A Dual Wide-Band Slotted Rectangular Patch Antenna for 2.4/5 GHz WLAN Applications

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Abstract- **This paper presents a dual band slotted rectangular patch antenna with partial ground for 2.4/5 GHz wireless local area network (WLAN) application. 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 34mm×20mm, 32.5mm×10mm and 50mm×8mm respectively. 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, 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. The 10-dB impedance bandwidth (2.23-2.44 and 4.99-6.0 GHz) completely meets the WLAN application requirements.**

***Keywords:* Dual band, Slotted patch antenna, Partial ground, WLAN**

1. INTRODUCTION

The wireless local area network (WLAN) is commonly used in home networks and in commercial complexes offering wireless access to their customers. Most modern WLANs are based on IEEE 802.11 standards. The frequency bandwidths of IEEE 802.11a and 802.11b/g are 5.15-5.825 GHz and 2.400–2.4845 GHz, respectively. The frequency ranges of IEEE 802.11a are 5.15–5.35 and 5.725–5.825 GHz in the US and 5.15–5.35 and 5.470–5.725 GHz in Europe are used for wireless local area network (WLAN) that offers data rate up to 54 Mb/s. The present scenario in the wireless communication systems indicates a shift of operating frequency from 2.4GHz band to the 5.2/5.8GHz band for various reasons. There is a need for a dual-band with high gain and broad bandwidth for higher data rates as this will permit a greater number of devices to share the available space with good signal strength [1, 2]. This dual-band patch antenna is very attractive because of its cost-effective solution for reducing the number of antenna units and minimizing the installation area for WLAN access points [3].

A dual-band dipole antenna has been investigated owing to its low profile, low cost and omnidirectional pattern; however, this type of antenna has a relatively low gain in where superior RF coverage is required [4]. Xiao Lei Sun, Li Liu designed a dual band planar antenna with overall antenna size of 40×30×0.8mm^3 for 2.4/5.2/5.8GHz WLAN application. The measured bandwidths were from 2.39 to 2.51 GHz and from 5 to 6.1 GHz for lower and higher band respectively. Gain for the both bands was less than 2dBi [5]. Various dual band monopole antennas operating in 2.4/ 5GHz band have been designed for WLAN application such as F-shape, L-shaped , triangular monopole and a U-shaped monopole, assembled ,split ring monopole in which The peak gain varies from 2.2-4.5dBi for 2.4GHz band and with 3.9 -6dBi for 5 GHz band. The impedance bandwidth varies from 7.5%-15.6% and from 12.6%-25% for lower and higher band respectively [6-10].planar inverted F antenna have also been investigated for dual band WLAN application, in which peak gain ranges from 1.6-2.4 dBi and impedance bandwidth ranges from 130 MHz- 146 MHz and 200MHz- 834MHz for lower band and higher band respectively.[11-14]. All the above antenna have lower peak gain and not suitable for superior WLAN coverage. slot antennas having peak ain from 4.95-6dBi and4.42-8dBi, but these have very large volume with multilayer structure.[15-19].several patch antenna of various shapes and size have also been designed [20-23]. Rectangular patch antenna operating at 2.4GHz frequency as 7dBi simulated ain and 38 dB return loss [24]. In this paper, dual-band edge-fed slotted rectangular patch antenna with partial ground for WLAN applications is presented. It can be easily designed, fabricated, and integrated with WLAN access points and other RF front-end circuits in a PCB.

2. ANTENNA DESIGN

Designing For designing of a microstrip patch antenna, we have to select the resonant frequency and a dielectric medium for which antenna is to be designed. The parameters to be calculated are as under.

Width (W): The width of the patch is calculated using the following equation.

$$W=\frac{C0}{2fr}\sqrt{\frac{2}{\varepsilon r+1}} \quad \text{................................} \quad (1)$$

Where, W = Width of the patch, $f\ r$ = Frequency of operation, C_0= Speed of light,
εr = Dielectric constant of substrate

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Effective dielectric constant ($\mathcal{E}eff$): The effective dielectric constant value of a patch is an important parameter in the designing procedure of a microstrip patch antenna. The radiations travelling from the patch towards the ground pass through air and some through the substrate (called as fringing). Both the air and the substrates have different dielectric values, therefore in order to account this we find the value of effective dielectric constant.

