*International Journal of Electrical, Electronics and Computer Engineering* **4**(2): 87-94(2015)
**ISSN No. (Online): 2277-2626**

# Fourth-Generation Cellular Networks Design and Simulation of Micro Strip Patch Antennas

***Arun Kumar Jain and Prof. Vinus Tyagi***
*Department of Electronic and Communication Engineering,*
*RITS, Bhopal, (MP), India*

*(Corresponding author: Arun Kumar Jain)*
*(Received 13 September, 2015 Accepted 02 November 2015)*
*(Published by Research Trend, Website: www.researchtrend.net)*

**ABSTRACT: Various shapes of microstrip patch antenna had been designed in antenna field. This paper represents two patch element combined together and formed antenna array I have focus on the design and simulation of Microstrip patch antennas (which are widely used in cell phone today) with an emphasis on optimization of a 2.4 GHz to 3.42GHz circular probe fed patch antenna. I have found that different parameter like substrate dimension,μ, $\varepsilon$, patch radius, feed radius etc. affects the directivty, radiation efficiency, total efficiency and return loss curve of the patch antenna. I have analysed the simulation result for far-field of different patch antenna and on comparing the parameter values of different patch antenna. I found an optimized patch antenna. I have designed and studied the simulated performance result of an optimized microstrip patch antenna using CST simulator. The rapid growth of wireless and satellite communication applications has provided an impetus for increased interest in the research and design of antennas with enhanced performance characteristics.**

**Keywords:** Loss, VSWR, Gain, Directivity and Antenna efficiency.

## I. INTRODUCTION

Antenna is a very interesting component in communication field. Antenna is responsible for converting sound waves into electromagnetic waves and vice-versa. Antenna also plays a very important role for transmission and reception process of signals from one place to another place. Due to the compactness the microstrip antennas are came into existence. Various shapes [1,5]of microstrip patch are available for such as rectangular, square, circular, annular etc. The purpose of choosing triangular shape is the triangular waveforms can b easily calculated rather than other waveforms. Triangular microstrip patch antenna consists of a triangular shape radiating patch on one side of dielectric substrate which mounted on a ground plane. For getting the good performance of patch antenna we must careful about the height, dielectric constant of material and operating frequency. Periodic structure has long been an active subject in the microwave community and has recently attracted considerable attention due to the incorporation of [2] electromagnetic band-gap (EBG) structures for enhancing antenna performance. In the proposed work, first of all an EBG structure has been designed on a dielectric substrate material. Then it has been employed to study microstrip patch antennas and arrays performance etched on another substrate layer. Thus, basic idea is to design the EBG substrate backed patch antenna, so that the band gap of EBG substrate and resonant frequency of patch antenna overlaps, therefore inhibiting the surface wave propagation. The feature of surface wave suppression helps to improve antenna's performance such as increasing the antenna gain and reducing back radiation in the case of finite antenna ground plane. In addition, the in-phase reflection feature leads to low profile antenna designs. A single patch has been investigated with the designed EBG [3] by varying number of EBG layers and their spacing with the patch. A novel design of an electromagnetic band-gap (EBG) structure using CST simulation software has been proposed for application in microstrip antennas. This EBG structure when incorporated with microstrip patch antenna is found to increase its directivity remarkably. The designed EBG structures suppress propagation of surface waves at a particular band-gap frequency and have been found to decrease reflection loss significantly.

The EBG structure has been designed for a band-gap 6.5 to 8.5 GHz. [7]. This structure has been applied on a rectangular patch substrate with dielectric constant 6.6. The directivity using the designed structure has been found to be 8.626 dB at 7.5 GHz. The return loss curve has been improved by using EBG structure [4] of microstrip Patch antennas. My paper focuses on the hardware fabrication and software simulation of several antennas. In order to completely understand the above it is necessary to start off by understanding various terms associated with antennas and the various types of antennas. This is what is covered in this introductory

## II. ANTENNA PARAMETERS

An antenna is an electrical conductor or system of conductors Transmitter - Radiates electromagnetic energy into space Receiver - Collects electromagnetic energy from space The IEEE definition of an antenna as given by Stutzman and Thiele is, "That part of a transmitting or receiving system that is designed to radiate or receive electromagnetic waves". The major parameters associated with an antenna are defined in the following sections.

