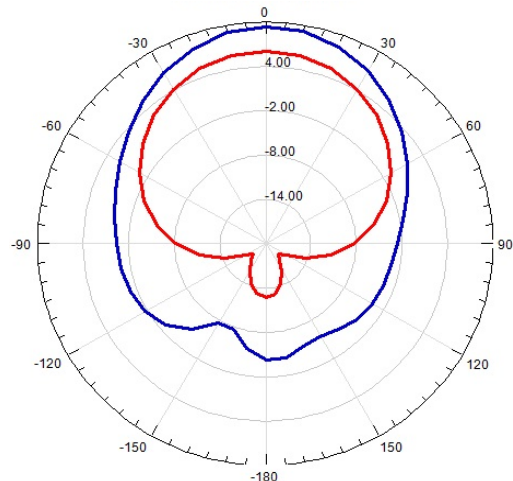


Fig.3. Comparison of gain of the conventional stacked patch antenna (Red) and PBG based stacked Patch (Blue) in E-plane.

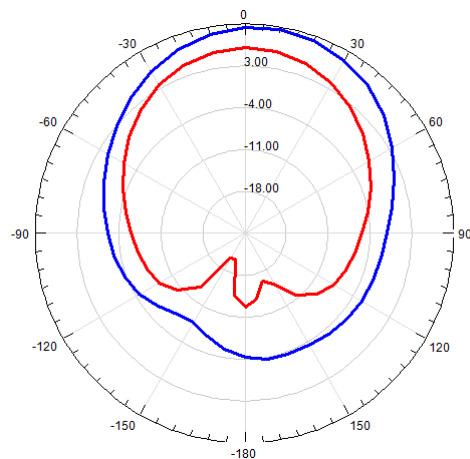


Fig.4. Comparison of gain of the conventional stacked patch antenna (Red) and PBG based stacked Patch (Blue) in H-plane.

The radiation patterns at resonant frequency are shown in Figs. 3 and 4, which is representative of the radiation in both planes throughout the bandwidth. From the simulated results, it is found that the gain of the conventional stacked antenna and the proposed stacked antenna is 6.2 dB and 9.38 dB respectively. So, the gain of the proposed patch antenna on PBG substrates is 3.18 dB more than the conventional patch antenna.

Table: 2. Comparisons of Return Loss and Gain

Antenna Type	Parameters	Return loss (dB)	Gain (dB)
Conventional stacked Patch Antenna		-18.55 dB with the center frequency 2.33GHz	6.20 dB
Proposed stacked Patch Antenna with PBG Structures		-21.60 dB with the center frequency 2.37GHz	9.38B

V. CONCLUSION

The goal of this paper is to design a stacked patch antenna operates at 2.4 GHz and study the performance of microstrip patch antenna integrated with PBG structure. From the simulated results, it is seen that the performances of a proposed stack patch antenna over the conventional patch antenna is better. The proposed antenna have offered gain enhancement of 3.18 dB at operating frequency of 2.4 GHz with a stable radiation pattern within the frequency range. The proposed antenna also exhibits a good impedance matching of approximately 50 Ohms at the center frequency. This antenna can be easily fabricated on substrate material due to its small size and thickness. The simple feeding technique used for the design of this antenna make this antenna a good choice in many communication systems.

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