The value of the effective dielectric constant ($\mathcal{E}eff$) is calculated using the following equation

$$\mathcal{E}eff = \frac{\mathcal{E}r+1}{2} + \frac{\mathcal{E}r-1}{2}\left[1 + 12\frac{h}{w}\right]^{-0.5} \text{ .... (2)}$$

Length: Due to fringing, electrically the size of the antenna is increased by an amount of (ΔL). Therefore, the actual increase in length (ΔL) of the patch is to be calculated using the following equation.

$$\frac{\Delta L}{h} = 0.412\,\frac{(\mathcal{E}eff+0.3)\left(\frac{W}{h}+0.264\right)}{(\mathcal{E}eff-0.258)\left(\frac{W}{h}+0.8\right)} \text{ .... (3)}$$

Where 'h'= height of the substrate

The length (L) of the patch is now to be calculated using the below mentioned equation.

$$L = \frac{1}{2fr\sqrt{\mathcal{E}eff\ \mu_0\varepsilon_0}} - 2\Delta L \text{ .... (4)}$$

Length (Lg) and width (Wg) of ground plane: Now the dimensions of a patch are known. The length and width of a substrate is equal to that of the ground plane. The length of a ground plane (Lg) and the width of a ground plane (Wg) are calculated using the following equations.

$$Lg = 6h + L \text{ .... (5)}$$

$$Wg = 6h + W \text{ ....(6)}$$

2.1 Proposed antenna geometry

The proposed slotted rectangular patch antenna with partial ground plane 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= 34mm and W_1= 20mm, 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= 32.5mm and W_2=10mm has been cut over the rectangular patch. The dimension of L_3, L_4, L_5,W_3 and W_4 are .75mm, 16mm, 8 mm, 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=50mm and W_G =8mm is etched on bottom layer of substrate. Fig1a, b show the proposed antenna geometry.

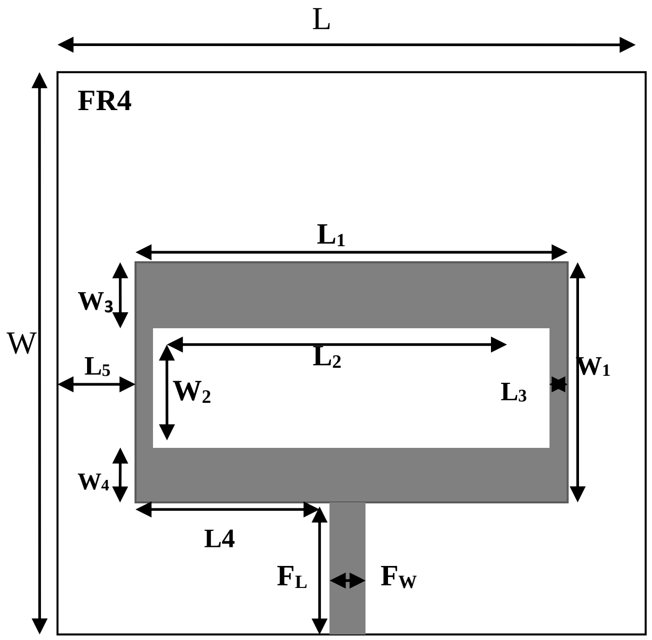

Fig.2a: Proposed antenna top view

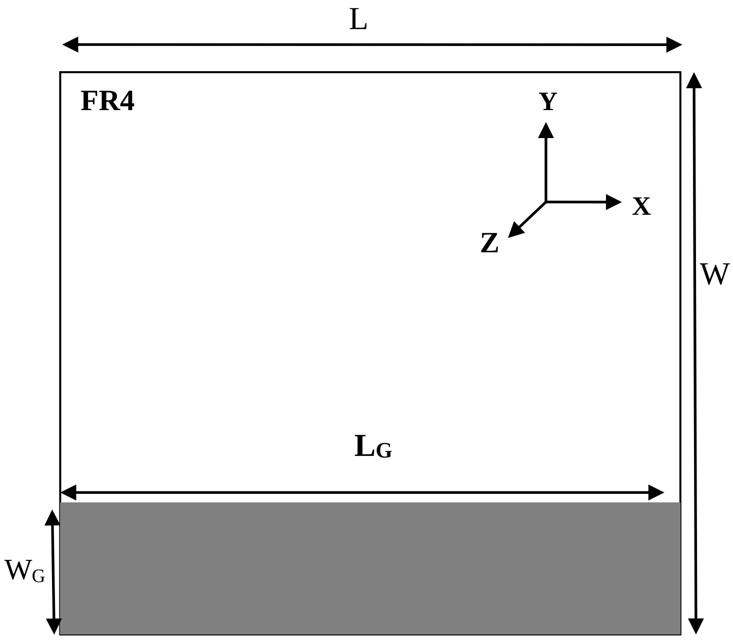

Fig.2b: Proposed antenna bottom view

3. SIMULATION AND RESULTS

The proposed antenna has been designed and simulated with Ansoft HFSS software. Fig.2 shows 2D view of design of proposed antenna on simulation software.

