International Journal of Latest Research in Engineering and Technology (IJLRET)
ISSN: 2454-5031
www.ijlret.com ǁ PP.19-24

Design and Analysis of Multiband Antenna using Square shaped EBG structures

Banuprakash .R[1], Archana A.R[2], Rachana Pai[3], Raksha Hegde[4], T.N Srinidhi[5]
[1]*Assistant Professor, Department of TE, BMS Institute of Technology and Management, Bengaluru, India*
[2,3,4,5]*Students, Department of TE, BMS Institute of Technology and Management, Bengaluru, India*

Abstract: In this paper, multiband microstrip patch antenna using square and Psi shaped Electromagnetic Band Gap (EBG) structures have been compared and analysed.Arranging the EBG structures in various designs provides multiple frequencies suitable for wide range of applications.The aim of this paper is to compare the results obtained by using different number of EBG structures and to study the performance of antenna in terms of frequency and VSWR.Therefore single antenna which supports multiple frequencies is obtained.The simulated results shows that the designed antennas gives best performance by analysing the VSWR values which is very close to the ideal value, 1.

Keywords: EBG structures, Multiband, Patch antenna, HFSS

I. INTRODUCTION

An Antenna is the key module of any Radio and Wireless Communication which is used to transform RF signal into an electromagnetic wave in free space. An Antenna is a device capable of transmitting and receiving simultaneously. It is always preferable to use a single multifunctional antenna instead of multiple single functioned antennas and not desirable to use many dedicated antennas to cover each of the varied wireless services. Therefore, in the antenna system we can use a concept known as reconfigurability. Reconfigurable antenna arrays that are capable of resonating at multiple frequencies and radiating multiple patterns using single feeder network are desirable in multiple applications. A reconfigurable antenna is an antenna capable of modifying dynamically its frequency and radiation properties in a controlled and reversible manner.

The capability of reconfigurable antennas is satisfying changing operational requirements and maximize the antenna performance in changing scenario. Reconfigurable antennas are classified based on the parameters such as Frequency of operation, polarization and radiation pattern. Reconfigurable antennas satisfy the requirements for increased functionality, such as direction finding, beam steering, radar, control and command, within a confined volume [3]. The reconfiguration of an antenna is achieved by changing the radiating fields of the antenna's effective aperture [4].

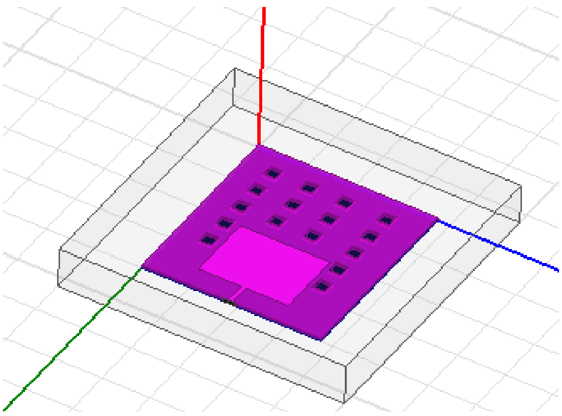

Fig 1: EBG structures on substrate

EBG structures are used to create forbidden band of frequencies in which surface waves cannot propagated [8]. They are periodic cells composed of dielectric or metallic elements [1]. EBG structures are also known as photonic band gap surfaces or high impedance surfaces that are used to build low profile and highly efficient antenna structure [7]. EBG structures are good candidate to be used under an antenna that needs to be placed close to a ground plane [2]. The surface impedance of EBG structure is high. EBG structures can also be used to supress undesired surface waves in various antenna engineering applications. Slots are made on the substrate which supresses the surface waves to achieve uniformity of current flow.

Surface waves reduce gain, increase end fire radiation, limit bandwidth, increase cross polarization levels, reduce antenna efficiency and limit the applicable frequency range of microstrip antenna[5]. Real solution to this problem is achieved by using EBG structures. They can be realized in one, two and three dimensional forms.By making changes in the arrangement of the structure on RT-duroid (5880) substrate with dielectric constant of 2.2 has proven to provide multiplefrequencies[6]. The various applications of this different arrangement of EBG structuresare wireless video links, wireless security cameras, wireless video transmitter, security systems, WiMAX Applications, mobile WiMAX, SOFDMA, WiFi systems, Radio LAN, wireless LAN, Met office, Mesh network, Military, Radio astronomy, space research, Defence Resonance Oscillator (DRO).

