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A Low-Cost and Dual band Microstrip Patch Antenna for Ku and K Band Applications

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Abstract. *This paper examines a dual-band, low-cost microstrip patch antenna for Ku and K applications through simulation study. Ansys High Frequency Structure Simulator (HFSS) software is used to do the simulation analysis of the suggested antenna. Using Ansys High Frequency Structure Simulator (HFSS) software, the suggested antenna is constructed and simulated to evaluate several characteristics including reflection coefficient (S11), radiation pattern, gain, and bandwidth. The substrate for the antenna is made of FR-4, which has a relative permittivity of 4.4 and a dielectric loss tangent of 0.02. Using the microstrip feed line technology, the planned millimeter wave dual band antenna is examined at operating frequencies of 13 and 22 GHz. At frequencies of 13 and 22, respectively, the antenna's maximum gain values are 4.81 dB and 4.82 dB in the x-y plane. The suggested material might be a decent substitute.*

Keywords*: Printed antenna, Dual band, Ku and K applications, millimeter wave antenna.*

1. INTRODUCTION

Rapid technological development in the field of telecommunications including wireless communication systems, mobile phones, satellites, radar applications (civil, military, aeronautics, maritime and meteorology…), etc. is noticeable. Wireless communication systems have developed enormously from the first generation 1G to the fifth generation (5G). The main characteristics and applications of 5G are detailed in, while the 5G services are described in. The fifth generation, also known as IMT-2020, will use the millimeter wave frequency band, specifically the 13 and 22 GHz frequency band because propagation losses at 13 and 22 GHz are not significant compared to other frequencies in the millimeter wave band. Antenna plays a very important and indispensable role in wireless communication system. The attributes such as ease in construction, compact in size, low fabrication cost etc make microstrip antennas appropriate for various applications such as mobile communications, radar applications, aircraft systems, etc. There are many commendatory characteristics of microstrip antennas; however these antennas suffer with the vital limitations of low gain and narrow bandwidth. To surmount these limitations, many designed antennas are proposed such as U-shaped slotted patch, triangular patch, circular patch, rectangular patch, irregular Diamond Edge Slotted patch etc. Furthermore, different substrate materials and different feeding techniques are also chosen to overcome those limitations. One of the propitious techniques to shoot up the antenna gain is to form array of antennas in such a way that the radiation from the individual antenna elements will add up and produce high gain. Researchers are ceaselessly working to improve the gain characteristics and have proposed various techniques to enhance the gain of the microstrip patch antennas. Copper and Silicon are known the best materials to be used as interconnects and semi-conducting devices. Among different types of patch antenna, the feed probe based rectangular patch antenna designing is much more efficient and easier to design. Moreover, the rectangular patch antenna can provide much more expected radiation patterns than others. The main drawback of microstrip antennas is their narrow bandwidth which results in high sensitivity to any frequency change and decreases the efficiency of their overall performance. Researchers in the past have prospected the design of antennas with various conducting media such as copper, graphene etc to increase the electrical characteristics. This paper furnishes the collation of various parameters like return loss, VSWR, radiation pattern, gain and band width of the rectangular patch antenna of the copper(cu)conducting media with the conventional patch antenna.

2. DESIGN OF ANTENNA

All the related works that have been done by other researchers that are related to the current research problem should be summarized in this section. Times New Roman font with size 10 must be used in this section. Sub topic should be written as given below: Numerous types of patch antennas have been studied and examined by several researchersdue to their excellent properties. The rectangular patch is the most extensively exercised configurations. Microstrip patch antenna contains a substrate over which a conductive patch is `deposited and a metallic conductor beneath the substrate to serve as a ground plane. The performance characteristics of the patch such as resonant frequency, gain, radiation and bandwidth depend on the patch dimensions, substrate type and feed. The effective permittivity of the substrate can be calculated using equation (1)while the patch dimension can be estimated using its required resonant frequency after a calculation from equations (2-5)with the assumption 'W' width being greater than substrate thickness 'h'.

