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Development of Microstrip Patch Antenna Design for S-Band Application

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Abstract: Microstrip patch antenna used to send onboard parameters of article to the ground while under operating conditions. The aim of the paper is to design as tacked nearly square microstrip patch antenna design for S band 2 GHz to 4 GHz and study the effect of antenna dimensions Length (L), and substrate parameters relative Dielectric constant (εr), substrate thickness (h) on the radiation parameters of Bandwidth and Beam-width. A stacked patch configuration is proposed to increase the narrow bandwidth, radiation efficiency and directivity. The proposed antenna is probe fed on a FR-4 substrate with dielectric constant of 4.4. At resonant frequency 2.42 GHz, antenna parameters like Return Loss, VSWR, Axial Ratio and Radiation pattern are verify and simulated on CST Microwave Studio by CST student edition.

Keywords: Electromagnetic Theory, CST Microwave Studio, Microstrip PatchAntenna, Stacked Patches, S-Band, Polarization

1. Introduction

ThisMicrostrip antenna has been one of the mostinnovative topics in antenna theory and design in recent years, and is increasingly finding application in a wide range of modern microwave systems [6]. Deschamps first proposed the concept of the MSA in 1953 [2]. However, practical antennas were developed by Munson [3]-[4] and Howell [5] in the 1970s. Microstrip antennas (MSA) offer many attractive features such as low weight, small size, ease of fabrication, ease of integration with Microwave Integrated Circuits (MIC) and can be made conformal to host surface. However, they suffer from low gain, narrow bandwidth, low efficiency, and low power handling capability [7]-[9]. In some applications, such as in government security systems, narrow bandwidths are desirable [7]. This proposed antenna has square patch used. The square patch is by far the most widely used configuration. It is very easy to analyze using both the transmission-line and cavity models, which are most accurate for thin substrates [7].

2. Antenna Design

The antenna design could be developed based on the following steps and analyses.

2.1. Mathematical Analysis

The design of the proposed antenna is shown in Figure 1. The design of the proposed microstrip patch antenna was modeled the classical equations.

Step 1: Calculation of the Width (W):

$$W=\frac{\lambda}{2}\left[\sqrt{\frac{\varepsilon r+1}{2}}\right],\ c=\frac{fr}{\lambda} \tag{1}$$

Where c= 3×10^{8} m/s, $\mathcal{E}r$=4.4, fr= Designed Frequency

Step: Calculation of Effective dielectric constant ($\mathcal{E}re$):

$$\varepsilon re=\frac{\varepsilon r+1}{2}+\frac{\varepsilon r-1}{2}\left[1+\frac{10h}{W}\right]^{-0.5} \tag{2}$$

Where h= 1.6mm

Step 3: Calculation of the Effective length (L_{eff})

$$L_{eff}=0.5\frac{\lambda}{\sqrt{\varepsilon r}} \tag{3}$$

Step 4: Calculation of the length extension (ΔL):

$$\Delta L = 0.412\left(\frac{\varepsilon re + 0.3}{\varepsilon re - 0.3}\right)\frac{\left[\frac{W}{t} + 0.264\right]}{\left[\frac{W}{t} + 0.8\right]}h \quad (4)$$

Step 5: Calculation of actual length of patch (L):

$$L = L_{eff} - 2\Delta L \quad (5)$$

Step 6: Calculation of input impedance:

$$Z_A(\Delta xp = 0) = 90\frac{\varepsilon r^2}{\varepsilon r - 1}\left[\frac{L}{W}\right]^2 \Omega \quad (6)$$

Step 7: Calculation of the feed set to be location (50Ω):

$$\Delta xp = \frac{L}{\pi}\cos^{-1}\sqrt{\frac{Z_A(\Delta xp)}{Z_A(\Delta xp = 0)}} \quad (7)$$

Step 8: Calculation of ground plane size

$$L_g = 6h + L_{patch} \quad (8)$$

$$W_g = 6h + W_{Patch} \quad (9)$$

2.2. Proposed Antenna Geometry

For microstrip antennas, a good first step to assume a standard substrate, to know importance of Ɛr, h, to avoid cross polarization the antenna must be kept 1<W/L<1.5 and rule of λ/2 versus~0.48λ.

