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Effects of an EBG Structure on Microstrip Patch Antenna for LTE Mobile Communication Systems

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ABSTRACT: Long Term Evolution (LTE) to achieve very high data rates in both the uplink and downlink channels. Such antenna systems are required to fit within the hand-held (mobile) terminal which occupies a small size (typically not more than 60*100 mm^2). Utilization of electromagnetic band-gap (EBG) structures is becoming attractive in the electromagnetic and antenna community. In this paper, the effects of a two-dimensional electromagnetic bandgap (EBG) Structures on the performance of microstrip patch antenna arrays are investigated using the HFSS.
Microstrip patch antennas became very popular because of planer profile, ease of analysis and fabrication, compatibility with integrated circuit technology & their attractive radiation characteristics. To improve surface wave losses uses Electro Magnetic Band Gap structures, for improving efficiency & bandwidth do proper impedance matching. This paper represents the design of Electromagnetic Band gap (EBG) structure having fractal shape and its effect on antenna performance. The aim of this paper is to design, simulate and fabricate the new EBG structure operating at 2.4GHz frequency and to study the performance of the rectangular microstrip antenna in terms of the bandwidth and VSWR with and without EBG structure which are characterized in terms of return loss and radiation pattern. The antenna has a measured Centre frequency of 2.4 GHz, bandwidth of 105 MHz and total size of 29.0 * 38.1 mm^2.

KEYWORDS: Microstrip Antenna, Electromagnetic Band Gap (EBG), LTE, VSWR, Mutual Coupling, R. L.

I. INTRODUCTION

Multiple-input-multiple-output (MIMO) transmission is one of the promising antenna technologies used for wireless communications. Through spatial multiplexing, MIMO achieves high capacities. The only limitation is that, the transmitting and receiving antennas should be placed at least half the wave length of the carrier signal in order to transmit or receive uncorrelated signals. Apart from that, each of transmit or receive antenna requires a separate circuit which means, higher the no of antennas used higher the cost. It is indisputable that antenna plays a significant part in communication system. Therefore, an increasingly number of technicians begin to do some research and development of antenna. However, with rapid development of the communication industry, the requirement of antenna will be achieved with high quality. Nowadays, there are different kinds of antennas in the market such as dipole antenna, microstrip patch antenna, loop antenna, meander-line antenna and so on [1].

The term that is given to fourth generation mobile communication networks is long term evolution (LTE). LTE will be internet protocol (IP) based and will provide high throughput, broader bandwidth and better handoff capabilities than current third generation networks. Theoretical peak data rates of 300 Mbps and 75 Mbps for the downlink and uplink channels are expected with the use of the enabling technologies [2], [3]. LTE will support two modes of operation, time division duplexing (TDD) and frequency division duplexing (FDD). TDD is not as attractive to mobile operators as FDD mode. In FDD mode, several high and low frequency bands are covered [4]. The 700 MHz bands represent the low frequency bands while the 2600 MHz bands represent the high frequency ones. LTE supports channel bandwidths up to 20 MHz per channel (i.e. uplink or downlink) [5].

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The reason why microstrip antennas have become very popular is that they have several advantages compared to conventional microwave antennas; light weight, low volume, thin profile, low fabrication cost, easy integration with microwave integrated circuits, ease of installation, etc. are some of them. However, they do have some limitations such as narrow bandwidth, low gain, low power handling capability (~100W), large ohmic losses in feed structures. A lot of new techniques have evolved to minimize these limitations [6].

II. LITERATURE SURVEY

Micro strip antenna is most common small sized antenna in which a metal patch is deposited on dielectric material. Micro strip patch antennas have been an attractive choice in mobile and radio wireless communication. Due to unique characteristics of an Electromagnetic bandgap (EBG) Structure, it enables it to be used in Radio frequency (RF) and microwave application which is considered to be among the significant breakthrough in the EBG technology nowadays. Many exciting phenomena appear when periodic structures interact with electromagnetic waves, which include band pass, band stop and also frequency band gap. Others include wave propagation, noise reduction for high speed electronic devices and mutual coupling effect reduction. Recently there is significant increase in utilizing EBG structures in antenna community [7].

