Study of U-Slot Electromagnetic Band Gap Structure and Its Effect on Hexagonal Patch Antenna

Kunal Srivastava
M.Tech student (Dept. of Electronic Science)
University of Delhi South Campus
Delhi, India
e-mail: kunal.1211@gmail.com

Raj Kumar
Dept. of electronic Science
DIAT giri nagar Pune
Pune, India
e-mail: aarzoo_raj@rediffmail.com

***Abstract--*This paper presents the analysis of electromagnetic band gap (EBG) structure using fractal geometry and simple mushroom type EBG and its effect on Hexagonal Patch antenna performance. The EBG structure attenuates the surface wave propagation in a specific frequency range. A new EBG structure is proposed to attenuate the surface wave better than 20 dB in frequency range from 3.1 GHz to 5.3 GHz. using this EBG structure, an antenna with center frequency of 3.8 GHz is designed. The bandwidth of this antenna is improved by 53.86 % in comparison to antenna without EBG. The simulated of radiation pattern with EBG exhibits reduction in backward radiation in comparison to radiation pattern without EBG.**

Key words-- Electromagnetic band gap (EBG) structure, periodic structures, fractal geometry, microstrip antenna, and surface wave suppression.

1. INTRODUCTION

Antenna is the back bone of the wireless communication system and microstrip antenna is one of them. Microstrip antenna has a narrow bandwidth, spurious feed radiation, poor polarization, gain and tolerance problem. The bandwidth of antenna can be enhanced by increasing the thickness of substrate but up to a certain limit .Beyond certain thickness of substrate, the efficiency of antenna starts decreasing due to more surface wave generation [1]. The EBG periodic structure exhibits wide band pass and band rejection properties at certain microwave frequencies. This unique property has been utilized in enhancing the performance of microstrip antenna and components [2,3] such as high surface impedance, increasing antenna bandwidth, gain, reducing backward radiation, improve forward radiation and suppressing the surface wave, when mounting an antenna close to the ground plane [6] . The band gap characteristics depend on the material structure such as dimension, periodicity, and permittivity [4]. The various periodic structures have been studied namely photonic crystals, helical structure and materials depending on their application [2, 5]. The EBG structure consists of four parts, which are: 1) A ground plane; 2) A dielectric substrate; 3) connecting vias; 4) metallic patches. The convention mushroom type EBG has been reported in literature. The size of mushroom type EBG structure is very large at lower frequency which increases the overall size of antenna. The size of EBG structure should be compact to make the antenna compact.

In this paper, a new EBG structure is reported. The simulated performance of this EBG structure is calculated. A circularly polarized antenna has been simulated and achieved the large bandwidth in comparison to antenna without EBG.

2. UNIFORM MUSHROOM EBG

Mushroom-like EBG structure has a parallel LC resonator as shown in Figure 1, with inductance represented by vias of radius 0.3mm and capacitance represented by the gap between metallic patch. At the resonant frequency of the EBG structure, the surface impedance goes to infinity [7]. The surface impedance of the mushroom EBG structure is given by equation (1). The resonant frequency of the EBG structure is calculated as shown in equation (2),and the inductance and capacitance of EBG is calculated as shown in equation (3) and (4)[6].

$$Zs = \frac{j\omega L}{1-(\omega/\omega_0)^2} \quad (1)$$

$$\omega_0 = \frac{1}{\sqrt{LC}} \quad (2)$$

$$C = \frac{\varepsilon_0(1+\varepsilon_r)}{\pi}\cosh^{-1}\left(\frac{w+g}{g}\right) \quad (3)$$

$$L = \mu_0 t \quad (4)$$

978-0-7695-4941-5/13 $26.00 © 2013 IEEE
DOI 10.1109/ACCT.2013.33

Where,

Zs = surface impedance of mushroom EBG structure.
Wo = Resonant frequency of of EBG structure.
C = Capacitance of EBG structure.
L = Inductance of EBG Structure.
w = length of mushroom.
g = gap between the two mushroom.
t = thickness of dielectric layer.
ε_r = Permittivity of substrate.