Figure 1 shows a 3D model of a proposed s band patch antenna. The upper patch resembles a truncated corner nearly square patch with a total size of 28.55x27.33mm^2. There are many ways to get circular polarization for the patch antennas. Common ways to achieve circular polarization is by cutting corner of the patch. In the proposed design, the antenna is truncated to get left handed circular polarization or LHCP. The lower patch has a same size with the upper patch shape with different slots as v-slit, l- slit. The purpose with these different structures for the patch layer is that the current needs to travel a longer way on the patch surface which increases the electrical length. One of the methods to increase the bandwidth is using a thick substrate layer such as stack more than one radiation path. The size of the ground plane can also be used to increase the bandwidth. Feeding techniques is mainly to transfer the power to the patch. There are many ways to feed the patch and all have their disadvantages and advantages. The coaxial feed method is one of the common feed techniques. It is easy to match because the feed position can be placed anywhere to the patch to get impedance matching but narrow bandwidth.

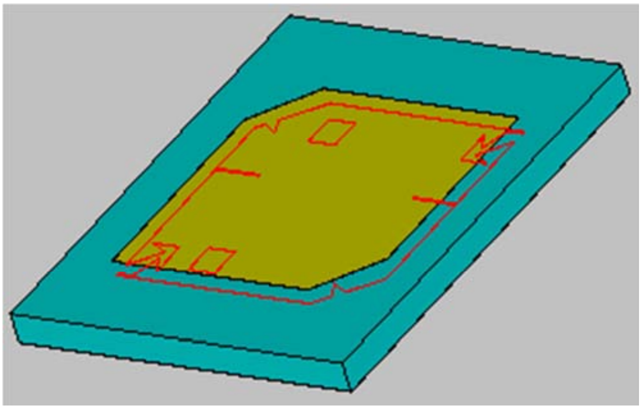


Figure 1. *Front view of the Microstrip Patch Antenna.*

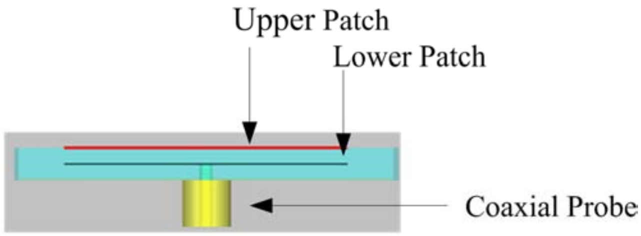


Figure 2. *Side view of the Microstrip Patch Antenna.*

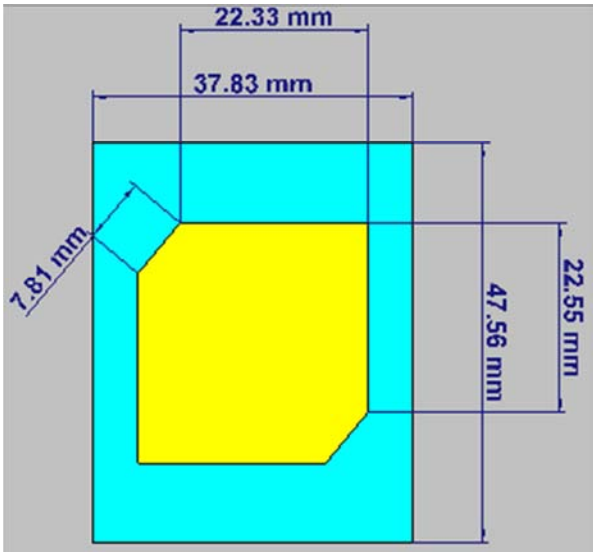
Table 1. *Calculation Of Antenna Parameters In Excel.*

Input_data 1	frequency	2.4
	one-wavelength	125
Input_data 2	dielectric constant	4.4
Input_data 3	thickness	1.6

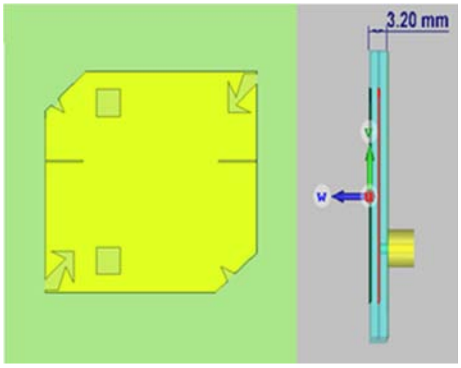
Antennas Theory and Design PP.469-471					
Width	2.7	0.608581	38.03629		
Effective dielectric constant	2.7	1.7	1.420651	0.838989	4.126281
Delta_Length	106.3931	95.05404	0.737836		
Length	28.32003				
ZA	284.0928				
Delta_x	0.419522	1.137877	10.26265		
Ground Width				54.72003	
Ground Length				64.43629	