Electromagnetic band gap structures sometimes called as photonic band gap materials are the artificially engineered objects that avert the propagation of electromagnetic waves in a specified band of frequency. These structures have interesting properties which cannot be seen in the natural materials such as they reflect incident plane wave's in-phase rather than out of the phase [8].In this paper, the rectangular microstrip patch antenna has a new fractal electromagnetic band-gap (EBG) structure. The patch antenna is fed by a driven terminal and is integrated within a fractal electromagnetic band-gap structure, on same substrate to raise the antenna gain and bandwidth. The fractal electromagnetic band-gap structure applied is a periodic structure with similar periods[9].

In its most basic form, a Microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown in Figure 1. The patch is generally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate. In order to simplify analysis and performance prediction, the patch is generally square, rectangular, circular, triangular, and elliptical or some other common shape. For a rectangular patch, the length L of the patch is usually $0.3333\lambda_0 < L < 0.5\ \lambda_0$, where λ_0 is the free-space wavelength. The patch is selected to be very thin such that, $t \ll \lambda_0$ (where't'is the patch thickness). The height *h* of the dielectric substrate is usually $0.003\ \lambda_0 <= h <= 0.5\ \lambda_0$. The dielectric constant of the substrate ε_r is typically in the range $2.2 <= \varepsilon_r <= 12$[10].

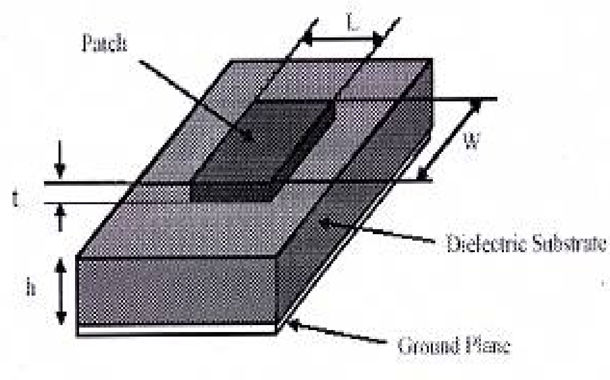

Fig.1 Structure of a Rectangle Microstip Patch Antenna

Microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane. For good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation. However, such a configuration leads to a larger

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antenna size [11].

The typical electric field lines for a microstrip line are non-homogenous lines of two dielectrics viz. substrate and air. Most of the electric field lines reside in the substrate and parts of some lines exist in air shown in fig 2. As L/H>>1 and $\varepsilon_r >> 1$, the electric field lines concentrate mostly in the substrate. Fringing in this case makes the microstrip line look wider electrically compared to its physical dimensions. Since some of the waves travel in the substrate and some in air, an effective dielectric constant ε_e is introduced to account for fringing and wave propagation in the line.The effective dielectric constant is defined as the dielectric constant of the uniform dielectric material such that, the microstrip line with its original dimensions and height above the ground plane, embedded in this dielectric material, has identical electrical characteristics as the actual line, with air above the substrate.

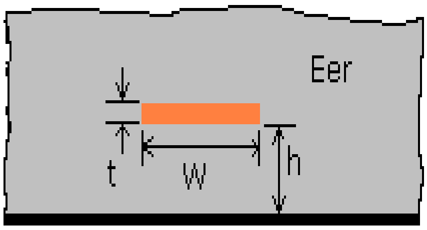


Fig. 2 Effective dielectric constant geometry.