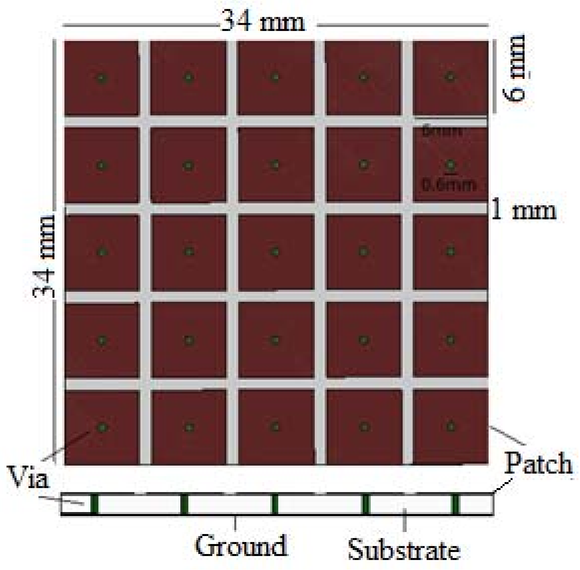

Figure 1: Mushroom-like EBG structure

This EBG structure exhibits a distinct stop band for the surface wave propagation and its operation mechanism could be explained by a combination of series LC circuits, and a parallel LC circuit as shown in Figure 2 [8].

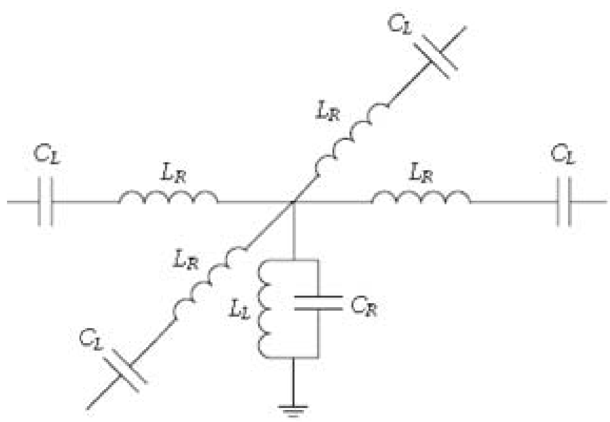

Figure 2: Equivalent circuit model of the conventional EBG unit cell.

In this case, the stop and start frequency of the band gap are given by this equation (5) [9].

$$f_1, f_2 = \frac{1}{2\pi\sqrt{L_R C_L}}, \frac{1}{2\pi\sqrt{L_L C_R}}, \quad (5)$$

Where the parameters L_L, C_L, L_R and C_R represent shunt inductance, series capacitance, series inductance and shunt capacitance respectively. From equation (5), it can be seen that, in order to achieve an even more compact EBG structure, the capacitance and inductance should be increased, but in the EBG design procedure, if the dielectric material and thickness are chosen, the inductances cannot be altered. Therefore, only the capacitances can be enlarged.

III. SIMULATION OF MUSHROOM EBG

The mushroom type EBG structure is shown in Figure 1.The 5 rows and 5coloums of mushroom type patches are taken with patch size 6x6mm, gap between the patches 1mm, vias of radius 0.3mm, substrate size 34mm x 34mm and thickness of substrate is 1.53mm. The EBG structure is simulated using HFSS software. Over EBG structure another substrate of same dielectric constant and thickness is used to test it by putting the 50 Ω line and connecting the port input and output. The simulated result of this EBG is shown in Figure 3. It is observed that this EBG structure exhibits the stop band characteristics from frequency 3.3 GHz to 5.2 GHz at surface wave attenuation better than -20 dB.

