IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

*International Advanced Research Journal in Science, Engineering and Technology*
*Vol. 3, Issue 5, May 2016*

# Design and Analysis of Reconfigurable Microstrip antenna using EBG structures

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**Abstract:** In this paper reconfigurable micro strip antenna using electromagnetic band gap structures [EBG] is presented. In this design, EBG structures are done by making a hole on substrate in order to tune for multiple frequencies for four different heights of substrate. The antenna design makes use of micro strip feeding technique. EBG concept is taken into consideration to achieve reconfigurabality. For the antenna design a box shaped EBG structure has been considered and the performance of the designed antenna is analyzed. For different heights of substrate, the performance of antenna is analyzed. The result shows for a substrate height of 1.6 mm at X band frequencies the VSWR is close to one.

**Keywords**: Microstrip patch antenna, Reconfigurablity, Electromagnetic Band Gap, FR4_epoxy and HFSS.

## I. INTRODUCTION

Reconfigurable antenna arrays that are capable of resonating at multiple frequencies and radiating multiple patterns using single feeder network are desirable in many applications. A reconfigurable antenna is an antenna capable of modifying dynamically its frequency and radiation properties in a controlled and reversible manner. Reconfigurable antennas came into existence to cover different wireless services that operate over a wide frequency range. In order to provide a dynamical response, reconfigurable antennas integrate an inner mechanism (such as RF switches, varactor diodes, mechanical actuators or tunable materials) that will allow the intentional redistribution of the RF currents over the antenna surface and produce reversible modifications over its properties. Reconfigurable antennas differ from smart antennas because the re configurability lies inside the antenna rather than in an external beam forming network. This type of antenna requires switching elements to change the antenna electrical properties as well as its radiation characteristics.

The capability of reconfigurable antennas is used to maximize the antenna performance in a changing scenario or to satisfy changing operating requirements. Frequency of operation, polarization, radiation pattern are the parameters on which reconfigurable antennas are classified on. A patch is typically wider than a strip and its shape and dimensions are important features of the antenna [1]. Patch antennas have limited bandwidth, meaning that the input impedance of the antenna only remains near the desired value for a small range around the designed center frequency [2]. Reconfigurable antennas satisfy the requirements for increased functionality, such as direction finding, beam steering, radar, control and command, within a confined volume [1], [3]. The reconfiguration of an antenna is achieved by altering the radiated fields of the antenna's effective aperture [4]. EBG structures are periodical cell 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 [5]. Serious problem in microstrip antennas is surface wave propogation. 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, it will improve significantly enhanced features, such as increasing the antenna return loss and bandwidth, gain etc.

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 structures can offer a real solution to this problem. Therefore mentioned challenges will become more prominent as CMOS scaling approaches atomic and quantum mechanical physics boundary [6]. The concept of electromagnetic band gap (EBG) structures originates from the solid-state physics and optic domain, where photonic crystals with forbidden band-gap for light emissions were proposed [4], [6]. Thus, the terminology, photonic band -gap (PBG) structures, was popularly used in the early days. Since then, an EBG structures are invented for radio frequencies and microwaves. EBG can be realized in one, two and three dimensional forms.

## II. ANTENNA DESIGN CALCULATION

Step 1: Calculation of Width (W)
The width of the Microstrip patch antenna is given as:

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

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Where, c is velocity of light, f0 is Resonant Frequency & εr is Relative Dielectric Constant. Keeping the calculated value as standard, widths can be chosen smaller than the standard value or greater than that. But varying width may decrease or increase radiator efficiency accordingly.

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Step 2: Calculating the Length (L) Knowing width 'W', length can be calculated, which involves other computations such as,

a)Effective dielectric constant (εeff) As the frequency of operation increases the Effective dielectric constant approaches the value of the Dielectric constant of the substrate is given by:

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

b) Effective length (Leff)
The effective length: This can be found by

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

c) Length Extension (ΔL)
Because of fringing effects, electrically the micro strip Antenna looks larger than its actual physical dimensions [4]. For principle E-plane x-y plane), length has to be extended by distance ΔL, where ΔL is function of width to height ratio (W/h) and effective dielectric constant.
The length extension is:

$$\Delta L = 0.412\, h \frac{(\varepsilon_{re} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{re} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

d) Calculation of actual length of patch (L)
Because of resonant element having inherent narrow bandwidth, critical parameter is length and actual length is obtained by:

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

## III. ANTENNA DESIGN

The basic structure of proposed antenna is as shown in the figure1.It consists of three layers, where lower layer constitutes the ground plane and it covers the rectangular plane of the substrate with side of 80x75mm.The middle layer is substrate where in the material used here is Fr4_epoxy which has dielectric constant εr=4.4 and the height of substrate is 1.6mm. The upper layer consists of patch with dimensions 258.8x37.7mm. The feed line is placed 7 mm from the center of the patch. The feed location is selected to offer better impedance matching. Feeding technique used here is microstrip line with 50Ω input impedance.

