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Bandwidth Enhancement of Microstrip Rectangular Patch Antenna Using EBG

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ABSTRACT *Microstrip patch antennas offeres advantages like planar configuration, light weight, reduced size and ease of portability, but in spite of these advantages, patch antennas suffer from drawbacks such as low gain, narrow bandwidth. These drawbacks limit their application in other fields. Recently, the development in the field of EBG has offered to overcome the limitations of surface waves by designing the antenna with EBG structure. In this paper, the proposed antenna is simulated on the HFSS simulation software. The substrate used is FR-4 with dielectric constant of 4.4 and the patch dimensions are 25 x 17.5 mm. The bandwidth increases from 4.3% to 28%.*

KEYWORDS : Microstrip Patch Antenna, Bandwidth, Electromagnetic Bandgap (EBG), HFSS

I. INTRODUCTION

Microstrip patch antennas has been said to be the most inventive in the antenna designing and they are broadly utilized on account of their elements such as low cost, low profile, light weight, and ease of production[1]. These antennas have different applications in aviation, satellite communication, radars, biomedical application, etc[2]. Although, they experience some setbacks such as, a limited bandwidth, low gain and surface waves excitation, and so on and these setbacks have constrained their applications in numerous different fields[3].

The electromagnetic bandgap (EBG) structures displays a bandstop conduct over a specific frequency range, in which the radiation of electromagnetic waves is restricted. EBG structures can likewise be called as Photonic bandgap (PBG) structures [4]. EBG materials have an extensive variety of utilizations in RF and microwave designing. By utilizing an intermittent dielectric or metallic structure an EBG structure can be realized. Extensively, EBG structures are 3-D periodic structures that keep the propagation of the electromagnetic waves in a predefined band of frequency for all angles of reception and for all polarization conditions of electromagnetic waves. By and by, in any case, it is extremely hard to get such complete band-gap structures and partial band-gaps are accomplished. It is exceptionally hard to get such complete band-gap structures and fractional band-gaps are accomplished [5]. The main plus point of EBG structure is their capacity to suppress the surface wave current. The generation of surface waves badly affects the antenna efficiency and radiation pattern [6].

The bandwidth enhancement can be done via different methods like stacking of patches, using slotted structures. In this paper, a basic rectangular microstrip patch antenna is designed. The simulation is done on HFSS simulation software. Then the microstrip patch antenna is designed with a double U slot. Then the antenna is made using periodic EBG unit cells placed between two dielectric substrates, which is the primary objective of this paper. The bandwidth of basic patch antenna is compared with the bandwidth of antenna with an EBG structure.

II. ANTENNA DESIGN

A basic rectangular microstrip patch antenna (RMPA) is designed by using a substrate of FR-4 dielectric (ε_r=4.4) placed between an antenna patch and a conductive ground plane. The operating frequency of antenna is 3.5 GHz.

Calculation of the width (W) of antenna, which is given by:

$$W = \frac{c}{2f_0\sqrt{\frac{(\varepsilon_r+1)}{2}}}$$

Substituting c = 3.00*10^8 m/s, ε_r =4.4 and f_o = 3.5 GHz,

$$= \frac{3.00*10^8}{2*3.5*10^9\sqrt{\frac{(4.4+1)}{2}}}$$

W = 26.08 mm

Calculation of the Effective dielectric constant (ε_{reff}):

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$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}[\ 1 / \sqrt{[1 + 12\frac{h}{W}]}\ ]$$

$$\varepsilon_{reff} = \frac{4.4 + 1}{2} + \frac{4.4 - 1}{2}[\ 1 / \sqrt{[1 + 12\frac{2.5}{26.08}]}\ ]$$

ε_{reff} = 3.8593

Calculation of the effective length, L_{eff} which is given by:

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}}$$

$$L_{eff} = \frac{3 * 10^8}{2 * 3.5 * 10^6\sqrt{3.8593}}$$

$$\boldsymbol{L_{eff} = 21.81\ mm}$$

Calculation of the length extension, ΔL, which is given by:

$$\Delta L = 0.412 * 2.5[\frac{(\varepsilon_{reff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{reff} - 0.258)(\frac{W}{h} + 0.8)}]$$

$$\Delta L = 0.412 * 2.5[\frac{(3.8593 + 0.3)(\frac{26.08}{2.5} + 0.264)}{(3.8593 - 0.258)(\frac{26.08}{2.5} + 0.8)}]$$

$$\boldsymbol{\Delta L = 1.132\ mm}$$

Calculation of the effective length extension of patch L which is given by:

$L = L_{eff} - 2\ \Delta L$

L = 21.81- 2*1.132

L= 19.5123 mm

III. Proposed Antenna Design

The microstrip patch antenna is incorporated with EBG unit cells. This EBG unit cell is square patch sandwiched between two dielectric layers and connected to ground plane using cylindrical metal vias. The figure 1 shows a basic patch antenna. Figure 2 shows a patch antenna with a double U slot structure. The figure 3 shows the antenna with EBG top view. Figure 4 shows the antenna with EBG elevation.

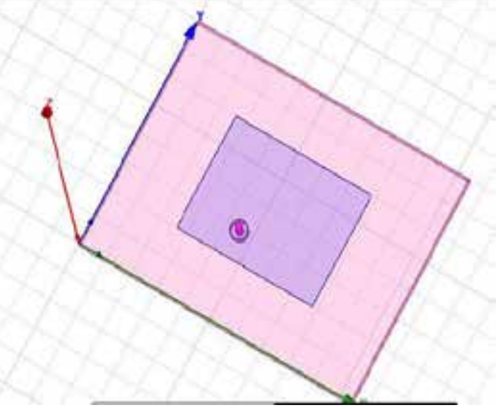

Figure 1. Basic Patch Antenna

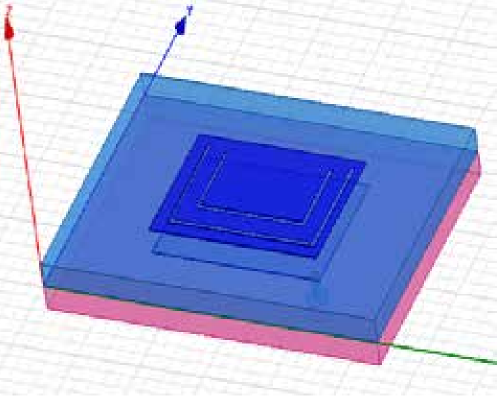

Figure 2. Patch Antenna with a double U slot

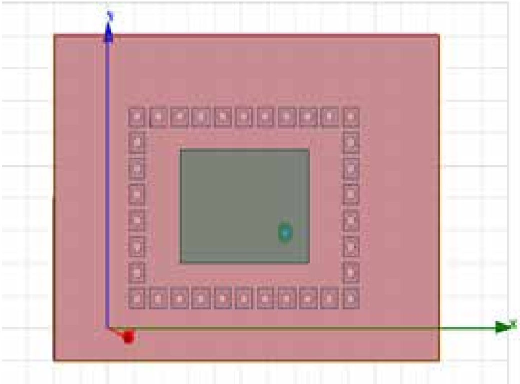

Figure 3. Antenna with EBG structure-Top View

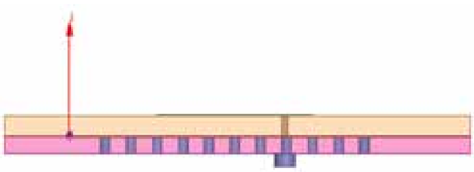

Figure 4. Antenna with EBG structure-Elevation

The antennas are simulated on HFSS simulation software. The dimension of the patch is 26 x 19 mm. The height of the substrate is 2.5 mm. The coaxial feed point is optimized using trial and error method. The dimensions of 2-D mushroom like EBG unit cell square is 3 x 3 mm. The vias radius is 0.8 mm. The height of vias is 2 mm. Varying this dimensions affects in the output of the antenna.