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\frac{1}{\sqrt{1+\frac{12h}{W}}} \qquad \text{….. (1)}$$

$$W = \frac{\vartheta_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \qquad \text{….. (2)}$$

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{W}{h}+0.8)} \qquad \text{….. (3)}$$

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\mu_0\varepsilon_0}} - 2\Delta L \qquad \text{…. (4)}$$

$$L_{eff} = L + 2\Delta L \qquad \text{….. (5)}$$

A Characteristic impedance of 50 Ω is applied to the feed line. Figure. 1 below shows the antenna at operating frequency 12 GHz antenna used by HFSS software designed is shown in Figure 2.

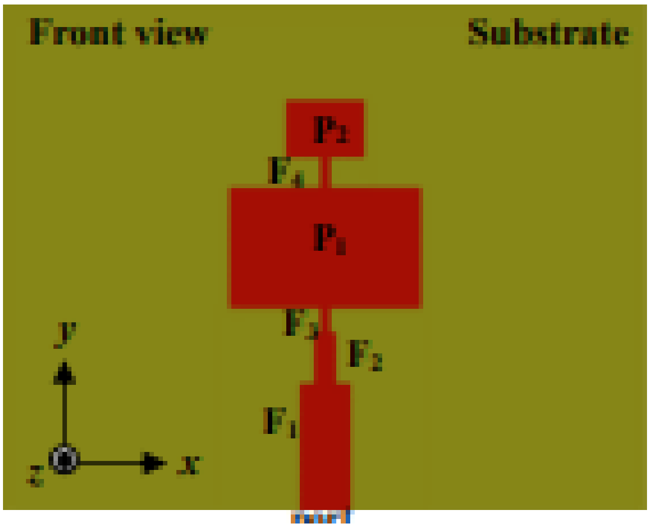


FIGURE 1. Front view

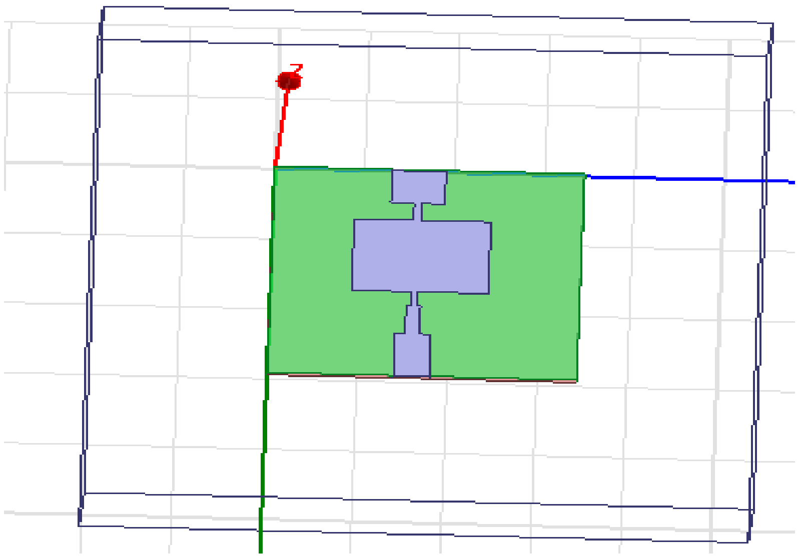


FIGURE 2. Designed Rectangular Patch Antenna Using HFSS

The conducting patch (5.1mm x 7.6mm) has been designed using copper material with FR-4 substrate (dielectric constant = 4.4 and loss tangent (δ) = 0.02) with dimensional size of 14.7mm x 17.2 mm and copper at its ground layer with the same dimensional size. The patch and its ground layer have a thickness of 1.6 mm while the substrate is 1.6mm thick. The patch is excited through a feed with the dimension of 34.7 mm x 37.2 mm x21.6 mm. The design parameters are tabulated in Table 1.

