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RESEARCH ARTICLE

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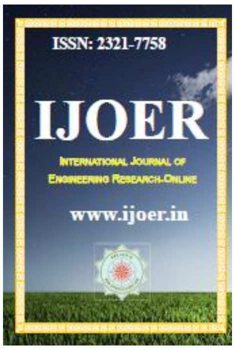
GAIN AND BANDWIDTH ENHANCEMENT OF MICROSTRIP PATCH ANTENNA FOR 2.4/5 GHZ WLAN APPLICATIONS USING EBG STRUCTURE

VIJAY KUMAR SRIVASTAVA[1], GARIMA SAINI[2]
[1] ME student, Department of Electronics and Communication
National Institute of Technical Teachers Training and Research, Chandigarh, India
[2] Assistant Professor, Department of Electronics and Communication
National Institute of Technical Teachers Training and Research, Chandigarh, India



ABSTRACT

In this paper gain and bandwidth enhancement of a dual band microstrip patch antenna for 2.4/5 GHz wireless local area network (WLAN) application using EBG structure is presented. The antenna operates at 2.4 GHz and 5.2 GHz frequency which are reserved for IEEE802.11b/g and IEEE802.11a WLAN standard. The substrate used for antenna design is FR4 substrate with relative permittivity of 4.4 and loss tangent of 0.02, which is a inexpensive and widely used printed circuit board (PCB).The overall dimension of antenna is 50×50×1.6 mm^3, where 1.6 mm is the thickness of FR4 substrate. Dimension of the patch, rectangular slot and ground plane are 20mm×34mm, 10mm×32.5mm and 8mm×50mm respectively. Size of each EBG cell is 6mm×6mm, which has the shape of H and rotated H. Due to reduction in the surface wave effect, the patch antenna-EBG prototype shows improved radiation properties without increasing the prototype size and the thickness. The slotted patch is directly edge-fed by 50-Ω microstrip line. The effective omni-directional / directional radiation pattern and impedance bandwidth, return-loss, VSWR, and gain have been investigated using computer simulation on HFSS. Using this antenna, simulated impedance bandwidths (/S11/< -10dB) of 10.07 % and 15.05 % were achieved at lower and higher band, with gains of 3.07 dBi and 7.3 dBi, respectively. The 10-dB impedance bandwidth (2.202-2.437GHz, and 4.934-5.738 GHz) completely meets the WLAN application requirements. The measurement has been done with help of copper mountain planar R140 vector reflectometer which shows good agreement with simulated results.

Keywords: Dual band, Slotted patch antenna, Partial ground, EBG structure, WLAN

1. INTRODUCTION

This paper investigates and attempts to enhance the gain and bandwidth of reference antenna using EBG presented in my previous work which was a dual-band edge-fed slotted rectangular patch antenna with partial ground for 2.4/5 GHz WLAN applications, where impedance bandwidths (/S11/< -10dB) of 9.05% and 18.12 % were achieved at operating frequencies 2.4 GHz and 5.2 GHz, with gains of 3.01 dBi and 6.36 dBi, respectively [1]. Several technique have been investigated to enhance the bandwidth and gain of patch antenna. Bandwidth of antenna increases with increase in antenna size or volume and substrate height but is makes antenna very large and bulky, use of low dielectric constant (εr) substrates like Arlon, Teflon, and Duroid, which basically reduce the surface wave loss are costly and not easily available [2-4]. One of the BW enhancement technique is proximity coupled feed but it makes the design more complex [5]. Different shapes or slotted patch antenna, in which E-shape as higher BW but as less quality factor[6-7]. multilayer dielectric substrate increase the volume of antenna and effectively reduces the dielectric constant (εr), which reduces the surface wave loss and eventually enhances the bandwidth, main drawback of it is large antenna volume, complex structure and high cost [8-11]. Gain is also proportional to effective area, large patch size increase the gain, reducing the surface wave loss by using low dielectric constant (εr) substrates and increasing the height of substrate usin foam or air between two substrate, which has drawback of large volume and high cost [12-13]. Superstrate structure increase the gain but as the problem of complex design, non–planar, feeding problem and impedance matching [14]. Array structure is a good technique but as draw of large size, feed network complexity and impedance matching. use of reflecting layer enhances the gain but antenna volume increases [15-17]. Inclusion of amplifier circuit and loading a lens on antenna also increases the gain but as non planar and complex design. Partial removal of substrate and parasitic patch is good choice for gain enhancement. Electronic band gap structure is very efficient technique which improves the antenna performance in term of bandwidth, gain and size of antenna without any change in existing antenna parameter [18]. In recent years there has been considerable effort in the EBG structure for antenna application to suppress the surface wave and overcome the limitations of the antenna. Many works have been done to improve the performance of the microstrip antennas [19-23]. The EBG structure utilizes the inherent properties of dielectric materials to enhance the microstrip antenna performance. EBG materials are periodic dielectrics that produce pass band and stop band characteristics.