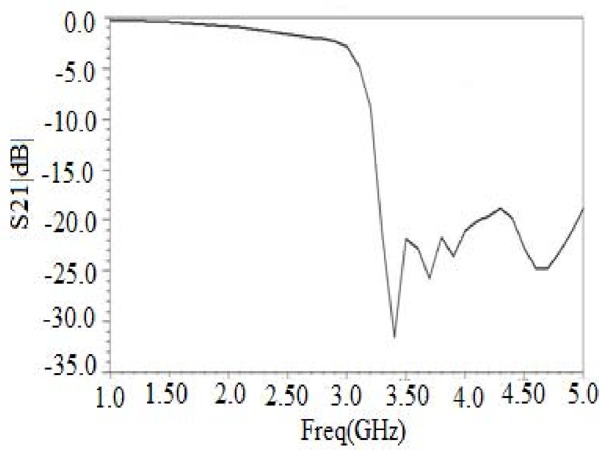

Fig. 3 Simulated result of Mushroom type EBG structure

3. ITERATIVE EBG STRUCTURE

New EBG structure is proposed as shown in Figure 4. This EBG structure is made by cutting the U-shape slot and inverting the U-shape slot and cascading these. The dimensions of slot in 6mm x 6mm metallic patch with row 5 by column 5 are shown in Figure 3. This EBG structure is simulated using the 50 Ω line over the FR4 substrate of dielectric constant 4.3 and thickness 1.53 mm. The simulated result of this EBG structure shown in Figure 5. It is observed from simulated result that the stop band exist from 3.1 GHz 5.3 GHz which wider than mushroom type EBG. This may be due to the increase in inductance and capacitance resulted in a shift at the lower frequency side.

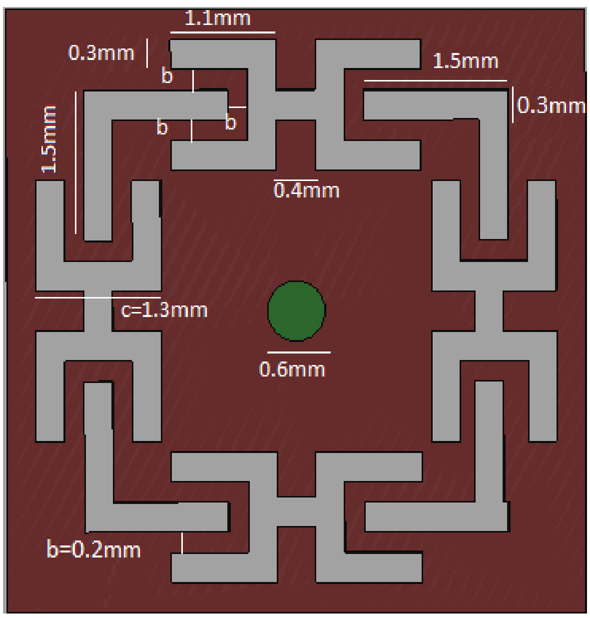

Fig. 4 New EBG structure

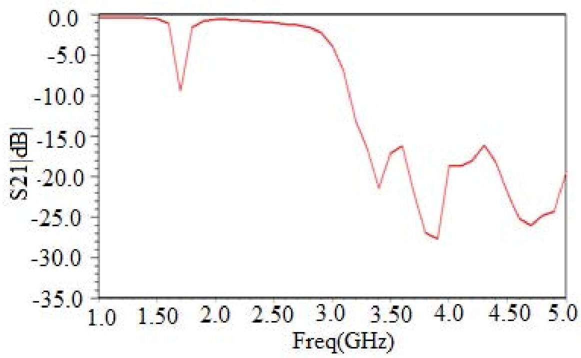

Fig. 5 Response $|S_{21}|$dB of Iterative EBG structure.

