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Design and Simulation of Rectangular Microstrip Patch Antenna with Triple Slot for X Band

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Abstract: In the present work an attempt has been made to design and simulation of rectangular microstrip patch antenna with triple slot for X band using microstrip feed line techniques. HFSS High frequency simulator is used to analyse the proposed antenna and simulated the result on the return loss, radiation pattern and gain of the proposed antenna. The antenna is able to achieve in the range of 8-12 GHz for return loss of less than -10 dB. The operating frequency of the proposed antenna is 8.4 GHz & 11 GHz with dielectric substrate, ARLON of ε_r = 2.5 and h= 1.6mm.
Keywords: ARLON substrate material, FEM, Microstrip Feed Line, X band

I. INTRODUCTION

In recent times, microstrip patch antenna is a turning point in wireless communication system and is continuing to satisfy the changing demands of new generation antenna technology. Wireless communications are moderately improving and creating modernize wants in case of antenna technology. It also covers an expansive of cellular phones in the modernize society included in growing interest connecting its detrimental radiation [1-4]. Microstrip patch antennas are broadly utilized in the current wireless communication system because of their regular facilities of less profile, less weight, consistent design; low cost, easy to fabricate and integrate. Patch is the main component of microstrip antenna and other components are substrate and ground which are two sides of patch [5]. The major disadvantages of microstrip patch antenna are narrow bandwidth, low efficiency and small size [6]. Various researches have been executed to enhance the bandwidth of printed antennas. To conquer this trouble numerous methods and techniques are raised in the literature.

The miniaturization of antenna and improvement in bandwidth can be obtained by adjusting to cut the slot in ground and patch of microstrip antenna of proper length and width [7-9]. X band technology has been broadly used in various applications because of its high data transmission rate, large bandwidth and short-range features. Designing X band antennas has tempted the interest of many researchers and is still a major challenge to equalize these applications [9-10]. An antenna of wide-slot belonging to a microstrip line is designed using a fork-like tuning stub to increase the bandwidth in ref. [11]. Bandwidth of 1.1 GHz has been achieved with gain changing below 1.5 dBi over the complete operational frequency bands.

In this research, both gain and bandwidth were low. A wide-band rectangular patch antenna with a single layer was proposed where impedance bandwidth of above 20% was acquired in ref. [12]. A rotated slotted antenna was proposed for enhancing bandwidth printed on FR4 substrate material in ref. [13].

This antenna exhibited bandwidth of about 2.2 GHz as well as gain changing below 2 dBi. On the other hand, the dimension of this antenna was 70 mm × 70 mm that was too large. A CPW-fed loop slot antenna with a tuning stub was used to amplify the bandwidth where 72 mm × 72 mm was the dimension of the antenna and the range of the gain was from 3.75 dBi to 4.88 dBi over the desired operational frequency band in ref. [14]. Due to consideration the position of a widened tuning stub, a flourished bandwidth was acquired. By using these bandwidth enhancement techniques, the CPW-fed slotted antennas showed 34% to 60% impedance bandwidth. Two E-shaped slot antennas were designed with using microstrip line and CPW as feeding transmission line for broadband applications in ref. [15]. The dimension of the antenna was 85 mm ×85 mm with reasonable radiation pattern and improved bandwidth. The size of this antenna is large that was the weak point.

This paper shows the reaction on microstrip antenna parameters and desired resonances owing to rectangular patch to design the proposed X Band microstrip antenna with flourished efficiency and bandwidth. Some methods are used such as increasing substrate thickness and triple slot on patch to obtain a desired parameters such as impedance matching, gain, radiation pattern, return loss and efficiency.

II. MATERIALS AND METHOD

A. Analysis Methods

The first part is to study Theoretical Pattern effect of Microstrip Patch Antenna. The second is analyzing the antenna using HFSS software and obtaining the simulation result. The substrate material will be used ARLON with dielectric constant 2.5 , feeding will be used as microstrip line feed technique and for analyzing and designing of the proposed work is on the HFSS (High Frequency Structure Simulator) simulator.

