Gain Enhancement of a Square Patch Antenna using EBG Structure

Amsaveni, M. Bharathi, P.J.Phavithra

***Abstract:** In this research work, the gain of a square shaped microstrip antenna has been enhanced using an electromagnetic bandgap (EBG). The dimension of the proposed antenna is 57x57x1.6 mm3. The proposed square patch antenna is simulated using commercially available FR4 substrate whose dielectric constant is about 4.7. The proposed antenna resonates at ISM band of 2.45 GHz. The antenna is powered by 50Ω transmission line using the microstrip feedline structure. The gain of this antenna is improved by 3.5 dBi from that of a conventional antenna. The antenna parameters such as radiation pattern, return loss, VSWR and gain have been evaluated. The antenna is designed and simulated on Computer Simulation Technology (CST) microwave studio.*

***Keywords:** Square patch, Electromagnetic Bandgap, microstrip feedline, Gain.*

I. INTRODUCTION

Microstrip patch antennas are commonly used in low profile, conformal, and low-cost wireless applications [1]. However, it has very narrow impedance bandwidth and low efficiency, which seriously affect their flexibility. In general, the gain of a single patch antenna is very small. There are various techniques that can be used to enhance the gain of a patch antenna. The resonance gain method [2] have used superstrate or cover layer over the substrate. An air gap can be introduced to minimize the effective permittivity of the cavity under the patch [3, 4]. The parasitic element or a reduced surface-wave antenna can be used to reduce the gain of the microstrip antenna [5–7]. An electromagnetic bandgap (EBG) structure can also be used to enhance the gain of the antenna. The microstrip antenna with a square lattice of small metal pads and grounding vias [8] which creates a mushroom-like structure results in a considerable suppression of the surface waves excited in the substrate and thus improving the antenna gain and the effective radiated power. EBG structure is defined as an artificial periodic structure that allows the propagation of electromagnetic waves in a particular band of frequencies for all incident angles and all polarization states. The EBG structures prevent the electromagnetic wave propagation and surface wave suppression within the band gap range. For best performance, the EBG structure must satisfy the following conditions,

$0.9 < a/p < 0.95$ for 3D EBG

$0.65 < a/p < 0.75$ for 2D EBG

Where,a -dimension of the mushroom patch; p – periodicity; εr - permittivity of the dielectric materials used. a/p - is the filling factor. It is defined by the ratio between size of the patches and the periodicity of unit cell. The EBG parameters of Mushroom type EBG are shown in Fig.1. Mushroom type EBG is a three dimensional EBG structure consisting of a solid patch and a cylindrical via. The transmission characteristics of mushroom type EBG purely depends upon the patch dimension, via diameter, the gap between the unit elements, thickness of the substrate and the substrate material used [9].

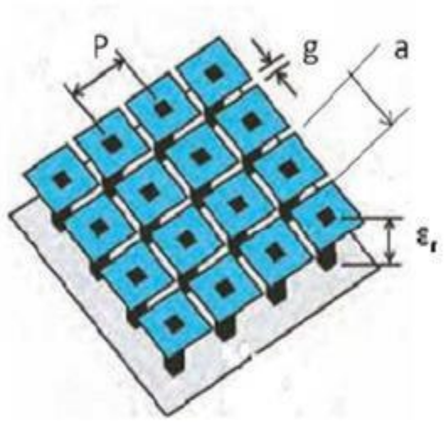

Fig .1 Mushroom type EBG structure

The main advantages of EBG structures are reduction in side lobe level and higher front to back ratio. There are different types of EBG structure in a single band and dual band. The new EBG structures are the hairpin like structure, folk like structure, Hilbert curve high impedance surface structure, spiral type EBG structure, fractal type EBG structure, slogan type EBG structure and the hexagonal patch type[10]. The bandwidth of the patch antenna can be improved by increasing the substrate thickness, by using a low dielectric substrate and appropriate feeding methods. Smaller the dielectric constant, lower will be the surface wave losses[11-12]. This article proposes a square patch antenna with a Mushroom type EBG unit cell which is used to increase the gain of the antenna. The remainder of this paper is organized as follows. Section 2 gives the proposed antenna design. Section 3 describes simulation results and comparison of conventional antenna and the proposed antenna with EBG. Section 4 presents conclusions.