II. DESIGN CALCULATION

i. Calculating the length (L):

This includes computation of other parameters such as

- Effective dielectric constant (ε_{eff})

Dielectric constant of the substrate becomes nearly equal to the effective dielectric constant with the increase in operating frequency.

$$\varepsilon_{re} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}}$$

- Effective length (L_{eff})

$$L = \frac{c}{2 f_o \sqrt{\varepsilon_{re}}}$$

- Calculation of actual length of patch (L)

Length is a critical parameter, since the resonance element has inherent narrow bandwidth. Actual length is obtained by:

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

ii. Calculating the Width (W):

The width of the microstrip patch antenna is given as:

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

C = Velocity of light
f_0 = Resonant frequency
ε_r = Relative dielectric constant
The calculated value is considered to be standard and the widths can be chosen smaller or greater than the standard value. But the efficiency of the radiator varies as the width is increased or decreased.

III. ANTENNA DESIGN

[1]. DESIGN OF MICROSTRIP PATCH ANTENNA WITH SQUAREEBG STRUCTURE:

The proposed antenna has three basic layers, lower layer constituting the ground plane covered by the rectangular plane of the substrate with side of 80x75mm. The middle layer comprises of substrate where the material used is RT duroid which has a dielectric constant 2.2. The height of the substrate chosen is 1.6mm. The uppermost layer comprises of patch with dimensions 28.8x37.7mm. Feeding technique used is microstrip line with 50Ω impedance.

The basic structure of the proposed antenna with different number of EBG structures is as shown in Fig. 2. It consists of sixteen EBG structures with five to the left and five to the right and six to the top of the patch respectively. In this design two EBGs at the top of the patch are closed. The dimensions of the EBG are 5x5mm. The different frequencies obtained are analysed.

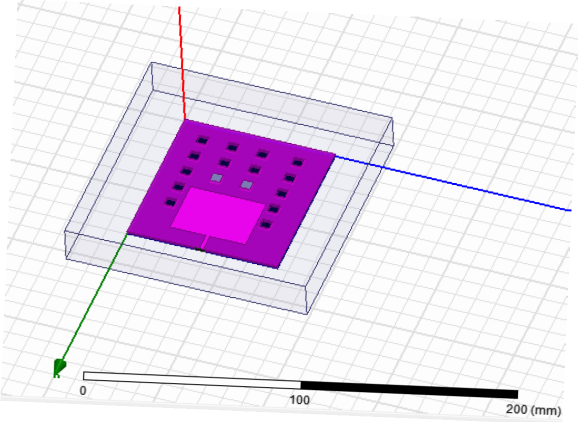

Fig 2: Initially filled EBG structures

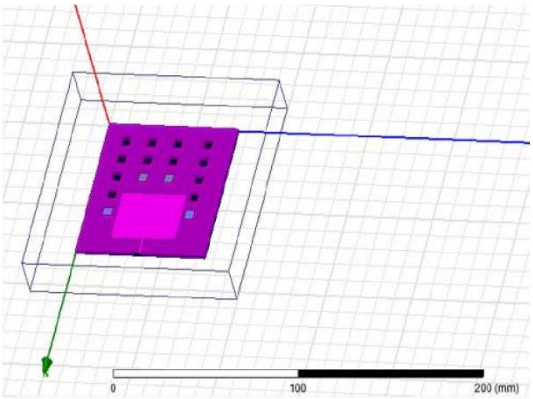

Fig 3: Symmetrically filled EBG

In Fig 3, one EBG each to the left and right of the antenna are closed symmetrically. The results obtained by simulating this design is analysed. By closing those two slots and comparing with the result of the previous design, we can determine the frequencies which were particularly produced by those two slots.

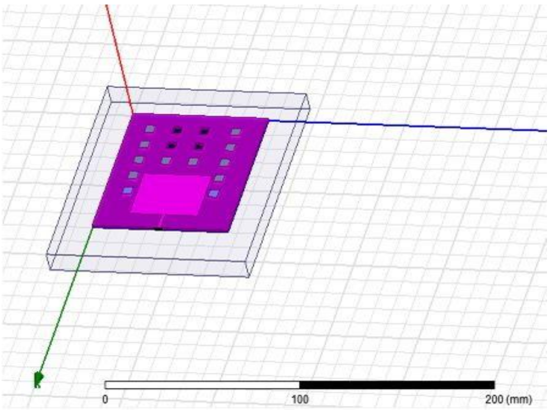

Fig 4: Microstrip antenna with four EBG structures.