IV. SIMULATED RESULTS

The results are simulated on HFSS. The bandwidth of the basic patch antenna is obtained 145 MHz, which is 4.312%. The bandwidth of double U slot patch antenna is 390 MHz which is 10.98%. Thus, bandwidth is more than doubled. The bandwidth of antenna with EBG is obtained 940 MHz, which is 28%. Thus, bandwidth is greatly enhanced. VSWR is almost unaffected for all these configurations. Directivity and Gain are also nearly same for all the designs. VSWR is 1.0955, 1.0083 and 1.0319 for basic patch antenna, double U slot patch antenna and EBG structured antenna respectively. Gain is 3.25 dB, 3.68 dB and 3.8 dB respectively. The results are shown in the following table.

The simulation results are shown. The s11 of basic antenna is shown in figure 5. The s11 of antenna with a double U slot is shown in figure 6. The s11 of antenna with EBG is shown in figure 7.

Parameter	Basic Patch Antenna	U-slot Patch Antenna	Antenna with EBG
Bandwidth	145 MHz	390 MHz	940 MHz
% Bandwidth	4.312 %	10.98 %	28%
VSWR	1.0955	1.0083	1.0319
Return Loss	-27.0011 dB	-56.2266 dB	-36.0829 dB
Directivity	5.0223 dB	4.7902 dB	4.4227 dB
Gain	3.25 dB	3.68 dB	3.8 dB

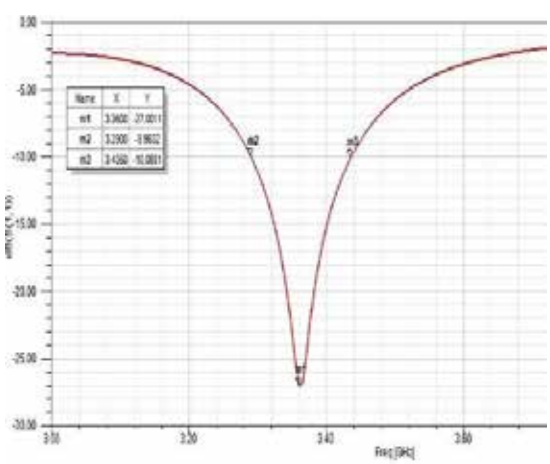

Figure 5. Bandwidth of basic antenna

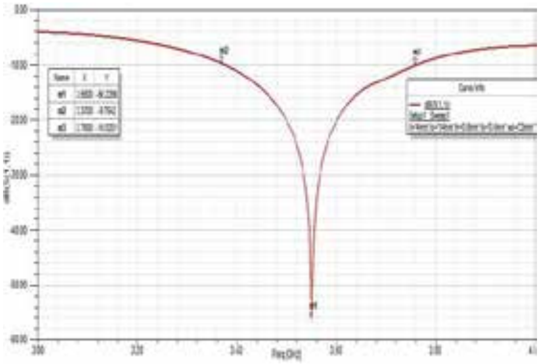

Figure 6. Bandwidth of double U slot antenna

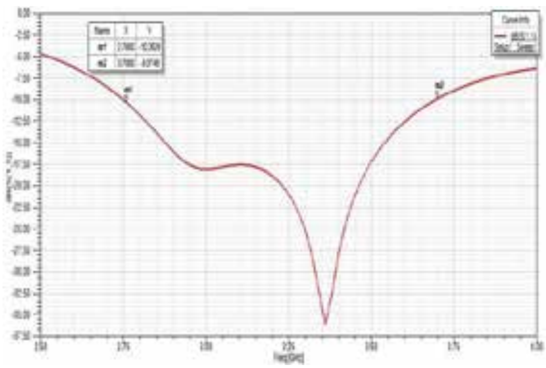

Figure 7. Bandwidth of EBG antenna

Thus, as seen in the results, the bandwidth of an antenna is enhanced .

V. CONCLUSION

In this paper, the microstrip rectangular patch antenna is proposed with periodic 2-D mushroom type EBG structures. RMPA is designed using square shaped EBG unit cells with cylindrical vias is designed. It is found that EBG structures greatly enhances the impedance bandwidth of an RMPA. The double U slot also enhances the bandwidth, but the EBG structures exhibit fascinating enhancement in bandwidth.

The bandwidth obtained for basic microstrip antenna is 4.312%. For double U slot structure, the bandwidth is 10.98%. For the microstrip antenna with EBG, the bandwidth is 28%, which is significantly enhanced.

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