II. ANTENNA DESIGN

The proposed antenna has a dimension of 57 x 57 x 1.6 mm3 and is excited by 50Ω transmission line using the microstrip feedline. The square patch and ground plane are made up of copper.

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The side length and width of square patch antenna is 28.45mm. The width of the feedline is 1.137 mm, length of the feedline is 9mm and gap between the feed and patch is 1mm. The substrate is made up of FR4 material whose dielectric constant is 4.7, thickness is 1.6mm and loss tangent is 0.02. Two slots are cut to provide a centre feed for the patch. Geometrical configuration of the antenna without EBG is shown in Fig.2.

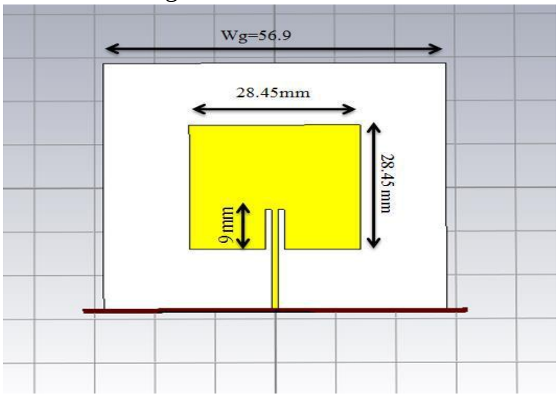

Fig.2. Antenna without EBG unit cell

Antenna wavelength is computed using the below formula,

$\lambda = c/f$ (1)

Actual length and width of the patch are obtained using the below formulas,

$$Lp = Leff - 2\Delta L \quad (2)$$

$wp = (c/2fr)\sqrt{2/(\varepsilon r+1)}$ (3)

The Effective length is given by,

$Leff = c/2fr\sqrt{\varepsilon reff}$ (4)

The normalized extension length is given by,

$$\Delta L = \frac{0.4}{2h}\frac{(\varepsilon_r^{eff}+0.3)(\frac{W_p}{h}+0.264)}{(\varepsilon_r^{eff}-0.258)(\frac{W_p}{h}+0.8)} \quad (5)$$

Where, $\varepsilon reff$ is the Effective dielectric constant, and the equation for it is given below ,

$$\varepsilon_r^{eff} = \frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}[1+12\frac{h}{W_p}]^{\frac{-1}{2}} \quad (6)$$

Substrate length and width are given by,

$Lg = Lp + 6h$ (7)

$wg = Wp + 6h$ (8)

Where Lg and wg are length and width of substrate and 'h' is given by,

$h = 0.0606\lambda/\sqrt{}$(9)

Fig.3 shows the mushroom type EBG unit cell. The side length and width of EBG unit cell is 56.25 mm and via radius is 0.5 mm. The dimensions of the square patch and the EBG unit cell are listed in Table.1.