TABLE 1. Design Parameters

S. No	Parameter	Value
1	Operating Frequency	12GHz
2	Patch Length	5.1mm
3	Patch Width	7.6mm
4	Dielectric Material	FR-4
5	Substrate height	1.6mm
6	Dielectric Constant	4.4
7	Dielectric Loss Tangent	0.02

The Microstrip patch antenna is designed and simulated using Ansoft HFSS software. It isone of the antenna designing tools and it is a high performance full-wave electromagnetic (EM) field simulator for the 3D volumetric passive device. The design and analysis of the rectangular micro strip antenna is designed at a frequency range of 12GHz. Performance of the antenna has been analyzed through Voltage Standing Wave Ratio, Return loss (or reflection coefficient), Radiation Pattern and Antenna Gain. For the acceptable range, it has been noticed that the value of return loss should be less than -10 dB [19]. In the simulation work, frequency results are observed to record the resonant mode. The simulated conventional copper patch antenna has shown up a reflectioncoefficient (S11) of -20.3 dB at 13.4 GHz and -44.3 dB at 22.9 GHz. The VSWR is found to be 1.32 at 13.4 GHz and 1.00 at 22.9 GHz. The S11 for the antennas at the operating frequencies is shown in Figure 3. Also the VSWR for the antennas at the operating frequencies is shown in Figure 4.From the S11 plot, the bandwidth of the copper antenna is observed to be 0.9 GHz (13.00-13.09 GHz) and 3.8GHz(20.7-23.89).