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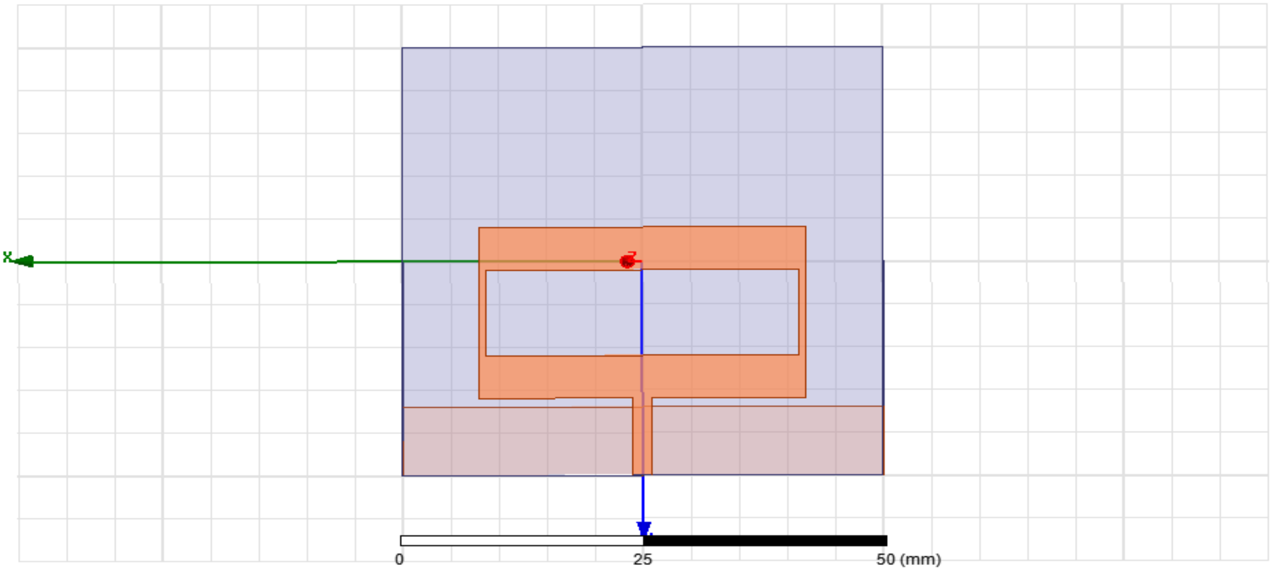

Fig.3: 2D view of design of proposed antenna

3.1a Return loss and Impedance bandwidth

Figure.3a(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. When the antenna operates at 2.4 GHz frequency it has impedance bandwidth of (2.23-2.44GHz) with central frequency of 2.33 GHz and return loss -17.6 dB and when it operates at 5.2 GHz frequency it has impedance bandwidth of (4.99-6.00 GHz) with central frequency of 5.58 GHz and return loss -12.8dB. Both the bands have wider impedance bandwidth.