2. Electronic Band Gap structure

Electromagnetic band gap structures can be defined as artificial periodic (or sometimes non-periodic) objects that prevent or assist the propagation of electromagnetic waves in a specified band of frequency for all incident angle and polarization state. One of the drawback of microstrip patch antenna is the excitation of surface waves that occur in the substrate layer. Surface waves are undesired because when a patch antenna radiates, a portion of total available radiated power becomes trapped along the surface of the substrate. It reduces total available power for radiation to space wave, The main advantage of EBG structure is their ability to suppress the surface wave current. The generation of surface waves degrades the antenna efficiency and radiation pattern. EBG structures are usually realized by periodic arrangement of dielectric materials and metallic conductors. In general, they can be categorized into three groups according to their geometric configuration; (i) three-dimensional volumetric structures, (ii) two-dimensional planar surfaces, and (iii) one-dimensional transmission lines [24-28].There are various 2D structures shapes like star, H , rotated H, I etc [29].

There are four main parameters affecting the performance of EBG structures. The parameters are like this: rectangle width w, gap width g, substrates thickness h and substrates permittivity. The parameters that are affecting the performance of EBG structures are directly dependent on the operating wavelength of the patch antenna. The parameters are varying with operating wavelength as like this that the rectangle width, w varies from 0.04_λ_{12GHz} to 0.20 λ_{12GHz} , gap width varies from 0.01 $\lambda_{12\ GHz}$ to 0.12 $\lambda_{12\ GHz}$ and the substrate thickness, h varies from 0.01 $\lambda_{12\ GHz}$ to 0.09 $\lambda_{12\ GHz}$. Here, λ_{12} means the wavelength between medium 1 and 2 i.e. the free space and the guiding device and GHz means the wavelength respect to the GHz range frequency [30].

3. Proposed antenna design

The proposed slotted rectangular patch antenna with partial ground plane and EBG structure upon radiating patch side is fabricated on FR4 substrate (εr=4.4 and tangent loss=0.02) of the size of (L×W×H),were L,W and H is length ,width and height of substrate respectively, the overall dimension of antenna is 50mm×50mm×1.6mm. Rectangular patch of size (L_1×W_1) were L_1= 20mm and W_1= 34mm, has been etched on the top layer of the substrate. For dual band operation a rectangular slot of size (L_2×W_2) were L_2= 10mm and W_2= 32.5mm has been cut over the rectangular patch. The dimension of W_3, $W_{4,}$ L_3 and L_4 are .75mm, 16mm, 5mm and 5mm respectively. The patch is fed with 50-Ω microstrip line of feed length F_L= 9mm and feed width F_W=2mm. Partial ground plane of size (L_G × $W_{G)}$ where L_G=8mm and W_G =50mm is etched on bottom layer of substrate.