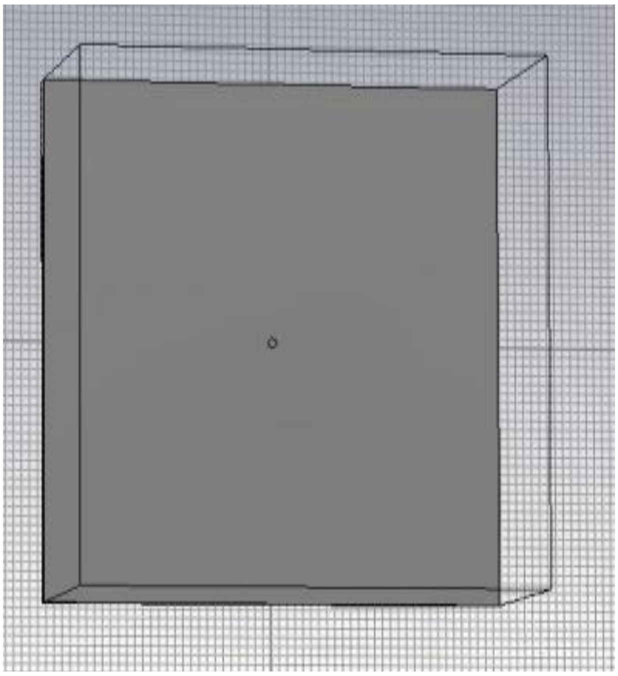

Fig 3.Mushroom type EBG unit cell

S.No	Dimensions	Values (mm)
1.	Length of the ground plane	56.9
2.	Width of the ground plane	56.9
3.	Length of the patch	28.25
4.	Width of the patch	28.25
5.	Length of the Feed line	9
6.	Width of the Feed line	1.137
7.	Height of the substrate	1.6
8.	Gap between the patch and feed line	1
9.	Length of the EBG unit cell	56.25
10.	Width of the EBG unit cell	56.25
11.	Via radius	0.5

Table 1: Antenna and EBG Dimensions

The square patch antenna is placed above the EBG structure at a distance of 5mm as shown in Fig.4.

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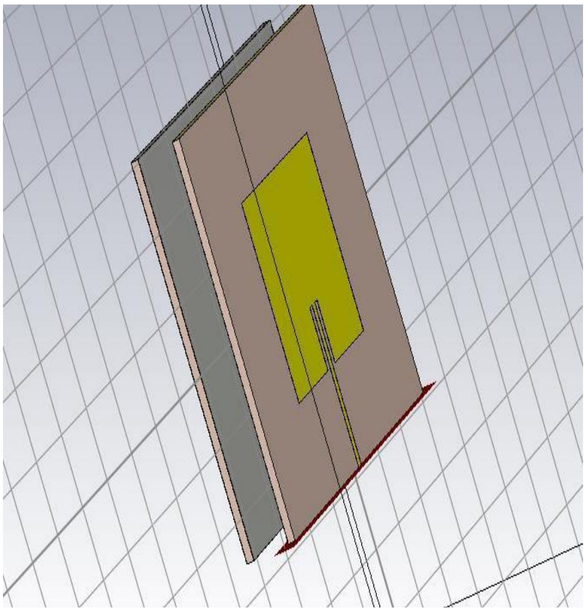

Fig. 4.Antenna with Mushroom type EBG unit cell

III. SIMULATION RESULTS AND DISCUSSION

The proposed antenna is designed and simulated using Computer Simulation Technology (CST) microwave studio. The performance of the antenna is analysed in terms of Return loss (S11),VSWR, Radiation Pattern, and Gain. The simulated return loss S11 of the proposed antenna without EBG and with EBG structure is shown in Fig.5. The antenna without EBG provides a return loss of about -22 dB at resonant frequency whereas the antenna with EBG provides -24 dB. Lesser the return loss, higher the radiated power

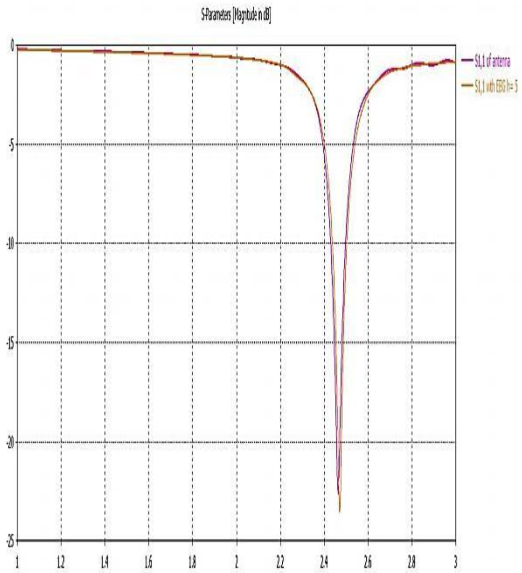

Fig.5.Return loss Vs Frequency

The antenna without EBG unit cell provides a gain of 5.25 dB and antenna with EBG unit cell provides a gain of 8.70 dB. This is due to the higher front to back ratio of EBG unit cell. Hence the performance of the square patch antenna is improved by the addition of EBG unit cell. The antenna without EBG provides a VSWR of 1.33 whereas the antenna with EBG provides a VSWR of 1.299 as shown in Fig.6