Table 2. *Design Parpmeter Specifications Of The Rectangular Microstrip Patch Antenna.*

Dielectric Constant of the substrate	FR-4 (Lossy)
Height of the dieletric substrate (h1&h2)	1.6mm
Height (t) of Patch and Ground	0.035mm
Patch Length (upper& lower)	27.33mm
Patch Width (upper &lower)	28.55mm
Substrate and Ground Length	37.83mm
Substrate and Ground Width	47.56mm
Design frequency	2.4GHz
Feed location (x, y)	(0,10.7) mm
Feed Diameter	1.3mm
Feeding technique	Coaxial Probe



(a) Upper Patch



(b) Lower Patch (c) Stacked Height

Figure 3. *Stacked TruncatedPatch Antenna Designed using CST Microwave Studio.*

3. Results and Discussions

The simulated return loss (S1,1) of the proposed antenna is depicted in Figure 4 and Figure 5. The graph shows the maximumreturn loss of -16.207dB at the resonant frequency 2.42GHz. The graph also depicts that below -10dB theantenna attained the bandwidth of 0.16024GHz (6.67%) The voltage standing wave ratio (VSWR) of the proposedantenna is shown in. Figure 6. It can be observed from the resultthat the VSWR value is less than 2 for whole operating band, which considered as suitable for the antenna. Figure 7 and Figure 8 depict far field radiation directivity and far- field radiation gain of proposed antenna respectively. Directivity and Gain is 5.78 dBi and 5.44dB respectively. Figure 9 and Figure 10 shows 3D radiation pattern. Beamwidth is 91.7 at 3dB. Table 3 shows the summary of results of the proposed patch antenna.