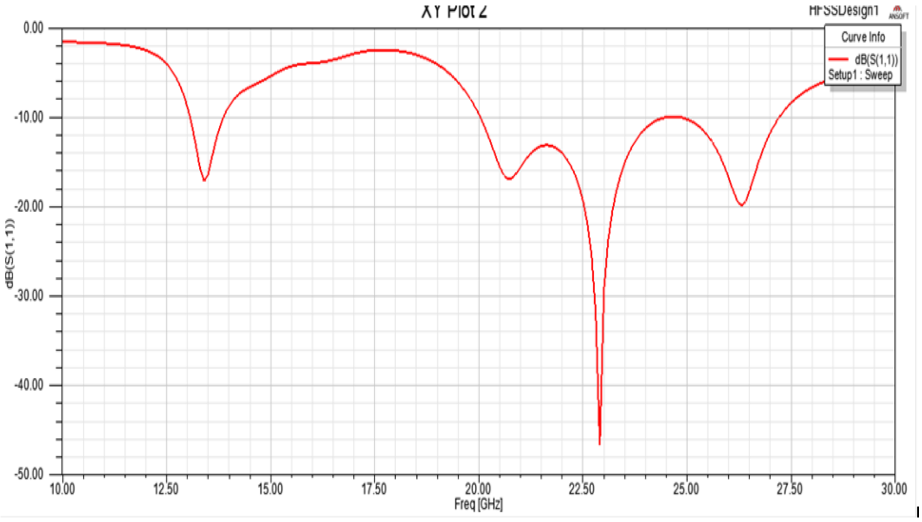


FIGURE 3. of S11 for the Antennas

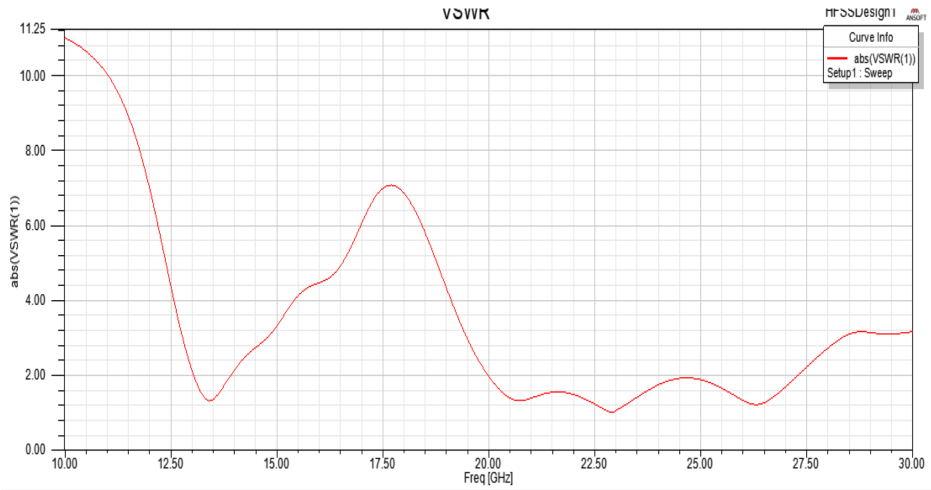


FIGURE 4. VSWR for the Antennas

The gain of the patch antennas are illustrated from the 3D polar plots. The 3D polar plots for the rectangular microstrip patch antenna at 13.4 and 22.9 GHz are is shown in the Figures 5 & 6 respectively, revealing a maximum gain of 4.81 dB obtained at 13.4 GHz and 4.82dB obtained at 22.9 GHz.

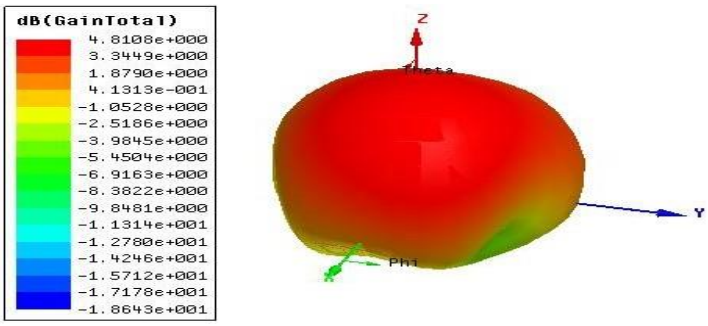


FIGURE 5. 3D Polar Plot of Cu Antenna at 13.4GHz

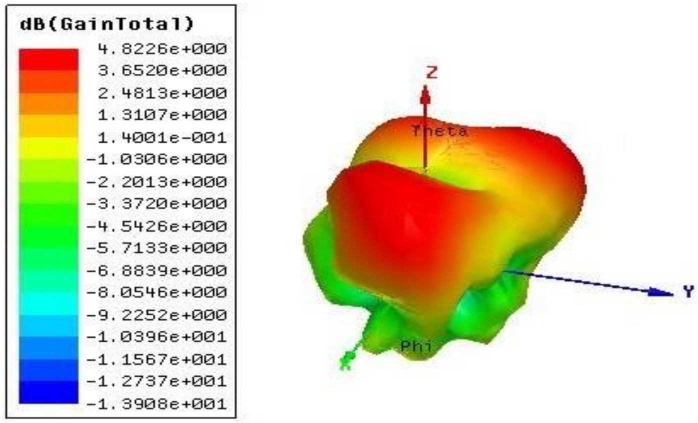
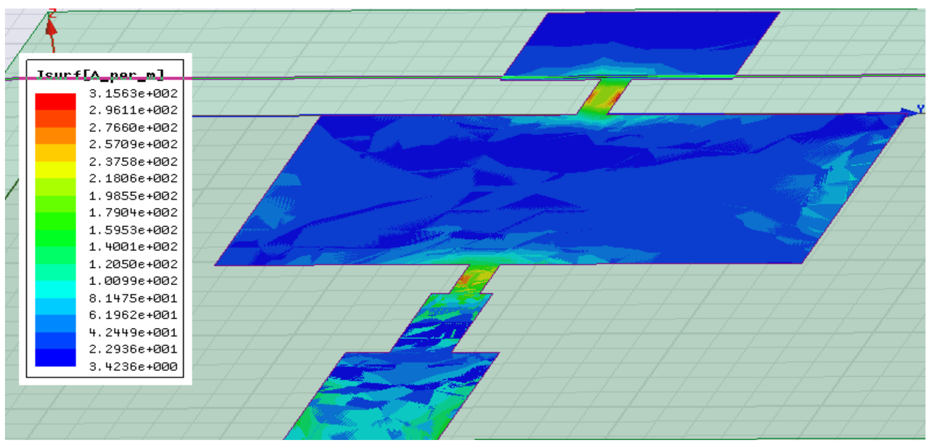
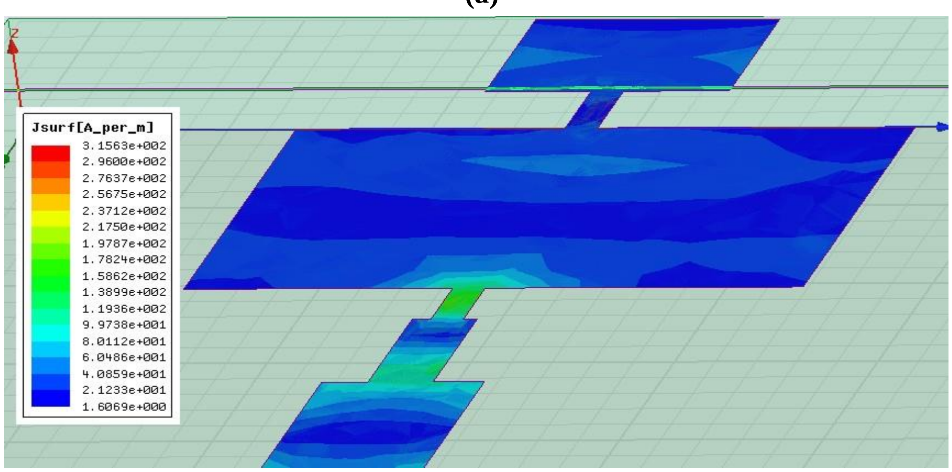