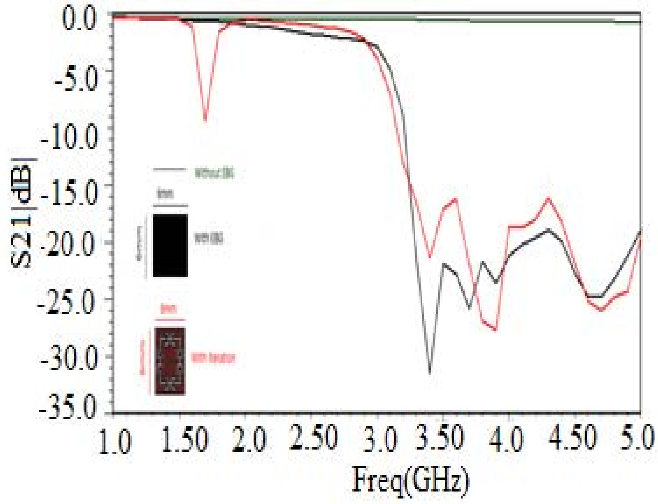

Figure 6: Simulated results $S_{21}|$dB of mushroom and new EBG structure

4. HEXAGONAL PATCH ANTENNA

Hexagonal patch antenna is designed on the substrate FR4 ε_r=4.4, thickness h=1.53mm with substrate size of 50mm x 50 mm. The hexagonal patch for circular polarization is designed at center frequency 3.73 GHz. The side length of hexagonal patch is taken 11mm, and one rectangle strip cut on the centre of patch with length 8.3mm and width 0.77mm for generating CP as shown in Figure 6. The antenna is fed using coaxial feed at an angle 45 degree. The side view of this antenna without EBG is shown in Figure 7. The simulated reflection loss $|S_{11}|$ of this antenna is carried out using HFSS software is shown in figure 10. The simulated axial ratio is shown in Figure 11. The bandwidth of this hexagonal patch is achieved 156.01 MHz at -10dB. The axial ratio is obtained 53.35 MHz at axial ratio 3dB.

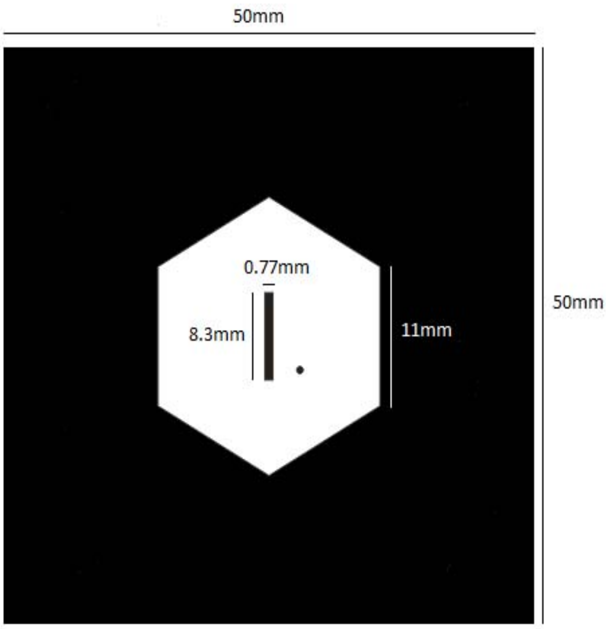

Fig. 6, Simple hexagonal patch Antenna for CP

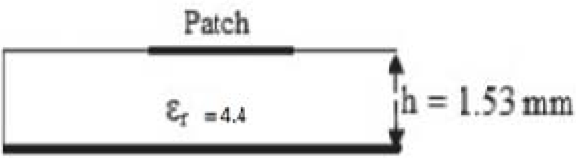

Fig. 7, Side view of Simple hexagonal microstrip patch antenna

5. HEXAGONAL PATCH ANTENNA AND EBG STRUCTURE IN SAME PLANE

The hexagonal patch antenna now is put in the same plane with new electromagnetic band gap (EBG) as shown in Figure. 8. The overall size of substrate with EBG structure is taken 55mm x 55mm on ε_r=4.4 and thickness h=1.53mm. A 2 x 2 EBG structure is used and at the centre, the Hexagonal patch side length 11mm and rectangle strip cut of width 0.77mm and length 8.3mm at center is placed. The gap between the EBG structure and hexagonal patch is maintained 5 mm and from edge 3mm. The antenna is feed with coaxial feed is at an angle 45 degree for achieving circular polarization. The side view of this antenna with EBG structure is shown in Figure 9.