The 2D planar EBG structure of one unit cell of H shape and rotated H shape is designed on the radiating side of the substrate, which reduces the surface wave loss with parasitic effect that eventually increases the antenna performance. H shape shows the property of minimum return loss, maximum gain and bandwidth enhancement among different EBG shapes [29]. To design the H shape, a square of 6mm×6mm (L_5×W_5) and a slot of 2mm× 2mm (L_6 ×W_6) has been cut in between the square. The designed H shape is alternatively rotated and repeated six time to cover the length and width of the substrate upper radiating plane. The vertical and horizontal gap (L_V, W_H) between the unit cell of H shape is 2.8mm. Dimensions of W_7, L_7 and L_8 are 2mm, 6.2mm and 3mm respectively which shows the gaps of unit cell around the radiating patch. Fig.3(i-vi) show the geometry of proposed design ,simulated and fabricated antenna geometry.

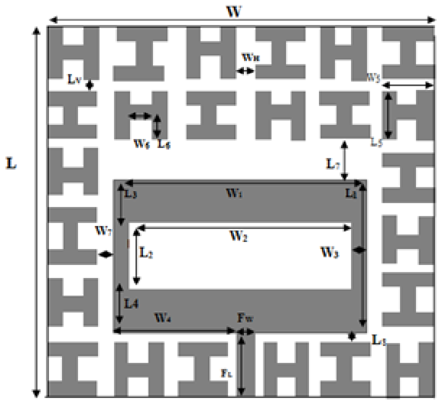


Fig.3(i) Dimensions of proposed antenna (front view)

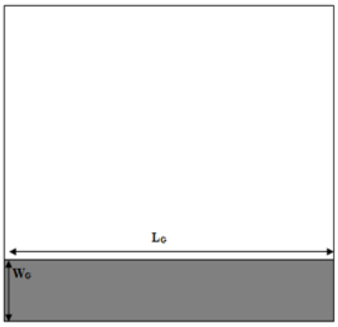


Fig.3(ii) Dimensions of proposed antenna (back view)

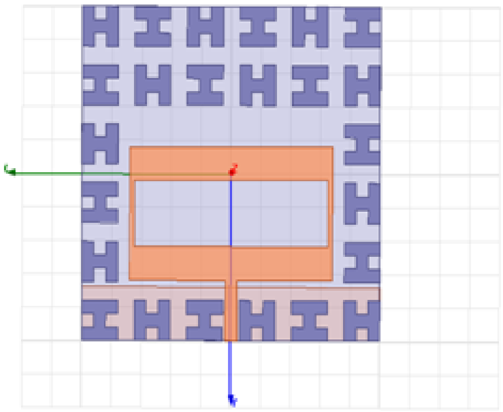


Fig.3(iii) Simulated proposed antenna (front view)

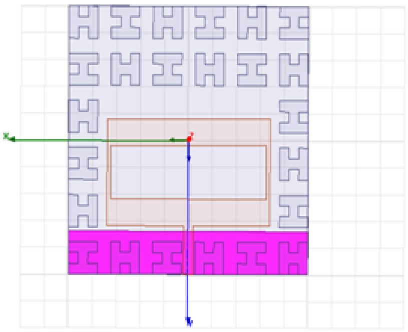


Fig.3(iv) Simulated proposed antenna (back view)

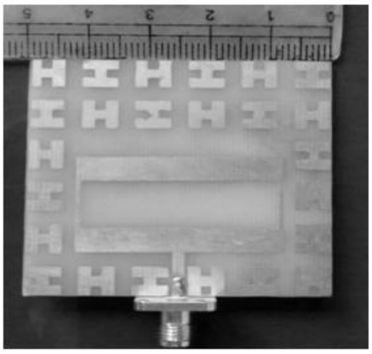


Fig.3(v) Fabricated proposed antenna (front view)

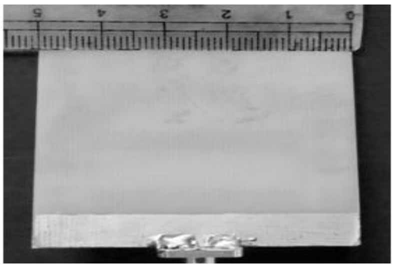


Fig.3(vi) Fabricated proposed antenna (back view)

4. Simulated and Measured Results

The proposed antenna has been designed and simulated with Ansoft HFSS software. The measurement has been taken with help of copper mountain R140 vector reflectometer.