FIGURE 6. 3D Polar Plot of Cu Antenna at 22.9 GHz

The surface current distribution of the copper antenna at 13.4 and 22.9 GHz is shown in the Figures 7(a) and (b). It is evident that a strong surface current intensity is visible in the feed line and in the inside patches of the antenna. The maximum surface current is observed to be 3.15 A/m at 13.4 GHz and at 22.9 GHz the maximum is 3.156 A/m.



(a)



(b)

From the Figures7 (a) and (b) which shows the surface current distribution of copper antenna at 13.4 and 22.9 GHz respectively, it is clearly noticeable that the surface current intensity is strong in the feedlines and also a considerable distribution in the inner and outer patches. It can be visualized clearly observing the Fig.7 The far field radiation patterns of microstrip patch antenna and patch antennas at both 13.4GHz and 22.9GHz are analyzed for assessment of gain in various directions. Radiations patterns in both electric plane (E-Plane) and magnetic plane (H-Plane) are studied. The co and cross polarizations are depicted in the radiation patterns. From the figures it is evident that the co-polar patterns are widesided and linearly polarized. The co-polar radiation pattern in E-plane at 13.4 GHz for the Cu antenna pattern. At 22.9 GHz the pattern for the antennas in E-plane and H-plane are almost Omni-directional. This can be a discribed to the presence of the nano film which suppresses the maximum back radiations compared to the rectangular microstrip patch antenna, which in turn intensifies the beam and hence enhances the radiation patterns. Figures 8 to 9 shows the radiation patterns of Cu antennas at 13.4 and 22.9 GHz