**Antenna Gain.** Gain is a measure of the ability of the antenna to direct the input power into radiation in a particular direction and is measured at the peak radiation intensity. Consider the power density radiated by an isotropic antenna with input power $P_0$ at a distance $R$ which is given by $S = P_0/4\pi R^2$. An isotropic[8] antenna radiates equally in all directions, and its radiated power density $S$ is found by dividing the radiated power by the area of the sphere $4\pi R^2$. An isotropic radiator is considered to be 100% efficient. The gain of an actual antenna increases the power density in the direction of the peak radiation:

$$S = \frac{P_0 G}{4\pi R^2} = \frac{|E|^2}{\eta}$$

Or $$|E| = \frac{1}{R}\sqrt{\frac{P_0 G \eta}{4\pi}}$$

Gain is achieved by directing the radiation away from other parts of the radiation sphere. In general, gain is defined as the gain-biased pattern of the antenna.

Power Density $$S(\theta,\phi) = \frac{P_0\ G(\theta,\phi)}{4\pi R^2}$$

$$U(\theta,\phi) = \frac{P_0 G(\theta,\phi)}{4\pi}$$ Radiation Intensity

**Antenna Efficiency.** The surface integral of the radiation intensity over the radiation sphere divided by the input power $P_0$ is a measure of the relative power radiated by the antenna, or the antenna efficiency.

$$\frac{P_r}{P_0} = \int_0^{2\pi}\int_0^{\pi} \frac{G(\theta,\phi)}{4\pi} \sin\theta\ d\theta\ d\phi = \eta_e$$

Where $P_r$ is the radiated power. Material losses in the antenna or reflected power due to poor impedance match reduce the radiated power.

**Effective Area.** Antennas capture power from passing waves and deliver some of it to the terminals. Given the power density of the incident wave and the effective area of the antenna, the power delivered to the terminals is the product.

$$P_d = SA_{eff}$$

For an aperture antenna such as a horn, parabolic reflector, or flat-plate array, effective area is physical area multiplied by aperture efficiency. In general, losses due to material, distribution, and mismatch reduce the ratio of the effective area to the physical area. Typical estimated aperture efficiency for a parabolic reflector is 55%. Even antennas with infinitesimal physical areas, such as dipoles, have effective areas because they remove power from passing waves.

**Directivity.** Directivity is a measure of the concentration of radiation in the direction of the maximum.

$$\text{Directivity} = \frac{\text{maximum radiation intensity}}{\text{average radiation intensity}} = \frac{U_{max}}{U_0}$$

Directivity and gain differ only by the efficiency, but directivity is easily estimated from patterns. Gain—directivity times efficiency—must be measured. The average radiation intensity can be found from a surface integral over [9] the radiation sphere of the radiation intensity divided by $4\pi$, the area of the sphere in steradians:

$$\text{average radiation intensity} = \frac{1}{4\pi}\int_0^{2\pi}\int_0^{\pi} U(\theta,\phi)\sin\theta\ d\theta\ d\phi = U_0$$

This is the radiated power divided by the area of a unit sphere. The radiation intensity $U(\theta,\varphi)$ separates into a sum of co- and cross-polarization components:

$$U_0 = \frac{1}{4\pi}\int_0^{2\pi}\int_0^{\pi}[\,U_c(\theta,\phi) + U_x(\theta,\phi)]\sin\theta\, d\theta\, d\phi$$

Both co- and cross-polarization directivities can be defined:

$$Directivity_C = \frac{U_{C,max}}{U_0} \qquad Directivity_X = \frac{U_{X,max}}{U_0}$$

Directivity can also be defined for an arbitrary direction $D(\theta,\varphi)$ as radiation intensity divided by the average radiation intensity, but when the coordinate angles are not specified, we calculate directivity at $U_{max}$.