Typically, ($\varepsilon_r >> 1$), the value of ε_e will be closer to the value of the actual dielectric constant ε_r of the substrate. The effective dielectric constant is also function of frequency. As the frequency of operation increases, most of the electric field lines concentrate in the substrate. Therefore, the microstrip line behaves more like a homogenous line of one dielectric (onlysubstrate), and the effective dielectric constant approaches the value of the dielectric constant of the substrate. The values of effective dielectric constant at low frequencies are referred to as the static values. For, W/h > 1,

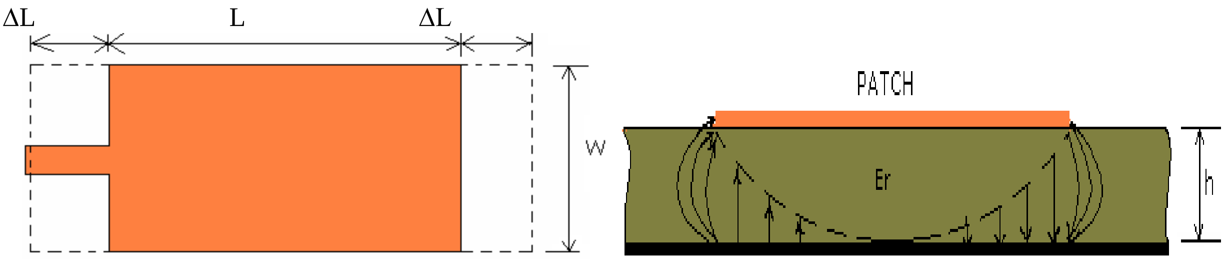
$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(\frac{1}{\sqrt{1 + 12h/W}}\right) \text{ eq. (1)}$$

Because of the fringing effects, electrically the patch of the microstrip antenna looks greater than its physical dimensions as shown in fig. 3. For the principal E-plane (xy-plane), the electrical dimensions of the patch along its length have to be extended by a distance ΔL, which is function of the effective dielectric constant ε_e and the width-to-height ratio (W/h). An approximate relation for normalized extension of the length is[12].

$$\frac{\Delta L}{h} = 0.412\left[\frac{(\varepsilon_e + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_e - 0.258)\left(\frac{W}{h} + 0.8\right)}\right] \text{ eq. (2)}$$

Since the electrical length of the patch has been extended by ΔL on each side, the effective length of the patch is now

$$L_{eff} = L + 2\Delta L \text{ eq. (3)}$$



(a) Top view (b) Side view

Fig.3 Principle of microstrip patch antenna

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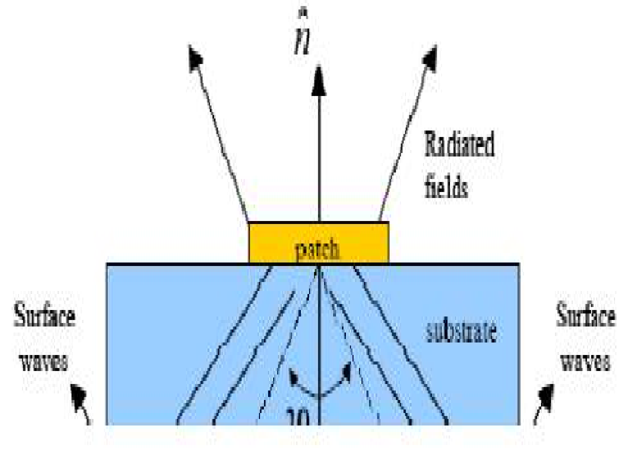
In this work, we design and fabricate a single microstrip antenna on a effect EBG structure with a center frequency around 2.412 GHz, bandwidth of at least 105 MHz and total size of an antenna 29.0 X 38.1 mm. This paper presents an overview design microstrip patch antennas in the ISM band by providing a good initial geometrical configuration of the antenna. This article has-been divided into four sections. Section I describes introduction. Section II describes in detail of the literature survey on microstrip patch antenna structure and design. Section III describes in detail band gap characterization of the EBG structure. Section IV describes in detail modelling of the microstrip patch antenna with effect EBG structure. The results obtained from our proposed antenna are listed and discussed in Section V. Finally concluding remarks are presented in Section VI.