B. Antenna Design

First we should fix the operating frequency (X band 8-12 GHz), then calculate effective dielectric constant.

$$\epsilon_e = \frac{1(\epsilon_r + 1)}{2} + \frac{1(\epsilon_r + 1)}{2}\sqrt{\left(1 + 10\frac{h}{w}\right)}$$

When, $\frac{h}{w} \ll 1$

Step 3:- Use the resonant frequency formulae for dimension. The resonant frequency is chosen at 10 GHz.

$$f_r = \frac{c}{2\sqrt{\epsilon_r}}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$

For dominant mode duration TE_{10}mode.

m = 1 n = 0

$$f_r = \frac{c}{2\sqrt{\epsilon_{re}}} * \frac{1}{a}$$

Where ‘a’ is the width of antenna.

Now we calculate effective length.

$$L = \frac{c}{2f_o\sqrt{\epsilon_r}} - 2\Delta L$$

$$\Delta L = 0.412h\frac{(\epsilon_e + 0.3)\left[\frac{w}{h} + 0.8\right]}{(\epsilon_e - 0.258)\left[\frac{w}{h} + 0.8\right]}$$

Microstrip feed width calculation.

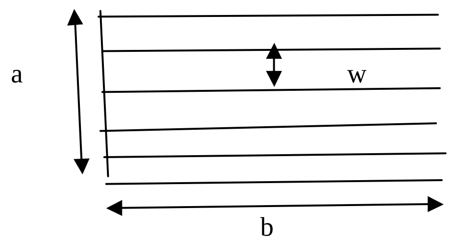
$$w = \frac{\dfrac{5.98*h}{e^{\left(Z_0*\frac{\sqrt{\varepsilon_r+1.414}}{87}\right)}} - t}{0.8}$$

Where Z_o= characteristics impedance

w = width of microstrip line

t = thickness of metal

h = height of substrate



The design is formed by using the equations in software environment for analysis. Electromagnetic frequency domain was used to form the design with 8.4 GHz & 11 GHz frequency which was applied on the lumped port. The study of design was done.

C. Design Procedure

First we take a sheet with which we make a ground. Second we select the substrate which is Arlon and give it the required dimension and placed above the ground. Then we would set the position of microstrip line feed to be input and also make a port. After the above step we add three slots on the surface of the patch and unite it to the cut it off the patch. We set the solution frequency as 8.4 GHz & 11 GHz. After the final analysing of the project to recheck for the presence of errors, we run the project and find out the results in six variables quantities:

1) Return loss
2) Radiation Pattern
3) Antenna gain
4) 3D Polar gain
5) VSWR
6) Directivity

The dielectric material of the microstrip patch antenna is Arlon and the dielectric constant is ε_r = 2.5. The frequency of the operation: The frequency of operation for the patch antenna design has been selected as 8.4 GHz & 11 GHz. Microstrip patch antenna has been designed in order to rule out the conventional antenna as the patch antennas are used in most of the compact devices. Therefore the height of the antenna is limited to 1.6 mm.

In this proposed work we are using **Microstrip (Offset Microstrip) Line Feed**, in this type of feed technique, a conducting strip is connected directly to the edge of the microstrip patch as shown in figure 1. The conducting strip is smaller in width as compared to the patch. This kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure. An inset cut can be incorporated into the patch in order to obtain good impedance matching without the need for any additional matching element. This is achieved by properly controlling the inset position.

Hence this is an easy feeding technique, since it provides ease of fabrication and simplicity in modelling as well as impedance matching. However as the thickness of the dielectric substrate increases, surface waves and spurious feed radiation also increases, which hampers the bandwidth of the antenna. This type of feeding technique results in undesirable cross polarization effects. Figure 1 shows the arrangement of microstrip line feeding technique and the elementary geometry of the proposed rectangular microstrip patch with triple slot is designed and simulated for X band applications. And the triple slot on patch makes it good for X band applications.