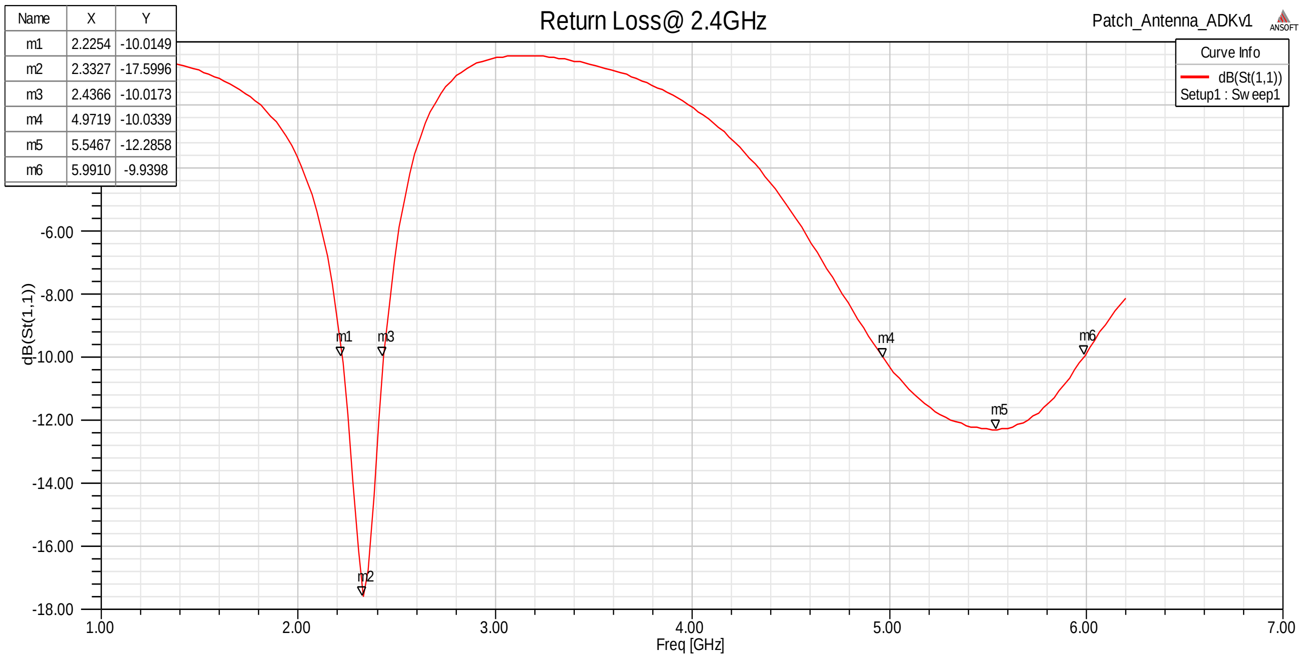

Fig.3a

(i) Return loss and impedance bandwidth at 2.4 GHz

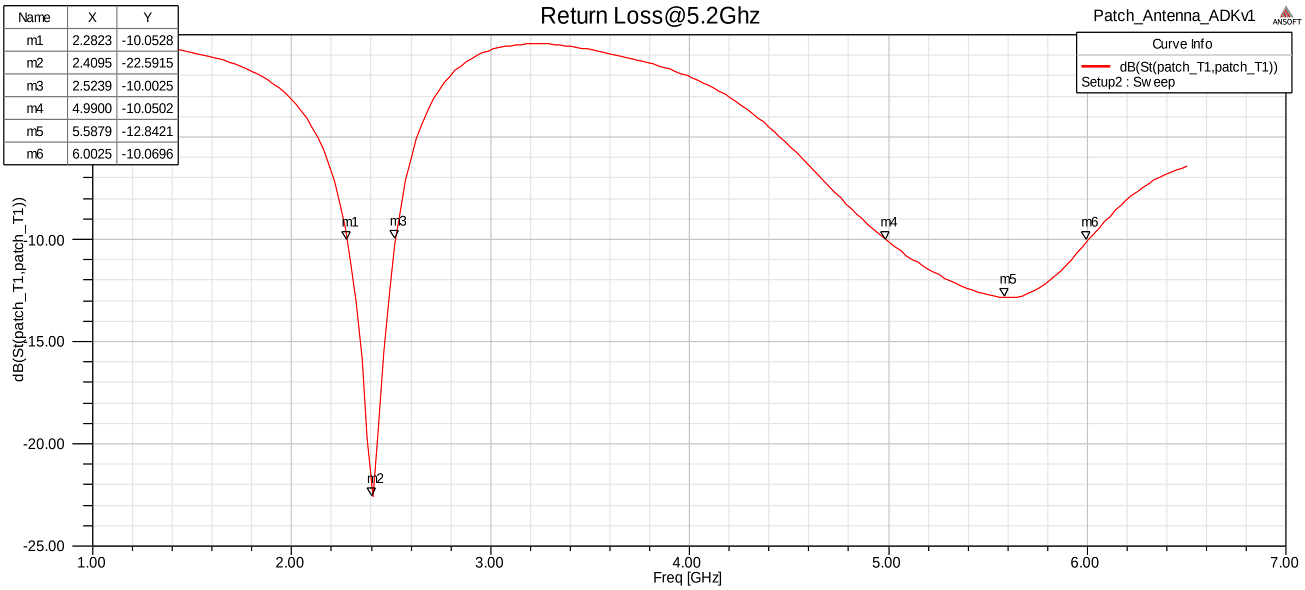

Fig.3a (ii) Return loss and impedance bandwidth at 5.2 GHz

3.1b VSWR

Fig. 3b shows the simulated VSWR at frequencies 2.4/5.2 GHz which is 1.58 and 1.71 respectively.