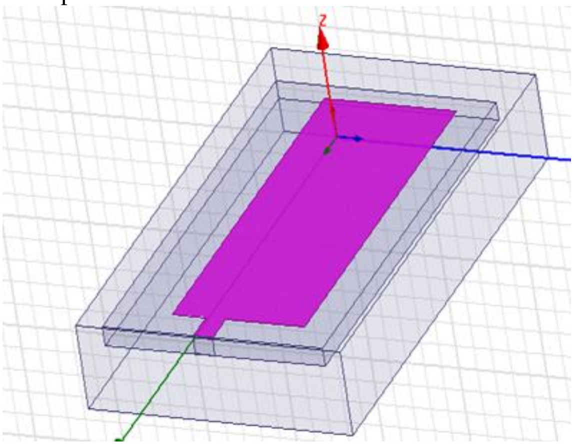


Figure 1: simple microstrip patch antenna with microstrip feed line

EBG can be realized in one, two and three dimensional forms.Here EBG structures are of box shaped with dimensions of 5x5x1.6mm. EBG structures can be implemented by making holes on substrate so as to obtain even flow of current.

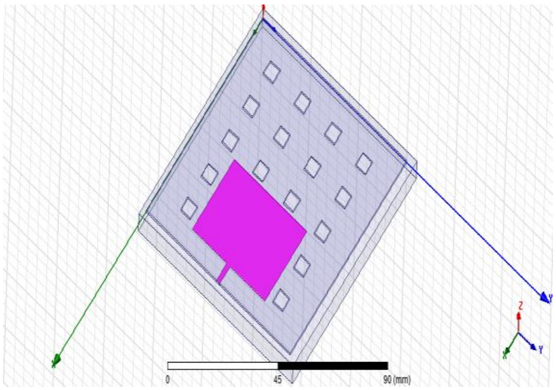

Figure 2: box shaped Electronic band gap structures implemented on substrate.

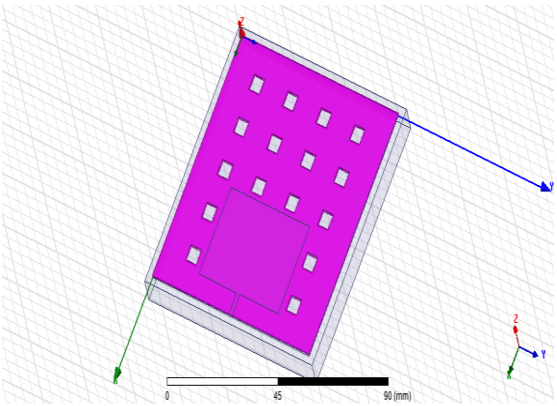

Figure 3:EBG structures on substrate.

Important parameters that has to be considered for designing a microstrip patch antenna with EBG structures are,

a) frequency of operation (f0): Appropriate resonant frequency of antenna has to be selected. Here the

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ISSN (Online) 2393-8021
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antenna was designed for earth exploration satellite, radiolocation, space research, maritime radio navigation, Aeronautical radio navigation.

b) Dielectric constant of substrate (εr): Fr4_epoxy which has dielectric constant of 4.4 is selected since it reduces the dimensions of antenna.

c) Height of the dielectric constant (h): For any wireless application, it is essential that antenna should be compact; hence height of dielectric substrate for our design is changed from 0.8mm to 1.6mm in steps of 0.2mm.

d) EBG structures have to be placed uniformly on the substrate so as to get the even flow of current for generating many useful frequencies.

In this process, a rectangular microstrip patch antenna and itsl EBG structure are designed by applying a Finite Element method (HFSS-Ansoft).

## IV. DESIGN ANALYSIS

To enhance the characteristics EBG concept was used. For the proposed design, height of the dielectric substrate was changed and its performance was checked accordingly. From the results obtained, it was observed that many useful frquencies were obtained at different heights which is used for many applications and its VSWR is approximately nearer to the ideal value.Considered heights are h1=0.8mm, h2=1.0mm, h3=1.2mm, h4=1.6mm.

Table no.1: Table consists of VSWR values for various frquencies.