III. BAND GAP CHARACTERIZATION OF THE EBG STRUCTURE

This technology manipulates the substrate in such a way that surface waves are completely forbidden from forming, resulting in improvements in antenna efficiency and bandwidth, while reducing side lobes and electromagnetic interference levels. These substrates contain so called Photonic Crystals. Also known as electromagnetic band-gap (EBG) structures and electromagnetic band-gap materials (EBMs), are a class of periodic metallic, dielectric, or composite structures that exhibit a forbidden band, or band gap, of frequencies in which waves incident at various directions destructively interfere and thus are unable to propagate. The first photonic-crystal structure conceptualized and manufactured was in 1991 by Yablonovitch, then at Bell Communications Research in New Jersey. If the periodicity in an EBG structure is perturbed by either removing or adding a material with a different dielectric constant, size, or shape, a "defect" state is created in the forbidden gap, where an electromagnetic mode is allowed, and localization of the energy occurs. This paper focuses the effect of two element microstrip patch antennas array on a uniform substrate and EBG structures. A mushroom-like EBG structure was compared to other EBG structures such as holes, this structure has a winning feature of compactness, which is important in communication antenna applications such as filters in microstrip lines, as high-power microwave components. Surface wave are excited on microstrip antenna when the substrate $\epsilon r > 1$. Besides end fire radiation, surface wave give rise to coupling between various elements of an array. Surface wave are launched into the substrate.



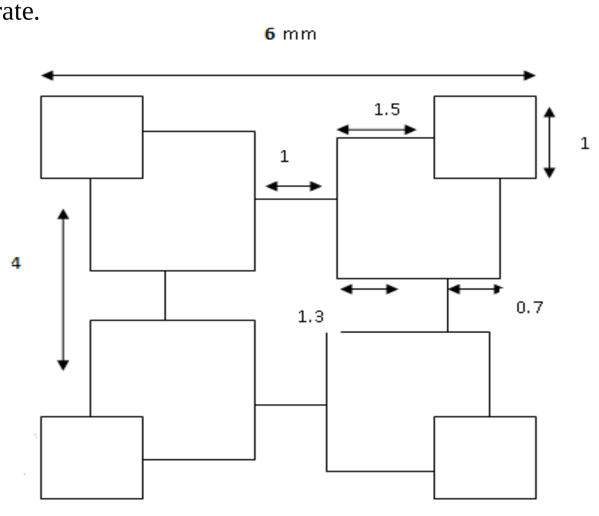


Fig. 4 Formation of Surface wavesFig.5 Fundamental Structure of an EBG

These waves are incident on the ground plane at some angle shown in Fig 4, get reflected, then meet the dielectric-air interface, which also reflect them. To reduce surface waves, conventional microstrip antenna is surrounded by layers of EBG structure. The EBG structure is shown in Fig. 5. EBG structures are periodical cells composed of metallic or dielectric elements. Unique feature of EBG structures is to create the forbidden band of frequencies in which surface waves cannot propagate. Surface wave propagation is a serious problem in microstrip antennas. Surface waves reduce antenna efficiency and gain, limit bandwidth, increase end fire radiation, increase cross-polarization levels, and limit the applicable frequency range of microstrip antennas. When the antenna operates in the frequency band of this prohibition, it will features, such as increasing the antenna return loss and bandwidth, the back, gain etc.It consists of four parts: a ground plane, a dielectric substrate, metallic patches, and connecting vias. This EBG structure exhibits a

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distinct stop band for surface-wave propagation. The operation mechanism of this EBG structure can be explained by an LC filter array. For an EBG structure with patch width *W*, gap width *g*, substrate thickness *h* and dielectric constant *εr*, the values of the inductor *L* and the capacitor *C* are determined by the following formula [13][14].

$$L = \mu_{\circ} h \quad \text{eq. (4)}$$

$$\text{L} = \frac{W\varepsilon_{\circ}(1+\mathcal{E}_{\circ})}{\Pi} \cos h \frac{(2W+g)}{g} \text{eq. (5)}$$

$\mu_0$is the permeability of free space and $\varepsilon 0$ is the permittivity of free space. Reference also predicts the frequency band gap as

$$\text{w} = \frac{1}{\sqrt{LC}} \text{ eq. (6)}$$

$$\text{BW} = \frac{\Delta w}{w} = \frac{1}{\eta}\sqrt{(\frac{L}{C})}\text{eq. (7)}$$

where η is the free space impedance which is 120π.