**Path Loss.** We combine the gain of the transmitting antenna with the effective area of the receiving antenna to determine delivered power and path loss. The power density at the receiving antenna is given by equation and the received power is given by equation By combining the two, we obtain the path loss as given below

$$\frac{P_d}{P_t} = \frac{A_2 G_1(\theta,\phi)}{4\pi R^2}$$

Antenna 1 transmits, and antenna 2 receives. If the materials in the antennas are linear and isotropic, the transmitting and receiving patterns are identical . When we consider antenna 2 as the transmitting antenna and antenna 1 as the receiving antenna, the path loss is

$$\frac{P_d}{P_t} = \frac{A_1 G_2(\theta,\phi)}{4\pi R^2}$$

We make quick evaluations of path loss for various units of distance *R* and for frequency *F* in megahertz using the formula

$$path\,loss(dB) = K_v + 20\log(f\,R) - G_1(dB) - G_2(dB)$$

where $K_U$ depends on the length units as shown in table 1.

| Unit | $K_U$ |
|---|---|
| km | 32.45 |
| nm | 37.80 |
| miles | 36.58 |
| m | −27.55 |
| ft | −37.87 |

**Input Impedance.** The input impedance of an antenna is defined as "the impedance presented by an antenna at its terminals or the ratio of the voltage to the current at the pair of terminals or the ratio of the appropriate components of the electric to magnetic fields at a point". Hence the impedance of the antenna can be written as given below.

$$Z_{in} = R_{in} + jX_{in}$$

where $Z_{in}$ is the antenna impedance at the terminals
$R_{in}$ is the antenna resistance at the terminals
$X_{in}$ is the antenna reactance at the terminals

The imaginary part, $X_{in}$ of the input impedance represents the power stored in the near field of the antenna. The resistive part, $R_{in}$ of the input impedance consists of two components, the radiation resistance $R_r$ and the loss resistance $R_L$.[10] The power associated with the radiation resistance is the power actually radiated by the antenna, while the power dissipated in the loss resistance is lost as heat in the antenna itself due to dielectric or conducting losses.

**Antenna Factor.** The engineering community uses an antenna connected to a receiver such as a spectrum analyzer, a network analyzer, or an RF voltmeter to measure field strength E. Most of the time these devices have a load resistor ZL that matches the antenna impedance.

The incident field strength $E_i$ equals antenna factor AF times the received voltage $V_{rec}$.

We relate this to the antenna effective height:

$$AF = \frac{E_i}{V_{rec}}$$

AF has units meter$^{-1}$ but is often given as dB(m$^{-1}$). Sometimes, antenna factor is referred to [12] the open-circuit voltage and it would be one-half the value given by equation.

We assume that the antenna is aligned with the electric field; in other words, the antenna polarization is the electric field component measured:

$$AF = \sqrt{\frac{\eta}{Z_L A_{eff}}} = \frac{1}{\lambda}\sqrt{\frac{4\pi}{Z_L G}}$$

This measurement may be corrupted by a poor impedance match to the receiver and any cable loss between the antenna and receiver that reduces the voltage and reduces the calculated field strength.

**Return Loss.** It is a parameter which indicates the amount of power that is "lost" to the load and does not return as a reflection. Hence the RL is a parameter to indicate how well the matching between the transmitter and antenna has taken place. Simply put it is the S11 of an antenna. A graph of s11 of an antenna vs frequency is called its return loss curve. For optimum working such a graph must show a dip at the operating frequency and have a minimum dB value at this frequency. This parameter was found to be of crucial importance to our paper as we sought to adjust the antenna dimensions for a fixed operating frequency (say 2.4 GHz). A simple RL curve is shown in figure 1.

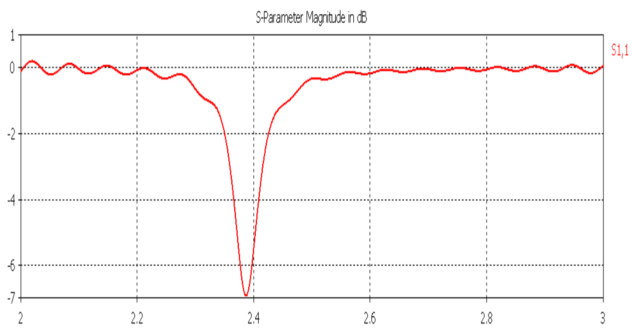


**Fig. 1.** RL curve of an antenna.

**Radiation Pattern.** The radiation pattern of an antenna is a plot of the far-field radiation properties of an antenna as a function of the spatial co-ordinates which are specified by the elevation angle (θ) and the azimuth angle (φ). More specifically [11] it is a plot of the power radiated from an antenna per unit solid angle which is nothing but the radiation intensity. It can be plotted as a 3D graph or as a 2D polar or Cartesian slice of this 3D graph. It is an extremely parameter as it shows the antenna's directivity as well as gain at various points in space. It serves as the signature of an antenna and one look at it is often enough to realize the antenna that produced it. Beam width of an antenna is easily determined from its 2D radiation pattern and is also a very important parameter. Beam width is the angular separation of the half-power points of the radiated pattern. The way in which beam width Microstrip antennas are planar resonant cavities that leak from their edges and radiate.Printed circuit techniques can be used to etch the antennas on soft substrates to produce low-cost and repeatable antennas in a low profile.