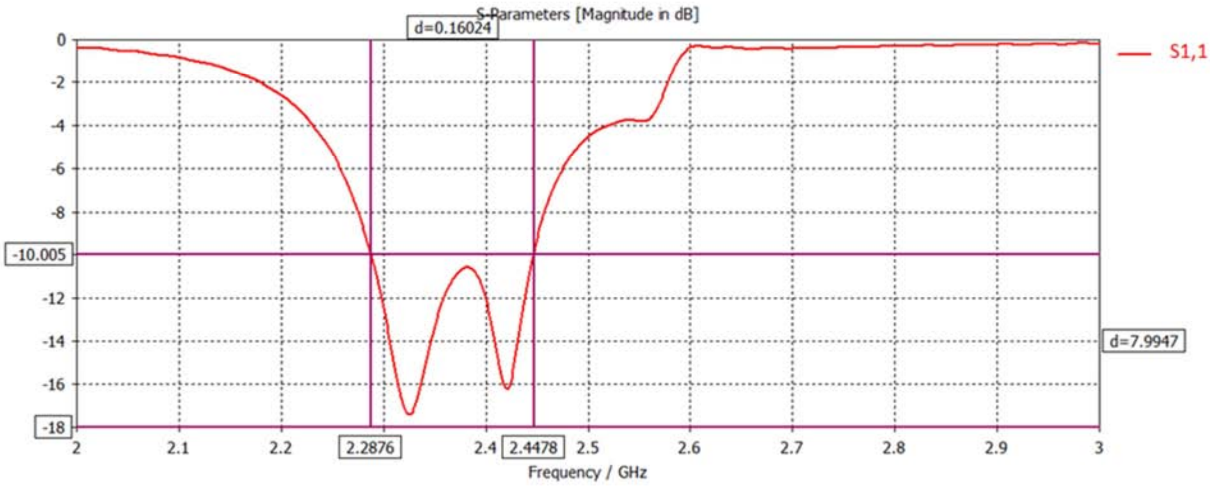


Figure 4. *Return Loss vs. Frequency.*

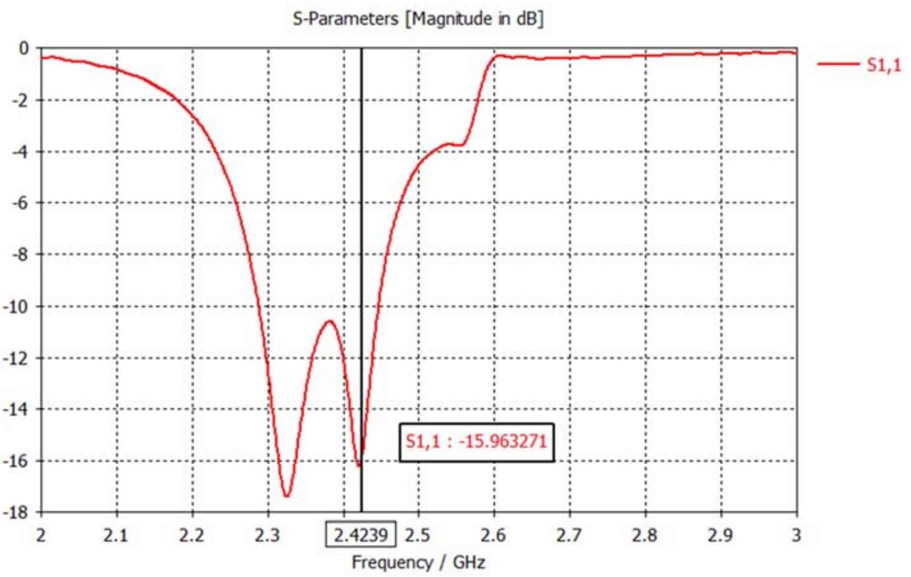