IV. MODELLING OF THE EBG MICROSTRIP ANTENNA

Recently, considerable research effort in the electromagnetic band gap (EBG) structure for antenna application to suppress the surface wave losses and improve the radiation performance of the antenna. When source signal is applied at metal ground plane & patch, the EM waves will be radiated. The radiation will not be perfect as there are some losses due to dielectric material. We have to minimize these losses. To minimize these losses we will insert EBG structures with Micro strip Patch Antenna.

EBG stands for Electromagnetic Band Gap Substrate. Electromagnetic band gap structures are defined as artificial periodic or sometimes non-periodic objects or say that dielectric materials and metallic conductors that prevent the propagation of electromagnetic waves in a specified band of frequency for all incident angles and all polarization states. At present time, there is a need of smaller and broad bandwidth antennas. This can be achieved by fabrication of antenna on thick piece of high permittivity substrate. The main disadvantage is that, the unwanted substrate modes begin to form and propagate towards the edges of the substrate, which have a deadly effect on the antenna radiation pattern.

EBG can be categorized into three groups according to their geometric configuration:

1. Three-dimensional volumetric structures.
2. Two-dimensional planar surfaces.
3. One-dimensional transmission lines.

An antenna that is placed on a high-permittivity dielectric substrate may couple power into substrate modes. As substrate modes do not contribute to the primary radiation pattern, these modes are a loss mechanism. EBG structure can offer a real solution to this problem. This method has advantages when antennas with low frequency of operation are of interest, since this will reduce the size of the antenna significantly. The size of the antenna will even get smaller because of the use of a dielectric substrate. Printed meander antennas usually have good radiation efficiency and close to directional radiation patterns.The designed single microstrip patch antenna structure is shown in Figure 1. Antenna dimensions were optimized using HFSS. The dimensions of the antenna are in mm and given by, L=38.1, W=29.0 mm, Lg=6.0 mm, W1=3 mm,The antenna was etched on an FR-4 substrate with 1.59 mm thickness, copper was used. A right angle PCB mount SMA connector was used as the feeding port for the antenna. Table I shows the Simulated results of conventional antenna for different width of the microstrip feed line.

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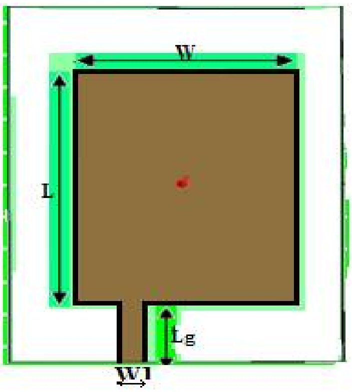

Fr (GHz)	Width (mm)	Length (mm)	R.L. (dB)	VSWR	Gain (dB)	Directi vity
2.4121	3	9	-25.03	1.27	5.5	5
2.4121	4	9	-19.94	1.33	5.5	5
2.4121	5	9	-17.39	1.56	5.5	5
2.4121	6	9	-10.60	2.01	5.5	5

Fig.6. Geometry of the microstrip patch antennaTable I: Simulated results fordiff. width of the microstrip feed line.

V. SIMULATION RESULTS

Figure 7 shows the top views of the fabricated single microstrip patch antenna structure. The radius of the sphere inclosing this antenna is 1.45. Figure 8 shows the measured and simulated reflection coefficients. An HP 8514BNetwork Analyzer was used to conduct this measurement. The correlation between the two is very well observed. The simulated f_c was 2.41 GHz, while the measured one was 2.40 GHz. The simulated -10 dB bandwidth was 105 MHz while the measured one was 95 MHz. This shows a good match between the two, although some discrepancy is expected due to the presence of the GND plane. The MLA total size is 29.0 X 38.1 mm.