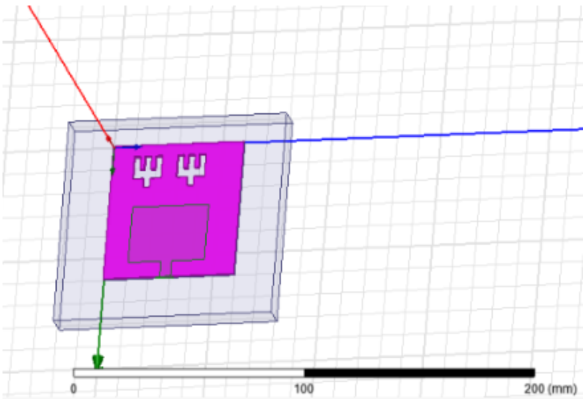

Fig 5: Psi shaped EBG structure

In Fig 4, all the 12 EBG slots are symmetrically closed towards the left, right and two at the top of the patch resulting in H shaped design. Thus, only four EBG slots among the sixteen are open which is equal to having only four EBG slots in the antenna.

According to the basic principle of a patch antenna, the radiations from a patch antenna is maximum in the forward direction when compared to the radiations towards the sides of the antenna. Therefore, Fig 5 depicts a microstrip antenna using Psi shaped EBG structure. The EBG's are placed only on the top of the patch. The performance of this design is analysed by simulation and the values of frequency and VSWR are compared with the frequencies that cover various applications.

IV. SIMULATION RESULTS

In this section, the simulation results of the above mentioned designs provides the plots of frequency v/s VSWR.