Fig.4 Experimental setup for proposed antenna

4.1 Return loss and Impedance bandwidth

Figure.4.1 (i)/(ii) shows the simulated impedance (S11< -10dB) bandwidth and return loss of proposed antenna. From the simulated plot it is obvious that the antenna shows dual-band characteristic in the frequency band of 2.4/5GHz. For lower band antenna has simulated impedance bandwidth of (2.202-2.437GHz, 10.07%) with central frequency of 2.332 GHz and return loss -16.8dB and For higher band it has impedance bandwidth of (4.934-5.738 GHz, 15.05%) with central frequency of 5.339 GHz and return loss 30.27dB. Both the bands have wider impedance bandwidth. The higher band can cover 5.2/5.8GHz WLAN band.

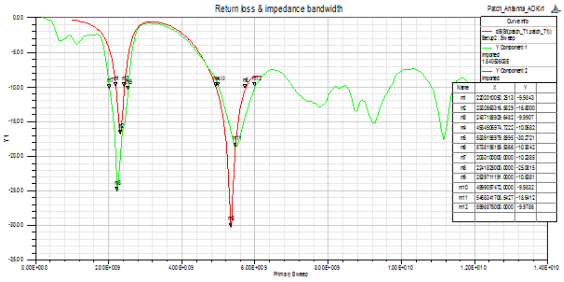


Fig.4.1(i) Simulated and measured return loss and impedance bandwidth

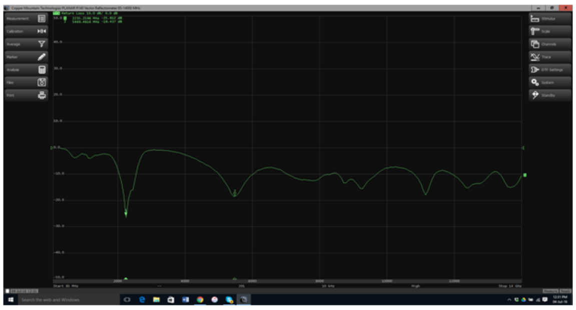


Fig.4.1(ii) Measured return loss and impedance bandwidth of proposed antenna

The measured return loss and impedance bandwidth for lower and higher bands are -25.08dB, 22.57% (2.033GHz -2.539GHz) with central frequency of 2.241GHz and -18.64dB,18.26% (4.999 GHz - 5.998 GHz) with central frequency 5.468 GHz respectively. At 2.4 GHz and 5.2 GHz the measured return is -15.90dB and -14.2237dB.

4.2 VSWR

The proposed antenna has simulated VSWR AT 2.4 GHz and 5.2 GHz is 1.7103 and 1.4379 . The minimum simulated VSWR is 1.0471 at 5.05 GHz frequency in 5 GHz WLAN band. Measured results show 1.1221 and 1.2557 VSWR at 2.24 and 5.46 GHz frequency respectively. Measured VSWR at 2.4 GHz and 5.2 GHz are 1.2746 and 1.5284 respectively. All the simulated and measured VSWR values are quite good which are less than 2.

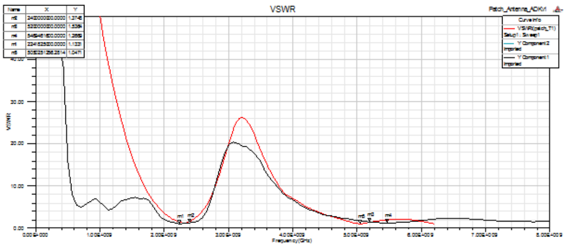


Fig.4.2(i) Simulated and measured VSWR of proposed antenna

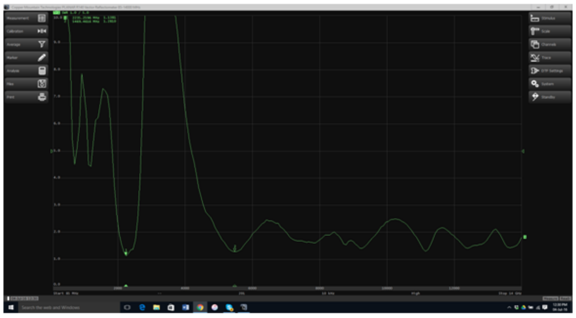


Fig.4.2(ii) Measured VSWR of proposed antenna

4.3 INPUT IMPEDANCE (SMITH CHART)

The simulated input impedance of microstrip feed line is 50Ω and the measured input impedance at 2.235GHz/5.460GHz are 45.286 Ω and 61.0 Ω, which shows the good agreement between simulated and measured results.