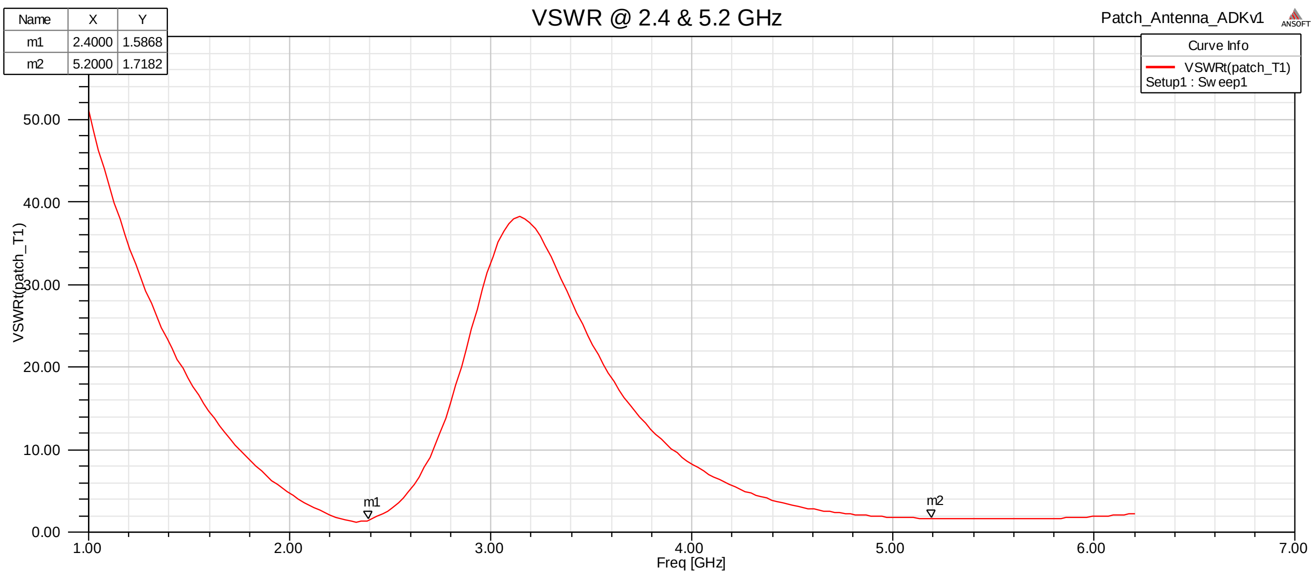

Fig.3b VSWR at frequencies 2.4 GHz and 5.2 GHz

3.1c Radiation pattern

Fig.3c(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.

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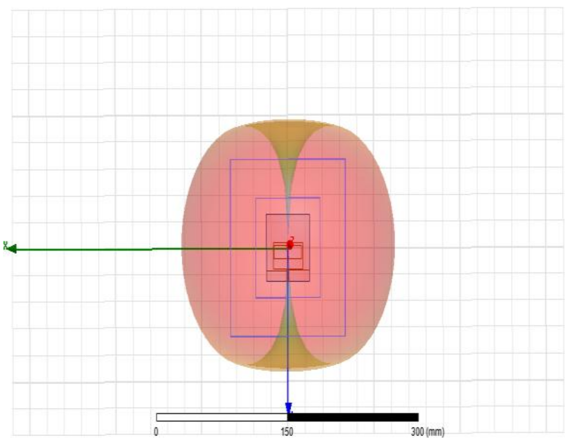