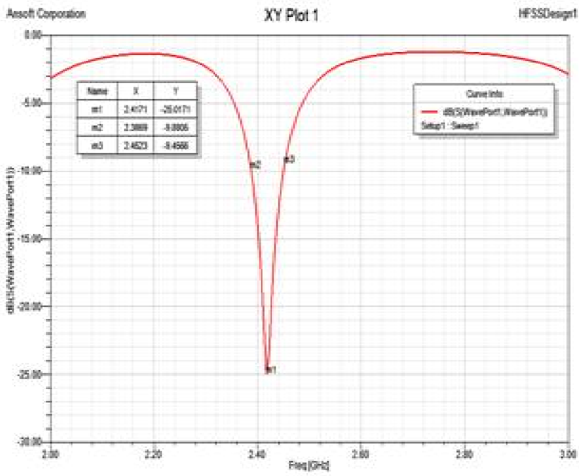

Fig.7 Photo of the fabricated Microstrip AntennaFig.8 Simulated R. L. for proposed Microstrip Antenna

This section presents the simulated results of modified microstrip patch antenna. HFSS has been used to simulate the antenna for several performance parameters such as impedance bandwidth, radiation patterns and VSWR. The parametric study of the antennas reveals the band behavior. The antenna is designed to operate on 2.41 GHz ISM band. Fig. 8 illustrates the S11 of microstrip patch antenna; where it shows a return loss of -25.1 dB for the operation on 2.41 GHz. The impedance bandwidth calculated at -10 dB scale for this band is 105 MHz. Figure 9 shows the simulated and measured VSWR for proposed microstrip patch antenna. In small antennas, the ground plane plays a major part in radiation. The current distribution on the ground plane and its effect on the resonant frequencies were also observed during simulation. The measured radiation patterns for the single element microstrip patch antenna are shown in figure 10.

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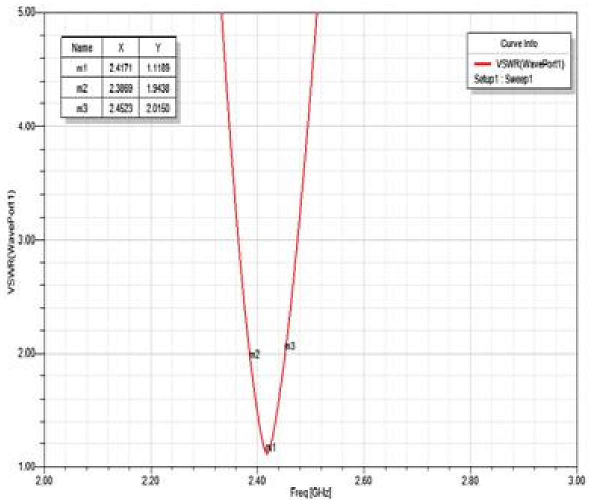

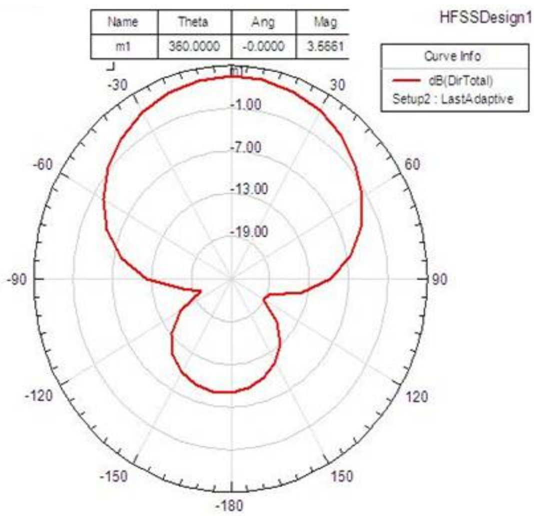

Fig.9 Simulated VSWR for proposed Microstrip Antenna Fig.10 Radiation Pattern of Proposed Microstrip Antenna

VI. CONCLUSION AND FUTURE WORK

A compact electromagnetic Band Gap (EBG) design and fabrication that is based on the microstrip patch antenna is presented. The antenna is intended for the use in the 2.4-2.7 GHz of the LTE mobile communication applications. Simulation and measurement results are compared. The single antenna has a measured center frequency of 2.41 GHz, bandwidth of 105 MHz, Return loss -25.1 is obtained and total size of antenna is 29.0 X 38.1 mm.