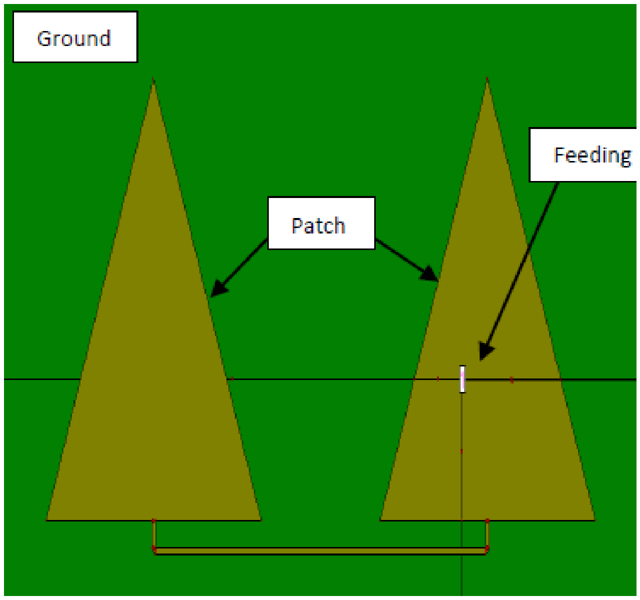


**Fig. 2.** Patch element antenna array.

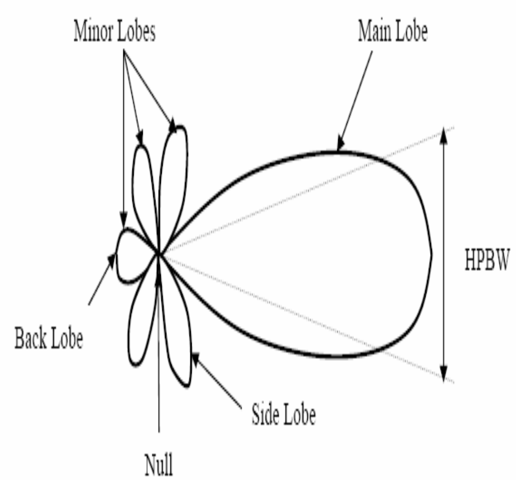


**Fig. 3.** Radiation pattern of HPBW form.

The antennas fabricated on compliant substrates withstand tremendous[15] shock and vibration environments. Manufacturers for mobile communication base stations often fabricate these antennas directly in sheet metal and mount them on dielectric posts or foam in a variety of ways to eliminate the cost of substrates and etching. This also eliminates the problem of radiation from surface waves excited in a thick dielectric substrate used to increase bandwidth.

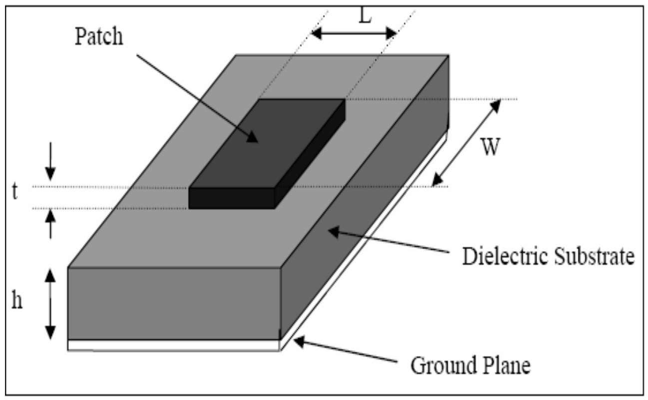


**Fig. 4.** Microstrip Patch Antenna.

I have designed large number of patch antenna by varying different parameters like $\mu_r$, $\epsilon_r$, substrate dimension ,patch radius and feed radius. I have studied the [16] simulation result for far-field for different patch antenna and on comparing the parameters values for different patch antenna we found an optimised patch antenna. I have found directivity = 7.166 dB, radiation efficiency = -0.157 dB and total efficiency = -0.527 dB.