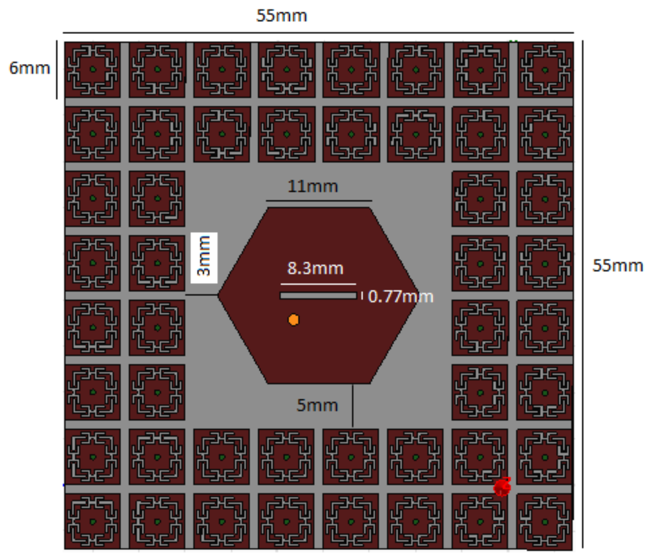

Fig. 8 New EBG structure with hexagonal patch in same plane

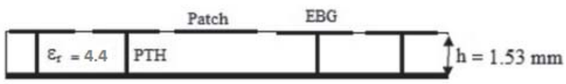

Fig. 9 Side view of EBG structure with microstrip hexagonal patch in the same plane

The simulated reflection loss $|S_{11}|$ of this antenna is carried out using HFSS software is shown in figure 10. The simulated axial ratio is shown in Figure 11. The bandwidth of this hexagonal patch is achieved 240.04 MHz at -10dB. The axial ratio is obtained 51.12 MHz at axial ratio 3dB.

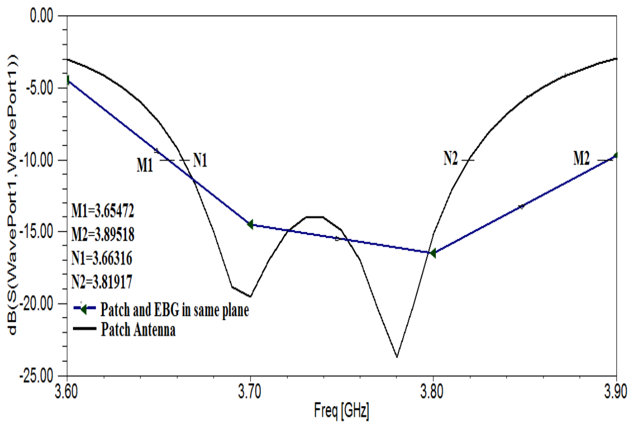

Fig. 10, Simulated reflection coefficient of Hexagonal antenna with and without EBG structure.

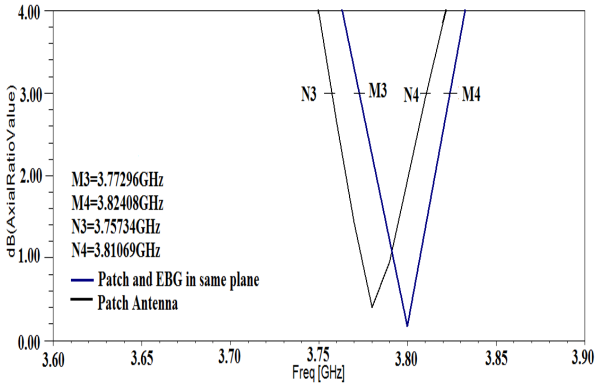

Figure 11: Response of hexagonal patch Antenna with EBG in same plane, and without EBG axial ratio in dB.