Figure 5. *Return Loss at 2.4239GHz.*

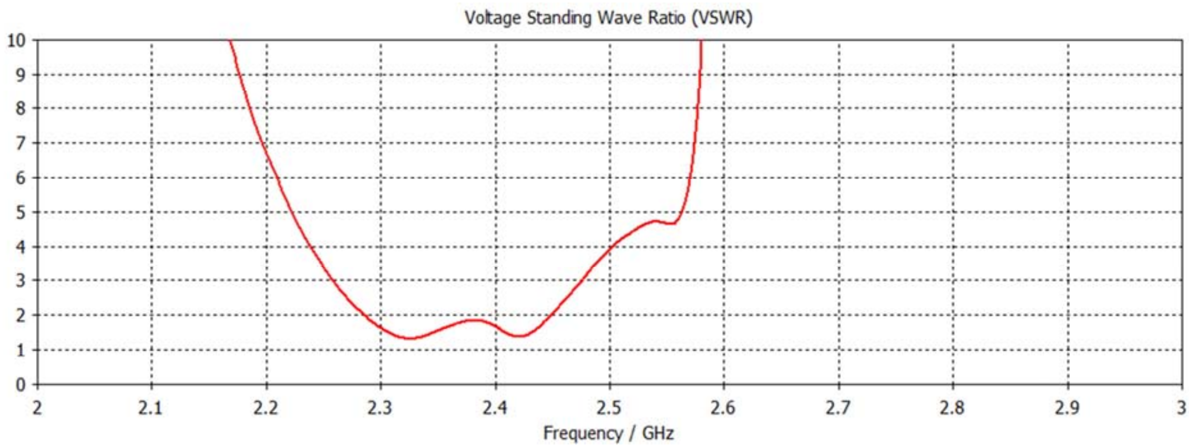
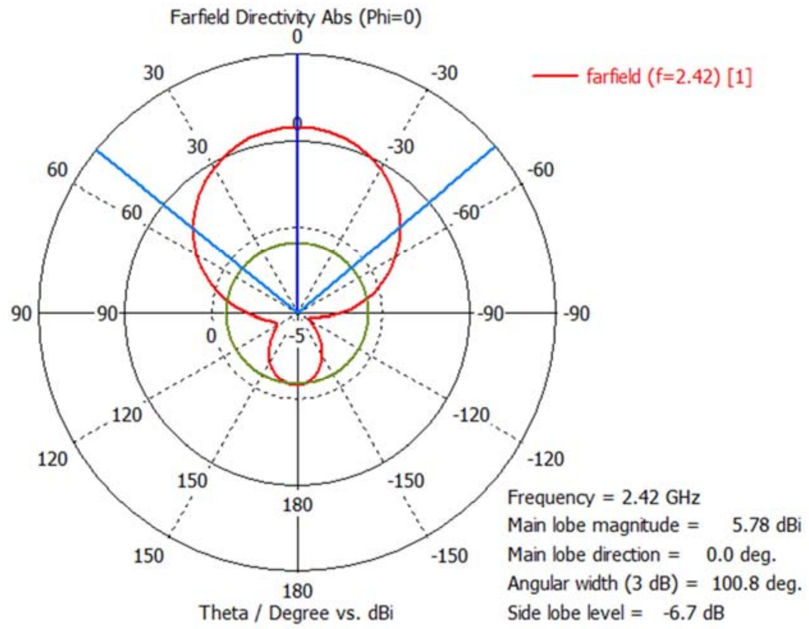
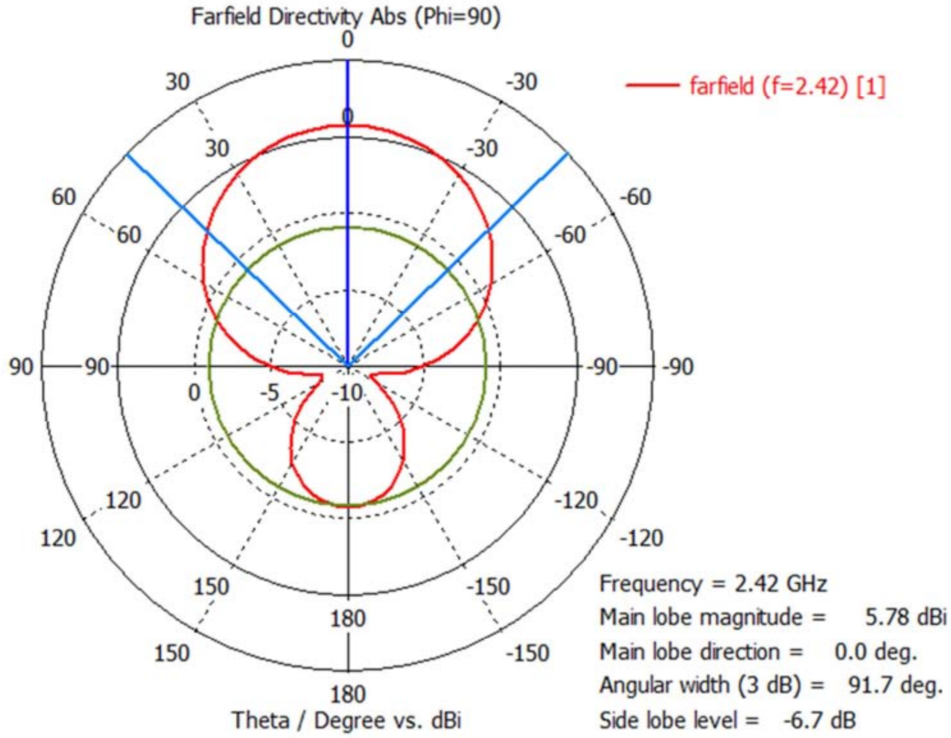