## III. RESULTS

The proposed EBG-based antenna design consists of 2.4 GHz to 3.42GHz drilled holes on a dielectric substrate. Parameters that described an EBG structure are radius and periodicity of the structures (drilled holes/cylindrical rods). Fig. shows the proposed antenna design with EBG and without EBG.

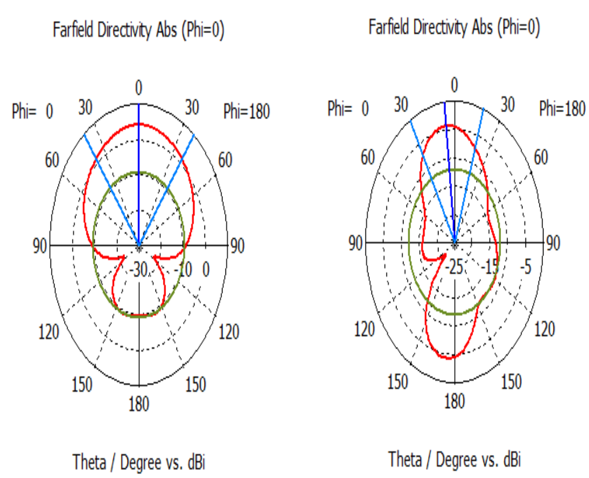


**Fig. 5.** Polar plot of directivity for phi and patch antenna.

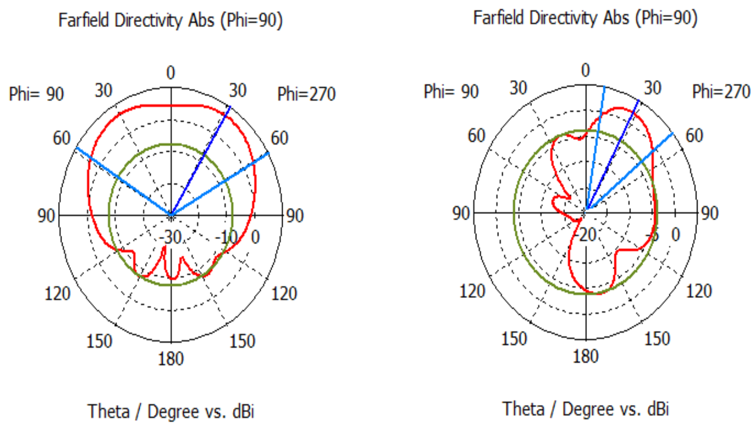


**Fig. 6.** Polar plot of Directivity  90 for phi = 90 for EBG patch antenna.

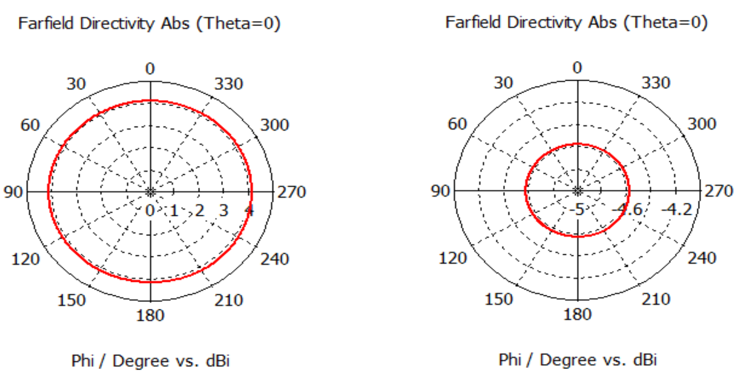


**Fig. 7.**  Plot of directivity for theta = 0 for simple patch = 0 for EBG  antenna.

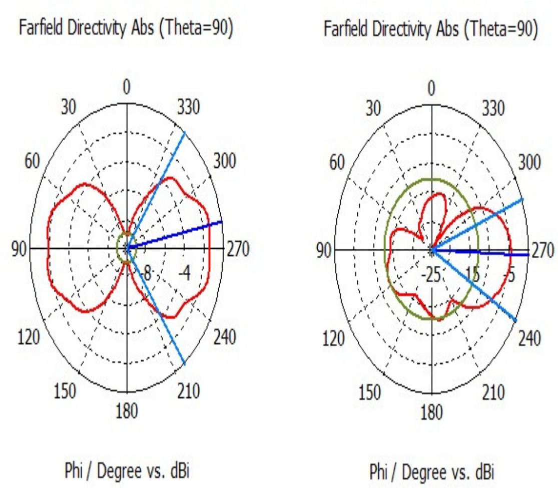


**Fig. 8.** Plot theta = 90 for antenna, directivity for theta = 90  EBG based antenna.

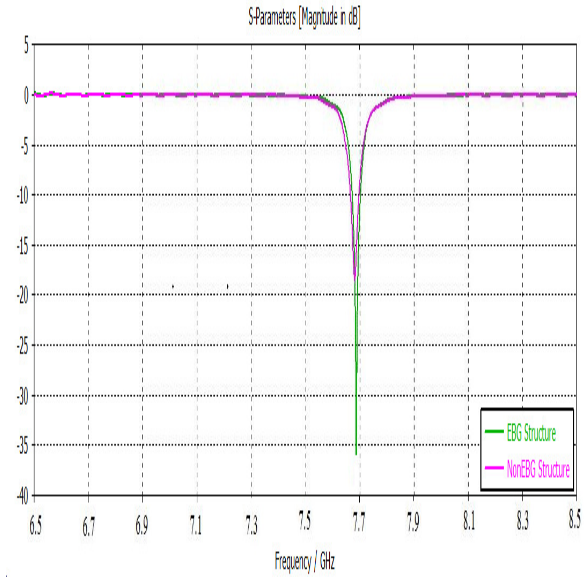


**Fig. 9.** Reflection Loss curve Patch antenna and EBG without EBG structure antenna**.**

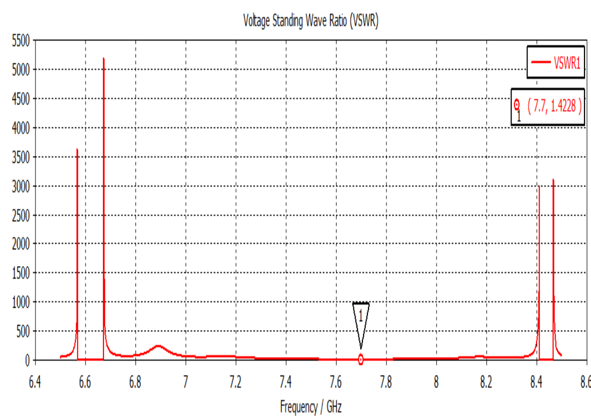


**Fig. 10.** VSWR Curve of Non EBG Structure of Patch Antenna.

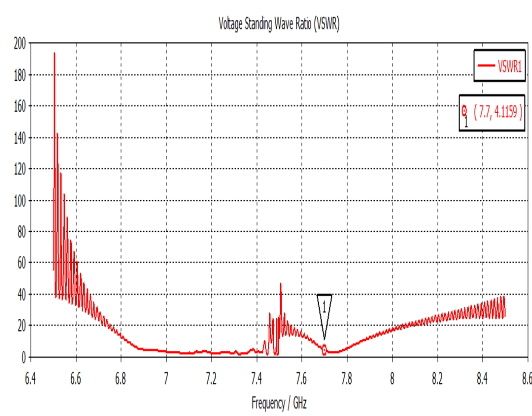


**Fig. 11.** VSWR Curve of EBG Structure of Patch Antenna.

## IV. CONCLUSION

A novel electromagnetic band-gap structure has been also designed and analyzed in this thesis using finite-difference time-domain solver and its incorporation in a microstrip patch antenna for improvement of gain has been investigated. The designed EBG structure is a periodic rectangular lattice of drilled holes (radius = 4.32 mm with periodicity 10 