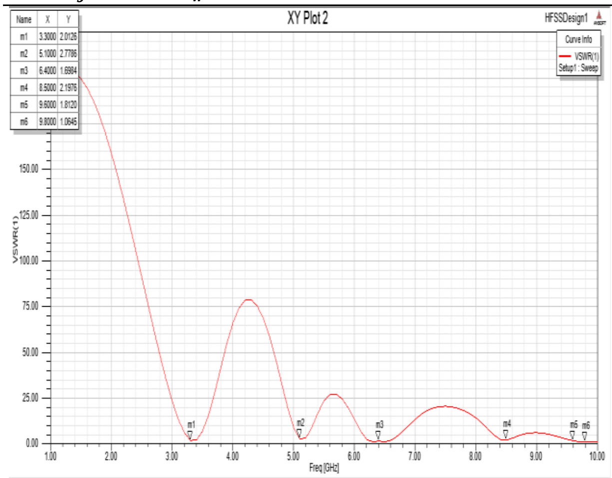

Fig 6: Plot formicrostrip patch antenna with 16 EBG's

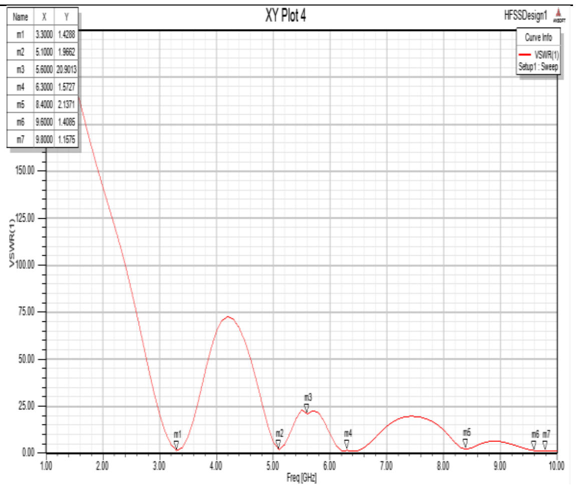

Fig 7: Plot for Initially filled EBG structures

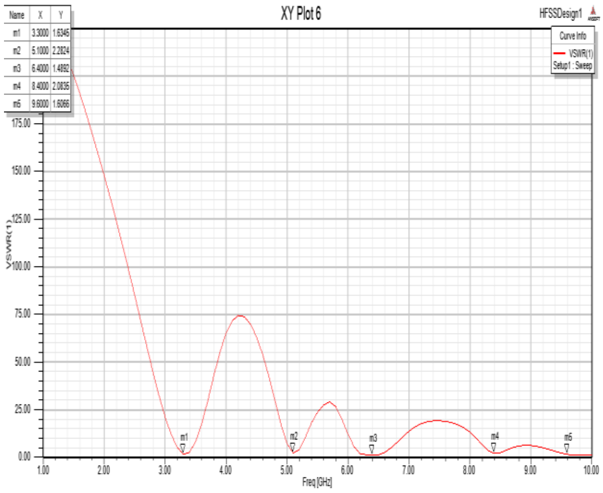

Fig 8: Plot for symmetrically filled EBG's

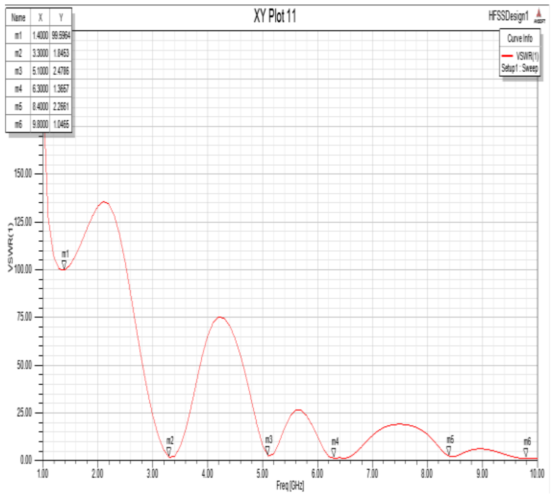

Fig 9: Plot for the antenna with only four EBG's

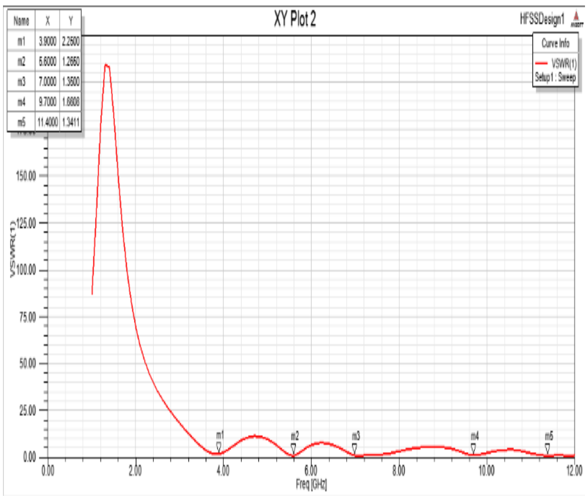

Fig 10: Plot for Psi shaped EBG structure

V. OBSERVATIONS AND ANALYSIS

Applications:

1.2 – 1.4 GHz	Wireless video links, wireless security cameras, wireless video transmitters, wireless security systems
3.3 – 3.9 GHz	WiMAX Applications, Mobile WiMAX
5.2 GHz	WiFi, Wireless LAN
5.4 – 5.8 GHz	WiFi systems, Radio local area networks (RLAN), WiMAX technology
6.4 GHz	Met office.
7.0 – 7.8 GHz	Military (Public Sector), Met office (space Science)
8.5 GHz	Radio Astronomy, Space Research (Space Science), Business Radio (Police and fire), Radar level gauges
9.6 – 9.8 GHz	Missile defence radar, missile guidance

Comparison Table:

Shape	Dimensions of EBG (mm)	Spacing (mm)	Total no of EBGs	Number of EBGs Filled	VSWR obtained	Frequency (GHz)
Square	5x5	9.16x11	16	0	2.01	3.3
					1.6	6.4
					2.19	8.5
					1.04	9.8
				4	1.63	3.3
					1.48	6.4
					1.6	9.6
				12	1.84	3.3
					1.04	9.8
Psi			2		2.25	3.9
					1.35	7.0
					1.66	9.7

From the comparison table it is evident that, on filling different number of square shaped EBG structures, various frequencies suitable for various applications are obtained. The substrate used for different number of closed and open EBG is the same (RT Duroid 5880) with thickness of 1.6mm and dimensions being 75x80mm. Thus we can see that by filling the EBG to the right and left of the patch yields nearly the same results as that obtained when the EBGs are opened. Thus using only four EBGs at the top of the patch yields better results than using 16 EBGs uniformly distributed throughout the substrate. Therefore the substrate width can be reduced and the antenna can be optimized.

VI. CONCLUSION

In this paper, the main aim is to analyse and compare the multiband antennas for various shapes and arrangements of EBG structures. The antennas are designed using standard formulas to choose the appropriate patch dimensions. EBG structures can overcome the limitations of patch antenna such as size, excitations of surface waves, constrict bandwidth, low gain. Thus we can see that, by filling the EBGs to the right and left of the patch, the results obtained are better than those which were obtained when the number of non-filled EBGs were more. Therefore, the dimensions of substrate can be reduced, thus making the antenna design compact.

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