Figure 6. *VSWR vs. Frequency.*



(a) E-plane



(b) H-plane

Figure 7. *Radiation Pattern (a) Phi=0 deg, (b) Phi=90deg.*

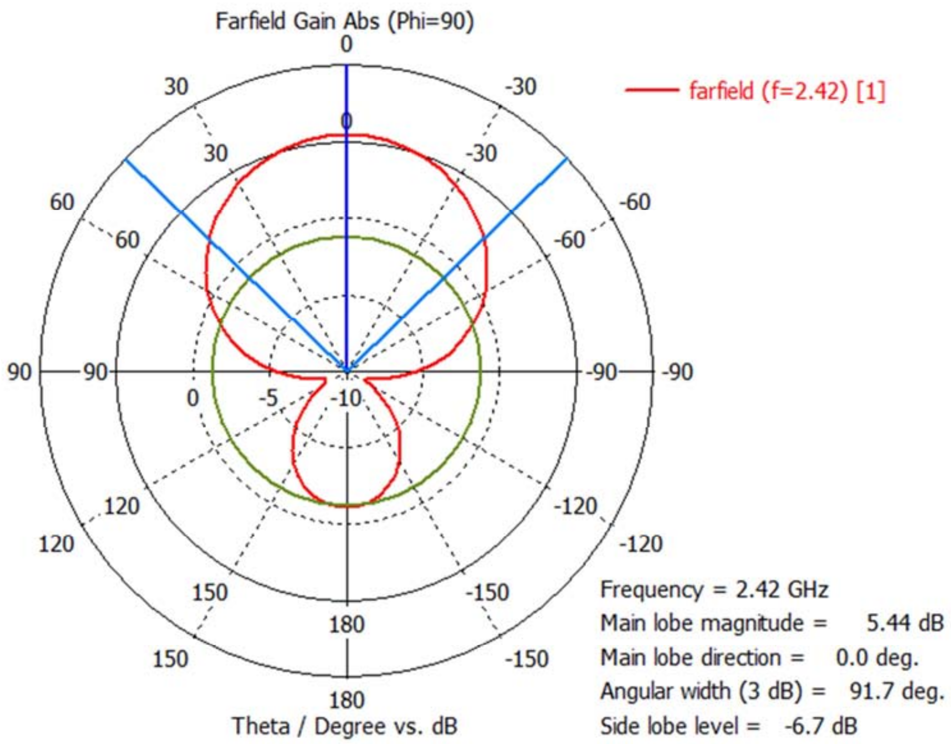


Figure 8. *Gain at 2.4GH.*

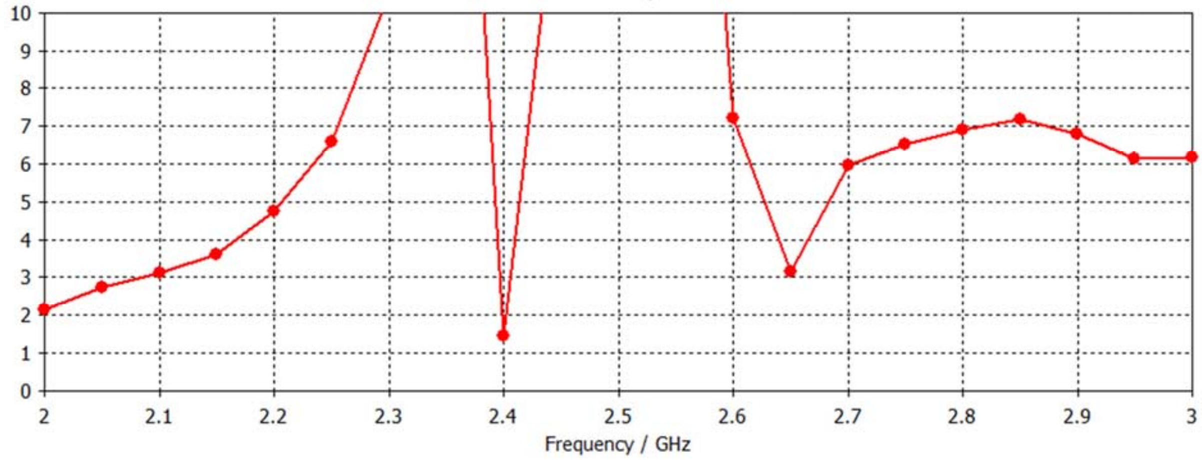


Figure 9. *Axial ratio vs. Frequency.*

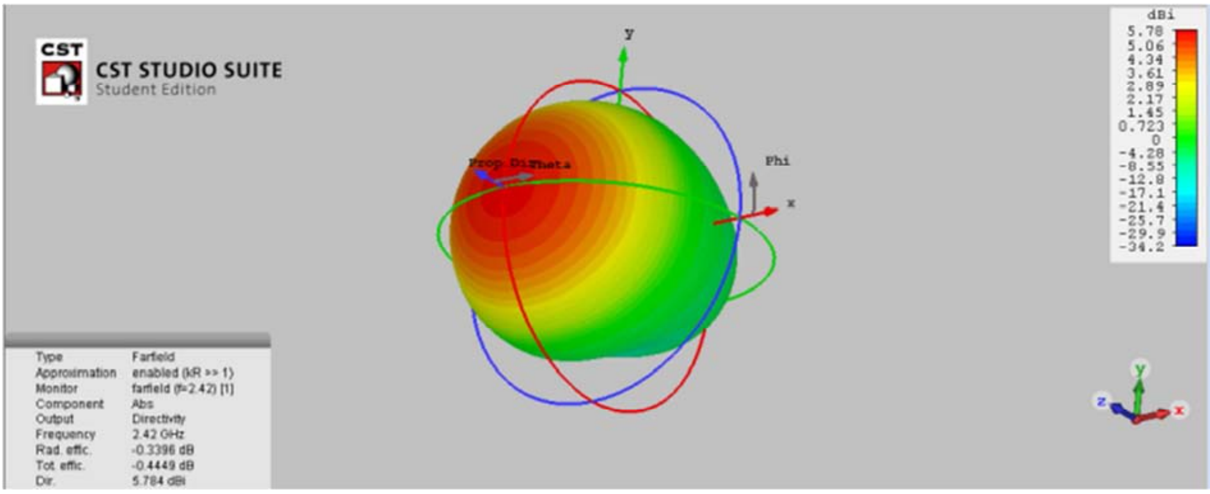


Figure 10. *3D far-field pattern at 2.42GHz.*

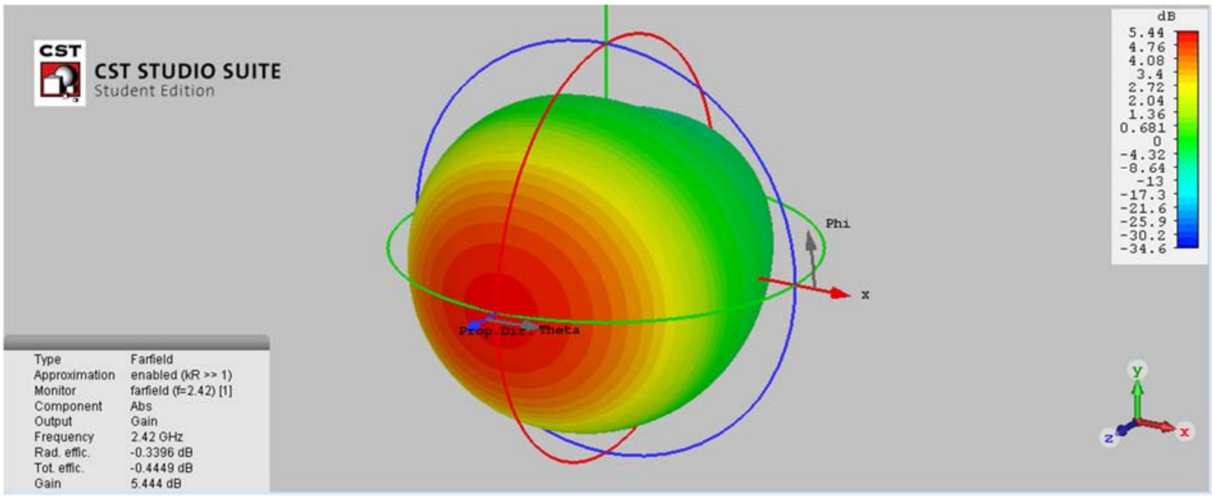


Figure 11. *3D gain pattern at 2.42GHz.*

4. Conclusions

The proposed frequency range at 2.42GHz and analysis Radiation Characteristics of microstrip patch antenna by CST STUDIO SUIT. The proposed antenna is designed on a FR-4 substrate with dielectric constant 4.4. At 2.42GHz resonant frequency the verify and tested result on CST Microwave Studio are Return loss = -16.207 dB, VSWR = 1.5, Directivity = 5.57dBi, Gain = 5.85 dB, Bandwidth = 160.24MHz (6.67 %) (at |S1,1| < -10dB and VSWR < 2), Efficiency= 96.34 % and Beamwidth at 3dB = 91.6°, all results shown in simulation results. Truncated corner in the patch cause circular polarization and return loss (S1, 1) is improved. Upper stack patch cause wide bandwidth is achieved. However, a good circular polarization at target resonant frequency is not achieved. The proposed antenna design is useful for wifi (2.40-2.48GHz) applications and CubeSat applications The future scope of work revolves around increasing the bandwidth up to (9%) increased frequency range between2300MHz-2500MHz and improving the axial ratio result closed to less than 3 dB in order to be a good circularly polarization by modifications in design of the proposed patch antenna. Detailed theoretical explanations can be derived to find out a best design with proper dimensions of proposed antenna.

Table 3. *Simulation Results Of The Proposed Microstrip Patch Antenna.*

Simulation Results			
Return loss		-16.207	dB
VSWR		1.5	
Directivity (D)		5.75	dBi
Gain (G)		5.54	dB
Radiation Efficiency	(η)	96.34	%
Bandwidth		160.24	MHz
		(2280MHz-2450MHz)	
		6.67	%
Polarization		CP	LHCP
Axial Ratio		1.52 dB	At 2.42GHz

Acknowledgements

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