mm) giving a band-gap of 6.5-8.5 GHz. These structures have been implemented on a rectangular patch of size 7 mm × 10 mm on a substrate with dielectric constant 6.7. A remarkable improvement in gain was observed when the patch substrate is replaced with the EBG-based substrate due to suppression of surface waves by the air-dielectric inside EBG structure. Thus, this EBG-based microstrip antenna design can be considered suitable for wireless communication requiring moderate bandwidth and high gain. It is known that the gain of the antenna can be increased by reducing any loss of the antenna. Selection of a good quality (low-loss) substrate will reduce the dielectric and conductor losses. However, surface waves travel inside the substrate and reduce the gain. To reduce this surface wave loss, wave propagation has to be stopped inside or reflected outside the substrate to enhance the gain in forward direction. The waves are arrested or retarded by obstructing their path with a high propagation impedance air ($\varepsilon_r$ =1). The impedance offered by a dielectric is given as $Z_0 = \eta/\sqrt{\varepsilon_r}$. This implies that the impedance offered is maximum for smallest value of $\varepsilon_r$ (the smallest value of $\varepsilon_r$ being 1 for air). In the proposed antenna, the surface waves are reduced by drilling holes in periodic fashion in the dielectric substrate. The remarkable improvement in Directivity can be attributed to the periodic effect of embedding EBG patches in the substrate.