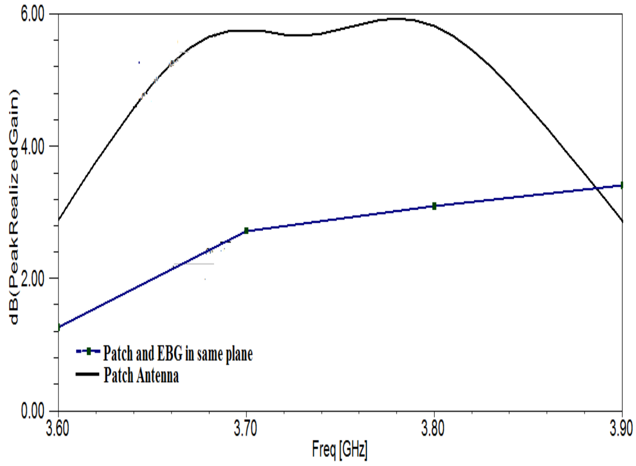

Figure 12: Average Gain of hexagonal patch Antenna with EBG, and without EBG

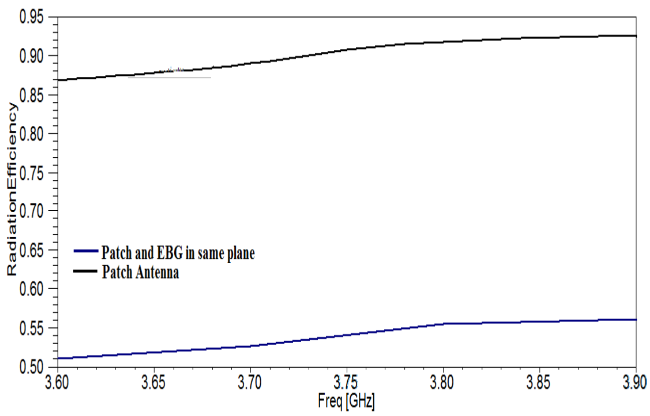

Figure 13: Radiation Efficiency of hexagonal patch Antenna with EBG, and without EBG.

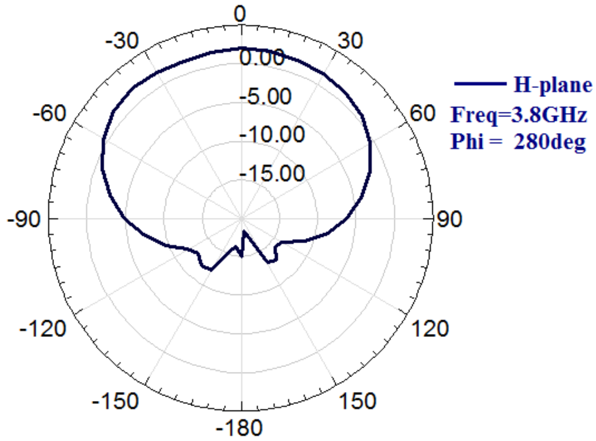

Figure 14: H-field radiation pattern of Hexagonal patch antenna with EBG in same plane.

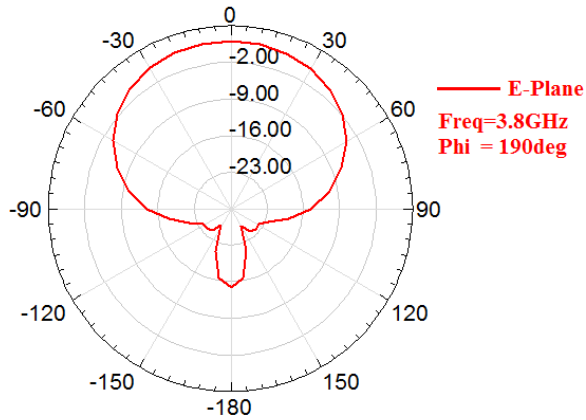

Figure 15: E-field radiation pattern of Hexagonal patch antenna with EBG in same plane.