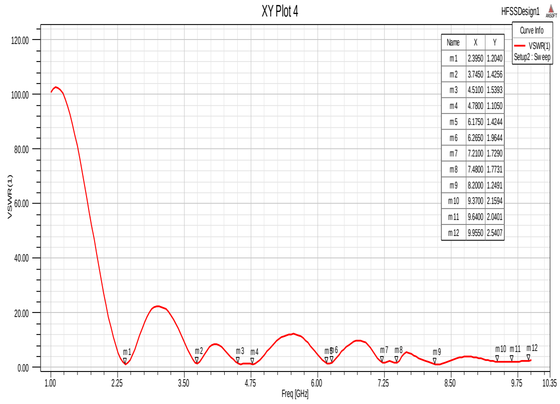
| Freq in Ghz | Parameter | Substrate=Fr4_epoxy | | | |
|---|---|---|---|---|---|
| | | h1=0.8 (mm) | h2=1 (mm) | h3=1.2 (mm) | h4=1.6 (mm) |
| 2.4 | VSWR | 1.2 | 1.21 | 2.1 | 1.5 |
| 3.7 | | 1.4 | 2 | 2.5 | 2.9 |
| 4.5 | | 1.54 | 1.52 | 1.50 | 2.0 |
| 4.7 | | 1.1 | 1.06 | 1.6 | 1.3 |
| 6.1 | | 1.4 | 1.2 | high | 1.5 |
| 7.2 | | 1.7 | high | high | 1.7 |
| 7.8 | | High | high | high | 1.5 |
| 8.2 | | 1.2 | 1.3 | high | 1.5 |
| 9.1 | | High | 2.1 | high | 1.3 |
| 9.4 | | 2.1 | 2 | high | 1.12 |
| 9.6 | | 2 | 2 | high | 1.2 |
| 9.8 | | 2.5 | 2.1 | 2.25 | 1.23 |

From the table it is seen that for higher frequencies that is x band range 8Ghz to 12 Ghz VSWR is nearer to 1when the height of substrate is 1.6mm.

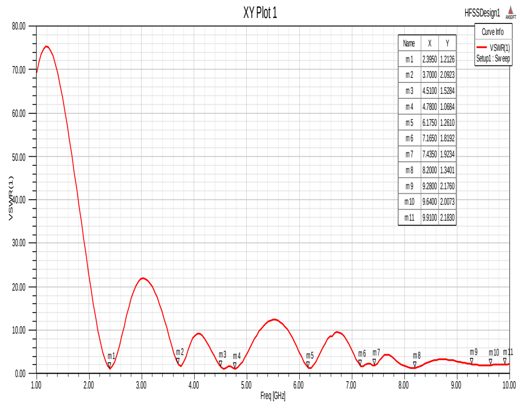
## V. RESULTS

Plot of VSWR versus frequencies.

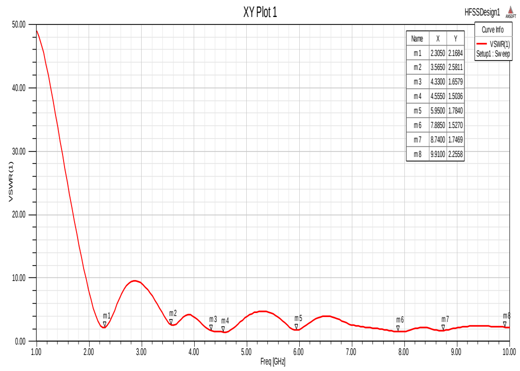
a) For h=0.8mm



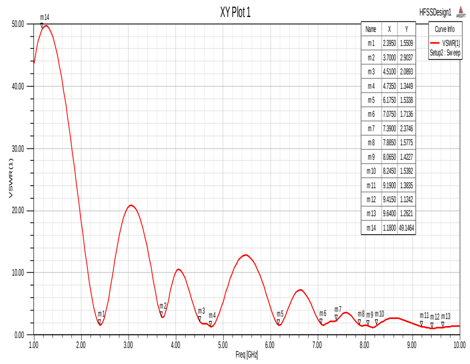

b) h=1mm




c)h=1.2mm




d) h=1.6mm



## VI. CONCLUSION

In this paper the main aim is to design a reconfigurable rectangular microstrip patch antenna. The antenna has been designed considering patch dimensions. Height of the substrate is changed and corresponding graph of VSWR versus frequencies is obtained. To overcome several limitations of patch antennas such as size, excitations of surface waves, low gain, constrict bandwidth, EBG concept is taken into consideration. This can be achieved by making holes on substrate to achieve uniformity of current flow which suppresses the surface waves. From the results, it is seen that many useful frequencies are obtained for compact design whose primary characteristic (VSWR) is nearer to ideal value.

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