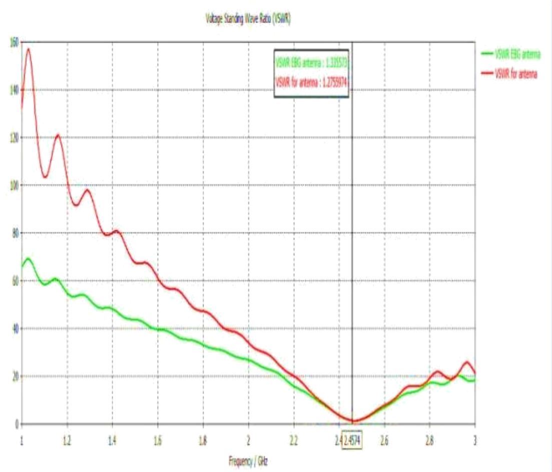

Fig.6. VSWR Vs. Frequency

The simulated 2D elevation patterns of the proposed antenna without and with EBG at resonant frequency are shown in Fig.7 and Fig.8 respectively.

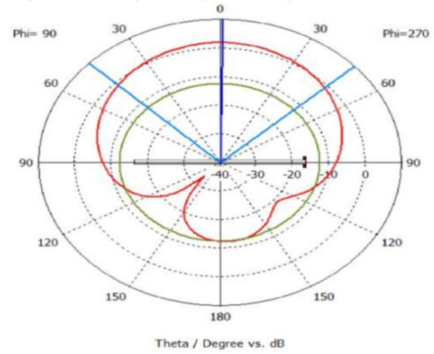

Fig.7. Elevation Pattern of the antenna without EBG

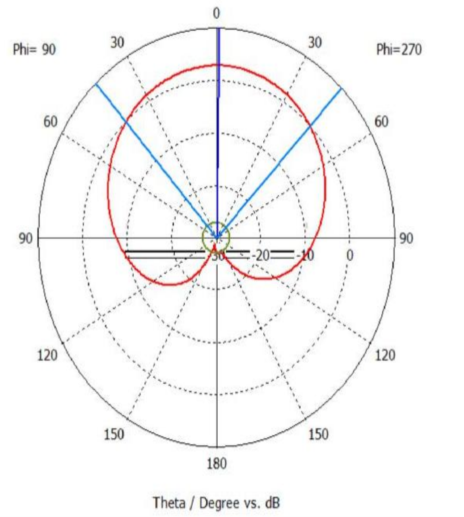

Fig.8. Elevation Pattern of the antenna with EBG

Here, the elevation pattern is observed, for phi (φ) value of 90 degree and for all values of theta (θ). It is observed that antenna exhibits symmetry uni-directional radiation pattern in elevation plane. Table. 2 compares various parameters of the proposed antenna with and without EBG unit cell.

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Antenna Structure	Return loss S_{11} in dB	VSWR	Gain in dB
Antenna without EBG unit cell	-22 dB	1.33	5.25 dB
Antenna with EBG unit cell	-24 dB	1.299	8.70 dB

Table 2. Comparison of Antenna parameters

IV.CONCLUSION

The proposed article presents a square patch antenna with EBG structure. The patch is designed using copper and substrate is made up of FR4. The dimension of the proposed antenna is 57x57x1.6mm3 and is powered through microstrip feed line structure. The proposed antenna structure resonates at 2.4GHz. Over the operating frequency, the antenna provides a maximum gain of about 8.7 dBi and the return loss of -24 dB. Hence it is concluded that the proposed antenna is suitable for wireless communication applications. As the antenna with EBG prevents backward radiation, it can also be used for wearable applications by using textile materials such as cotton and polyester as substrates.

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