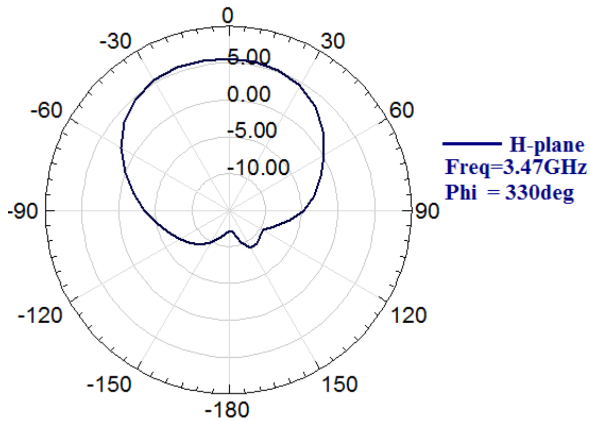

Figure 16: H-field radiation pattern of Hexagonal patch antenna without EBG.

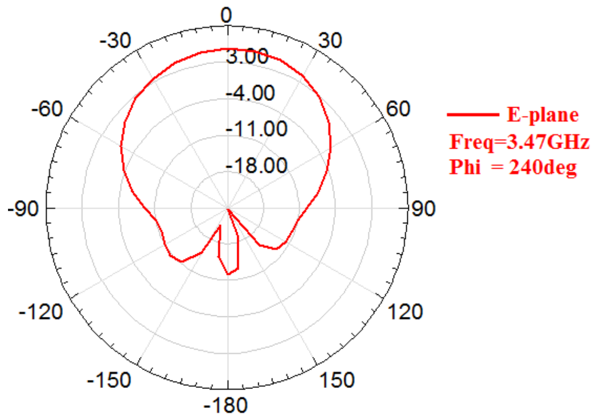

Figure 17: E-field radiation pattern of Hexagonal patch antenna without EBG.

6. CONCLUSION

After the analyzing the both structure hexagonal patch antenna without EBG and with EBG we get the increase in the bandwidth. Without EBG bandwidth is 156.01 MHz and with EBG 240.04 MHz, so increase in the bandwidth is 84.03 MHz that is 53.86% .that is a huge increase in the bandwidth.

REFERENCE

1. R Garg "progress in microstrip antennas", *IETE Technical Review vol.18 No.2and 3 pp.85-98, mar-june-2001.*
2. D Qu , L shafai, and A foroozesh "improving microstrip patch antenna performance using EBG substrates", *IEEE proceedings-microwave antenna propagation vol.153,No.6,Dec 2006.*
3. M-Fallah-Rad, and L Shafai, "Enhanced performance of a microstrip patch antenna using a high impedance EBG structure", *IEEE proceedings-microwave antenna propagation vol.149,No.3,pp.141-146, jun.2002.*
4. F.yang and Y.Rahmat-samii,"microstrip antenna integrated with electromagnetic band gap(EBG) structure.A low mutual coupling design for array application.",*IEEE Trans. Antenna propagation vol.51,No.10, pp.2936-2946, oct.2003.*
5. D Sievenpiper, L zhang, R F J Broas, N G Alex opolous, and E Yabonovicth "High impedance electromagnetic surface in a forbidden frequency band".*IEEE microwave theory tech. vol.47,pp.2059-2074,nov 1999.*
6. A.I.Zaghloul , S.palreddy, S.J Weiss,"A concept for broand band electromagnetic band gap (EBG) structure".U.S Army research laboratory USA.
7. D. Sievenpiper ,"High impedance electromagnetic surface",*Ph.D dissertation Dept. Elect. Eng. Uni. California at los angeles ,Los angeles ,CA,1999.*
8. A. Azarbar and J. Ghalibafan "A Compect Low-Permittivity Dual-Layer EBG Structure for Mutual Coupling Reduction."*hindawi publishing corporation international journal of Antennas and propagation vol.2011,article ID237454,6 pages*
9. A. sanada, C. Caloz, and T. Itoh,"Characterstics of the composite right/left-handed transmission lines,"*IEEE Microwave and Wireless component Letters, vol. 14, No. 2, pp. 68-70, 2004.*