Fig. 3c (i) 3D radiation pattern at 2.4 GHz

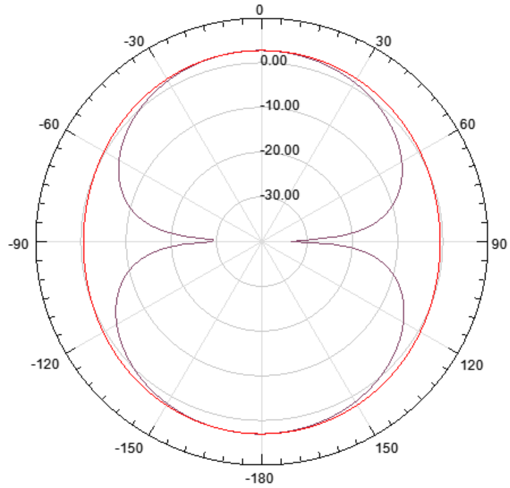

Fig.3c (ii) 2D radiation pattern at 2.4 GHz

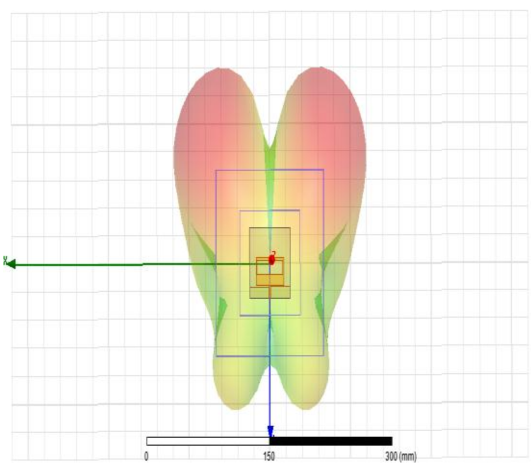

Fig.3c (iii) 3D radiation pattern at 5.2 GHz

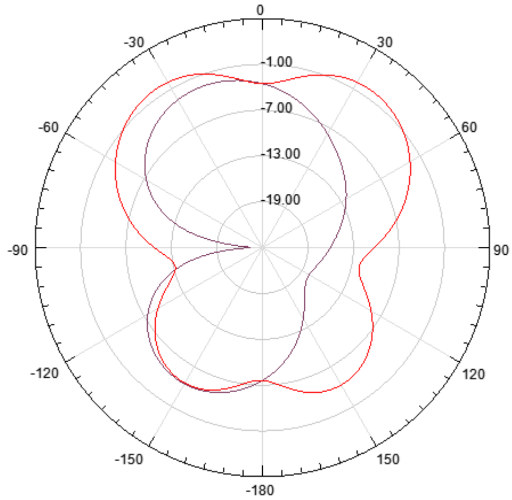

Fig.3c(iv) 2D radiation pattern at 5.2 GHz

3.1d Gain

Fig.3d(i)/(ii) presents the proposed antenna gain operating at 2.4 and 5.2 GHz frequencies. The peak gain at this frequency is 3.01dBi, which is promising gain for indoor WLAN application, hallways and large office space etc.peak gain at 5.2 GHz is 6.36 dBi which is good for superior WLAN coverage.

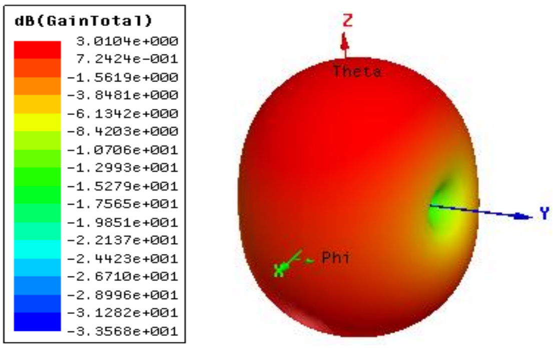

Fig.3d(i) Gain at 2.4GHz

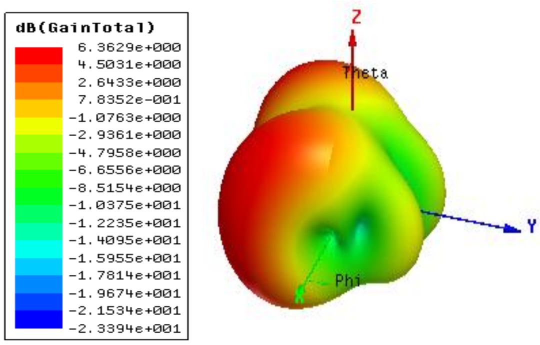

Fig.3d(ii) Gain at 5.2GHz

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4. CONCLUSION

The proposed antenna shows dual band characteristic in 2.4 /5GHz band. it shows wide impedance (9.05% &18.12%) bandwidth and less return loss in both bands, which are -17.6 dB and -12.8 dB respectively. VSWR has favourable values in both bands. Lower band gain and directional pattern is promising for indoor WLAN application with value of 3.01dBi and omnidirectional radiation pattern, where as in higher band peak gain is 6.36 dBi with dual beam directional pattern, which can have good application for superior WLAN coverage. Over all the proposed antenna has properties of low cost , low weight, wide dual- band ,easy fabrication and integration with RF circuit with favourable gains, these properties makes antenna a promising candidate for WLAN application.

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