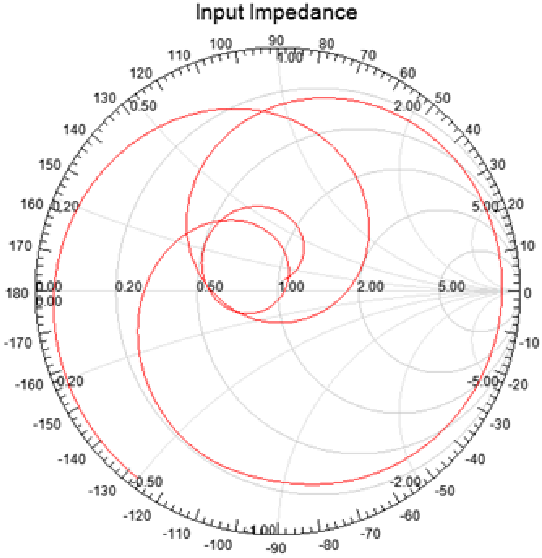


Fig.4.3(i) Simulated input impedance of proposed antenna

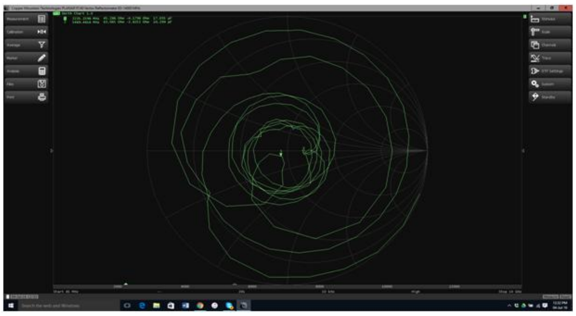


Fig.4.3(ii) Measured input impedance of proposed antenna

4.4 RADIATION PATTERN

Fig.4.4(i)/(ii) and (iii)/(iv) shows the 3D /2D radiation pattern of proposed antenna at 2.4 GHz and 5.2 GHz frequency respectively. 3D radiation is pattern is like doughnut shaped radiation pattern and 2D radiation pattern shows omni-directional in E-plane and H-plane at 2.4 GHz. for antenna operating at 5.2 GHz has dual beam directional pattern.