## V. FUTURE WORK

In this paper, we examined a circular probe fed patch antenna and the use of EBG structure on the feedline to help improve the directivity. The future work can involve changing the antenna type (including antenna shape and the dielectric of the substrate) and carry out further research into the EBG structures. Besides, we can also use different shapes of microstrip patches such as square shape and circular shape patch to carry out the research. While examining, similar EBG patterns proposed in the paper can be etched on the feedline of the proposed new antennas. Hence, one can formulate the results for every kind of patch shape for a patch antenna.

## REFERENCES

[1]. Constantine A. Balanis, "Antenna Theory: Analysis Design," Third Edition, 2005 John Wiley & Sons, Inc.

[2]. R. B. Waterhouse, "Design of probe-fed stacked patches," *IEEE Trans. Antennas Pmp*., vol. **47**, no. 12, pp. 1780-1784, Dec. 1999.

[3]. Bhal and Bhartia," Microstrip antenna Design-Handbook ", Chapters –3 &4, Artech House, Boston, London, 2001.

[4]. S. Zavosh, "Analysis of circular microstrip patch antennas backed by circular cavities," *Department of Electrical, Computer and Energy Engineering,* ASU,Tempe, AZ,USA,1993.

[5]. L.Greetis and E.Rothwell, "A self structuring patch antenna," in *Proc. IEEE Antennas Propg. Soc. Int. Symp.,* Jul. 2008,pp.1-4.

[6]. C. A. Balanis, Advanced Engineering Electromagnetics, 2nd ed. NewYork,USA: Wiley,2012.

[7]. Harrington, R.F.: 'Effects of antenna size on gain, bandwidth, and efficiency', J. Res. Natl. Bur. Stand. D, Radio Propag. , 1960, **64**, (1),pp. 1 – 12.

[8]. Newmanm E.H. and Tylyathan, P., "Analysis of Microstrip Antennas Using Moment Methods," IEEE Trans. Antennas Propag., vol. **AP-29**, No. 1, pp. 47-53, January 1981.

[9]. J.Y. Li, Zaw-Zaw Oo, and Le-Wei Li, "Improvement of characteristics of microstrip antennas using unbalanced structures," IEEE Antennas and wireless *Propagat. Lett,* vol. **1**, pp.71-73,2002.

[10]. Hammerstad, E.O., "Equations for Microstrip Circuit Design," *Proc. Fifth European Microwave Conf.,* pp. 268-272, September 1975.

[11]. James, J.R. and Hall, P.S., Handbook of Microstrip Antennas, Vol. **1** and **2**, Peter Peregrinus,London,UK,1989.

[12]. N. Rao, Dinesh Kumar, " Investigation of a Microstrip Patch Antenna with EBG structures using FDTD method" IEEE Transaction 2011, p.332-337.

[13]. J. Shumpert, T. Ellis, G. Rebeiz and L. Katehi, "Microwave and Millimeter-Wave Propagation in Photonic Band-Gap Structures," AP-S/URSI, p. 678,1997.

[14]. D.W. Prather, S. Shi, A. Sharkawy, J. Murakowski, G.J. Schneider," Photonic Crystals: Theory, Applications, and Fabrication", John Wiley & Sons, New Jersey, 2009.

[15]. C.M. Soukoulis, "The History and Review of the Modelling and Fabrication of Photonic Crystals", *Nanotechnology* **13**, 420-423, 2002.

[16]. M.A.G. Laso, M.J. Erro, D. Benito, M.J. Grade, T. Lapetegi, F. Faleone, and M. Sorolla, "Analysis and Design of 1D Photonic Band Gap Microstrip Structure using a Fiber Grating Model", Microwave and Optical technology Letters, Vol. **22**, No. 4, 1999.