The Microstrip Patch Antenna with EBG is simulated by using HFSS, fabricated and there results are compared.The antenna gain and directivity are also increased while the back lobes are reduced. The gain is increased from 3.48dB to 5.55dB for both types of EBG structures. Using the EBGs around the patch antenna in the same plane, the surface waves are suppressed effectively. Therefore, the performances of the antenna are improved greatly.The fractal EBG structure has been proposed. A comparative study of simple rectangular microstrip antenna without and with EBG had been demonstrated. The bandwidths, gain of the antenna get improved. This antenna can be used in many applications. Future work for the proposed control methodology is that it can be used with various antenna designs to obtain different possible results in an easy, fast, and low-cost manner.

Better Antennas can be designed and implemented by following tasks to be done in future to make the designed antenna more flexible while using in wireless applications.

- The VSWR of the antenna can be improved by using of thermo compression bonding or spot soldering.
- The bandwidth of the antenna can be improved by mentioning the chu limit.
- The input impedance of the antenna can be improved by slightly reducing the inset distance.
- The Efficiency of the antenna can be increased by increasing the no. of turns.

REFERENCES

1. Chandana K. K. Jayasooriya, Hyuck M. Kwon and Seok Bae, Yang-Ki Hong,“Miniaturized Circular Antennas for MIMO Communication Systems – Pattern Diversity pp.331-334 2010 International ITG. Workshop on Smart Antennas (WSA 2010).
2. V. K. Garg, *Wireless Communications and Networking*, Elsevier-Morgan Kaufmann, 2007.
   a. Larmo, et. al., “The LTE Link-Layer Design,” *IEEE Commun. Mag.*, Vol. 47, No. 4, pp. 52-59, April 2009.
3. 3 GPPTS 36.101,V8.3.0, “EUTRA User Equipment Radio Transmissionand Reception,” September 2008.
4. J. D. Kraus, R. J. Marhefka, Antennae for all applications, Tata McGraw Hill, 3rd Edition.
   a. A. Balanis, Antenna Theory: Analysis and Design. New York: Wiley,Second ed., 1997.
5. Muhammad Abdulhamid1, M. K. A. Rahim, Umar Musa, “Electromagnetic Bandgap Structure for Antenna Design”, IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 10, Issue 6, Ver. I (Nov - Dec .2015), PP 2527
6. Ajay kumar,DwejendraArya,D.KSrivastava,"Band Width of Microstrip Antenna Improved by using Mushroom type EBG Structure",IEEE 2013 IMPACT.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 2, February 2016

7. F. Yang, Y. Rahmat-Samii, “Microstrip Antennas integrated with electromagnetic band-gap structure: a low mutual coupling design for array application,” IEEE Trans. Antennas and Propagation, Vol. 51, Oct. 2003.
8. Yen-Liang Kuo. Tzung-Wern Chiou. Kin-Lu Wong. A dual-band rectangular microstrip antenna using a novel photonic band gap ground plane of unequal orthogonal periods. Microwave and optical technology IERS. Vol. 30, No.4, Aug. 2001. pp. 280-283.
9. George Splitt, Marat Davidovitz, Guidelines for design of electro-magnetically Coupled microstrip patch Antennae on two layer substrates. IEEE transactions on Antennae and Propagation. Vol. 38,. No. 7 July 1990.Pp. 1136 – 1140
10. P. C. Sharma, K. C. Gupta. "Analysis and optimum design of single feed circularly polarized microstrip antenna" IEEE Transaction on Antenna & Propagation. Vol. AP-31. No.6 November 1983.
11. H. F. Shaban, H. A. Elmikaty, and A. A. Shaalan, “Study The Effects Of Electromagnetic Band-Gap (EBG) Substrate On Two Patches Microstrip Antenna”, *Progress In Electromagnetics Research B, Vol. 10, 55–74, 2008.*
12. Xu, H.J., Y. H. Zhang, and Y. Fan, “Analysis of the connection between K connector and microstrip with electromagnetic bandgap (EBC) structures,” *Progress In ElectromagneticResearch*, PIER 73, 239–247, 2007.

BIOGRAPHY

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