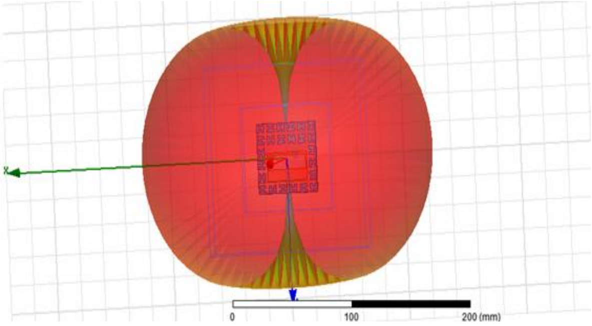


Fig.4.4 (i) 3D radiation pattern at 2.4 GHz

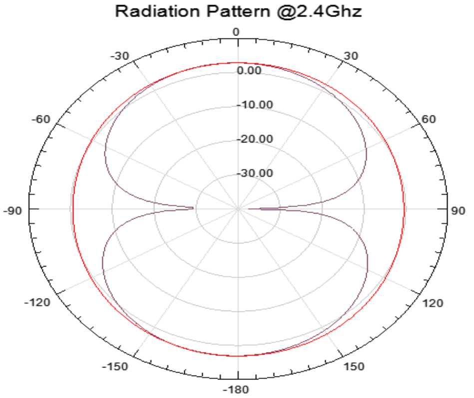


Fig.4.4 (ii) 2D radiation pattern at 2.4 GHz

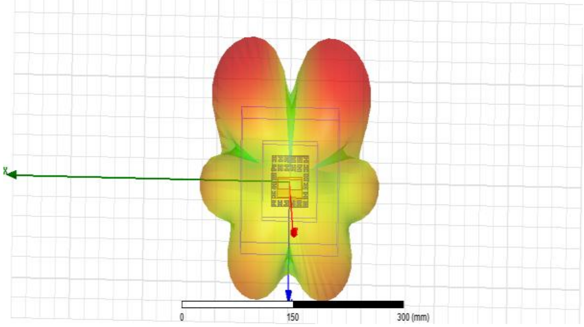


Fig.4.4(iii) 3D radiation pattern at 5.2 GHz

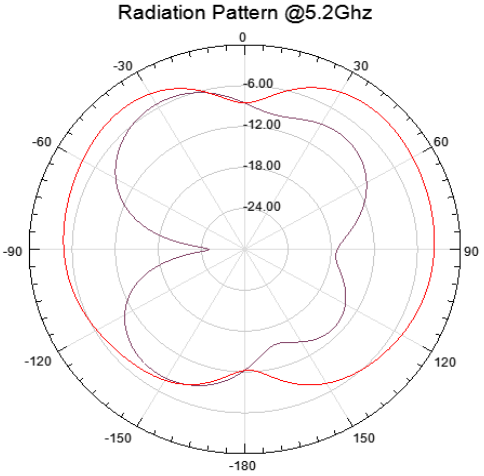
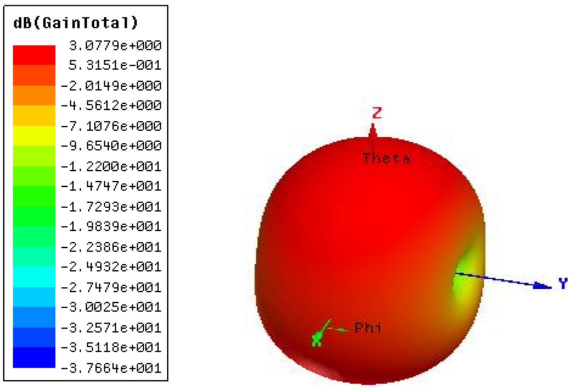


Fig.4.4 (iv) 2D radiation pattern at 5.2 GHz

4.5 Gain

Fig.4.5 (i)/(ii) presents the proposed antenna gain operating at 2.4 and 5.2 GHz frequencies. The peak gain at 2.4 GHz frequency is 3.07dBi, which is promising gain for indoor WLAN application, hallways and large office space etc. Peak gain at 5.2 GHz is 7.30dBi which is good for superior WLAN coverage.



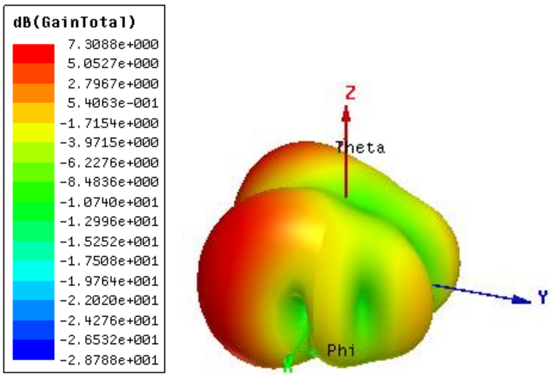


Fig.4.5 (i) Gain at 2.4GHz (Above)

Fig.4.5(ii) Gain at 5.2GHz (below)

Conclusion

The overall simulation and measured result shows that gain and bandwidth has been increased using EBG structure technique. Lower/higher band gain has been increased from 3.01 to 3.07 dBi and from 6.6 to 7.36 dBi respectively with respect to the reference antenna. There are increment in bandwidth of 2% for lower band and decrement of 3.2% for higher band. Antenna with EBG structure shows better retun loss with respect to the reference antenna. The proposed antenna is good candidate for WLAN application with acceptable antenna performance parameters.

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