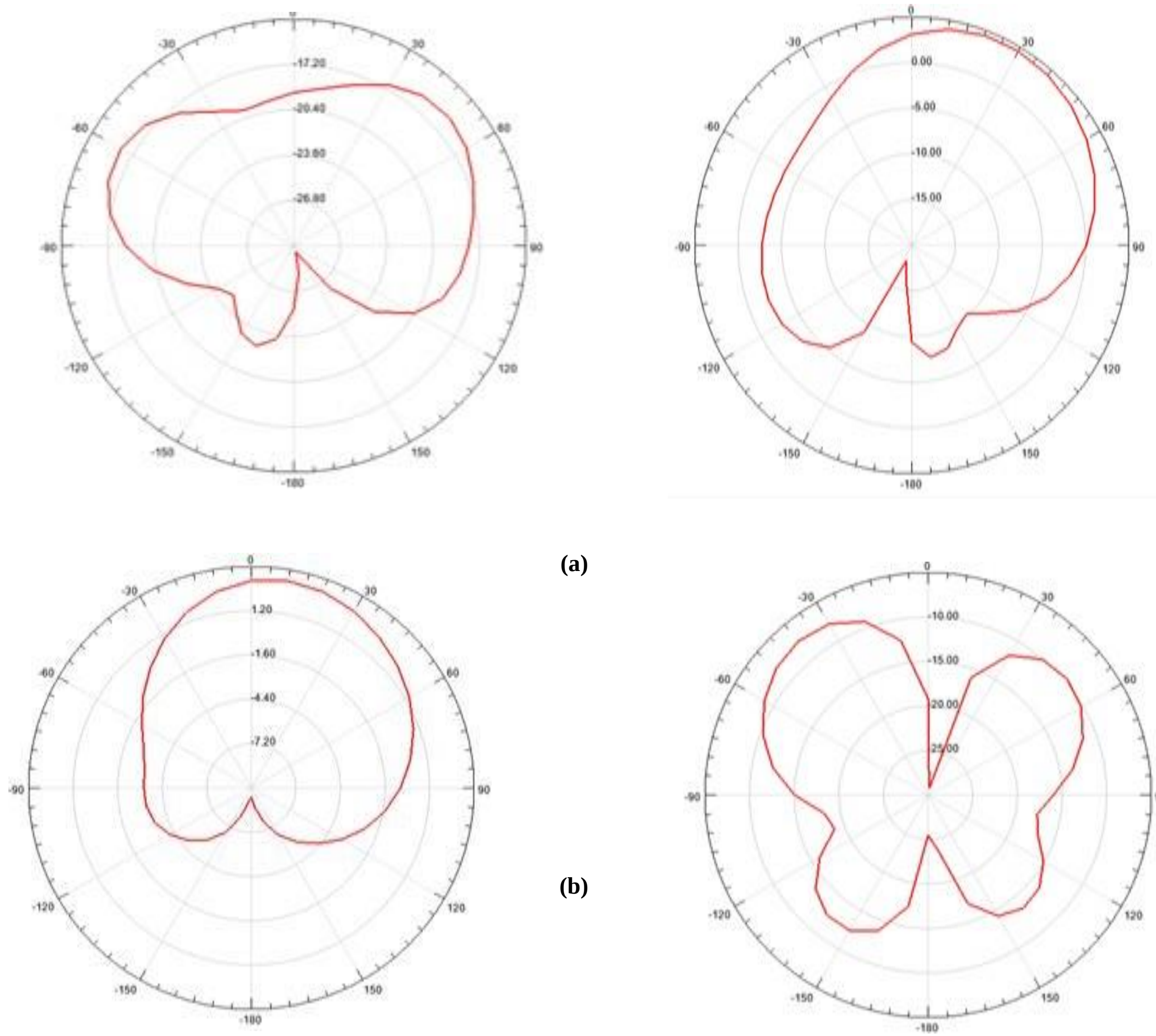
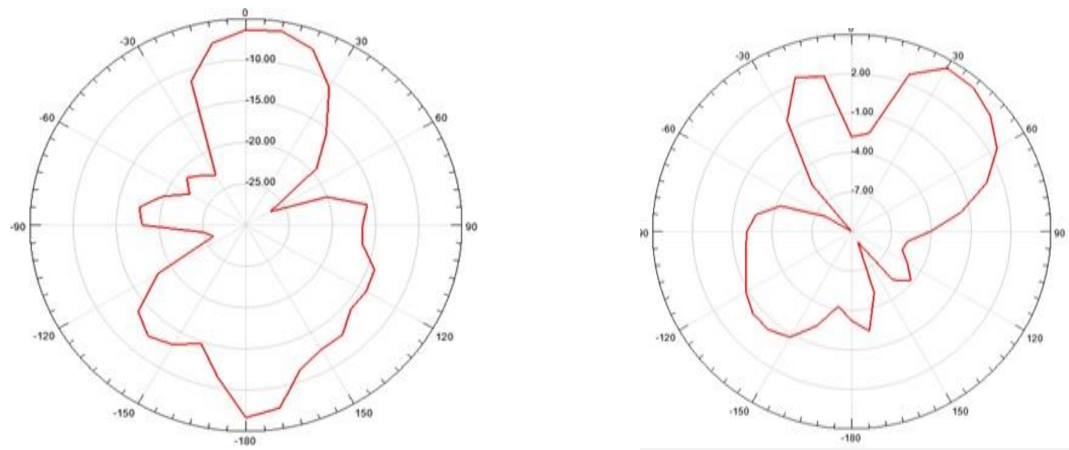
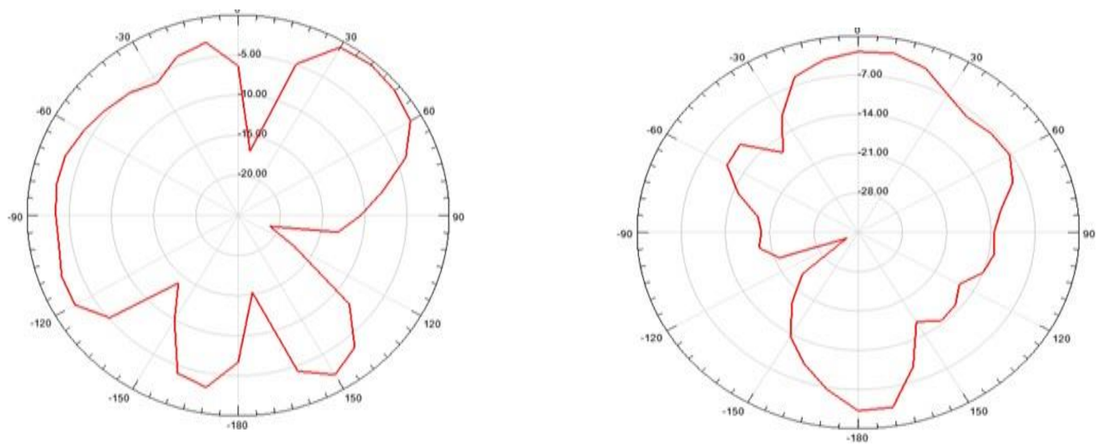


FIGURE 8. Radiation patterns of Cu antenna at 13.4. GHz (a) E-Plane. (b) H- Plane



(a)



(b)

FIGURE 9. Radiation patterns of Cu antenna at 22.9. GHz (a) E-Plane. (b) H-Plane.

The various parameters that were analyzed are tabulated in the Table II.

TABLE 2. Comparison of Parameters

Antenna	**Operating Freq(GHz)**	**ReasonanceFreq (GHz)**	**S11 (dB)**	**VSWR**	**Gain(dB)**	**Band widt (GHz)**
sCopper	12	13.4	-20.	1.32	4.81	0.9
		22.9	-44.	1.00	4.82	3.8

3. CONCLUSIONS

This work demonstrated the capabilities of a copper-conducting dual band antenna. These parameters have also been created and tested using simulations at operating frequencies of 13 and 22 GHz. The antenna and the simulated input antenna reflection coefficient agree well at 13 and 22 GHz. Maximum gain values at 13 and 22 GHz are 4.81 dB and 4.82 dB, respectively. Ku and K band applications are well suited for the suggested antenna.

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