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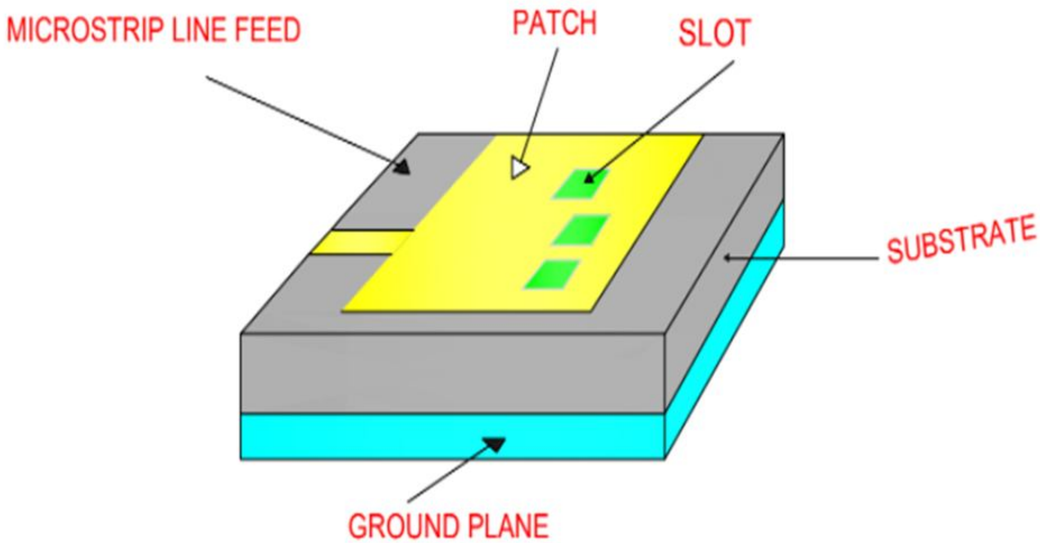

Figure 1 shows the proposed antenna with offset microstrip line feeding.

D. Antenna Parameters Table

Antenna Design Parameter	Values
Ground Material Length of Ground Width of Ground Position of Ground	Copper 24.88 mm 19.8 mm (0,0,0)
Substrate Material Substrate thickness "h" Length of Substrate Width of Substrate Position of Substrate Dielectric Constant	Arlon 1.6 m 24.88 mm 19.8 mm (0,0,0) 2.5
Patch Material Length of Patch Width of Patch Position of Patch	Copper 16 mm 14 mm (0, 3.25, 1.6)
Material of Feed Length of Feed Width of Feed Position of Feed	Copper 3.25 3.25 (8.275, 0, 1.6)
Material of Port Length of Port Height of Port Position of Port	Copper 8 1.6 (6, 0, 0)
Material of Slot 1 Dimension of Slot 1 Position of Slot 1	Copper 1 mm, 2 mm (x, y) (10, 11, 16)
Material of Slot 2 Dimension of Slot 2 Position of Slot 2	Copper 1 mm, 2 mm (x, y) (2, 10, 16)
Material of Slot 3 Dimension of Slot 3 Position of Slot 3	Copper 1 mm, 2 mm (x, y) (7, 11, 16)

Table shows the parameters of proposed antenna.

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III. DISCUSSION OF RESULT

The simulation results are made using High Frequency Structure Simulator (HFSS), with the finite element method (FEM). The return loss of rectangular microstrip patch antenna has a simulated frequency range of 8 to 12 GHz for S11 <-10 dB. The simulated Return loss of the proposed antenna is shown in Figure 2. Return loss of -38.62 dB & -26.19 dB are obtained at resonant frequency 11GHz & 8.4 GHz. Increasing negative values of return loss implies good impedance matching with respect reference impedance of 50 ohms. Return Loss can be further improved by using different feeding techniques. We get 463 MHz bandwidth on the operating band. This bandwidth covers X band frequencies. The Gain of the proposed antenna is shown in Figure 4. Gain 7.40 dB & 5.17 dB is obtained in the operating frequency band of 11 GHz & 8.4 GHz shows the antenna efficiency too and we can make out that the antenna is averagely efficient at this particular resonant frequency, which as shown in figure 4. The radiation efficiency is 98.63% & 95.15% in the proposed antenna.

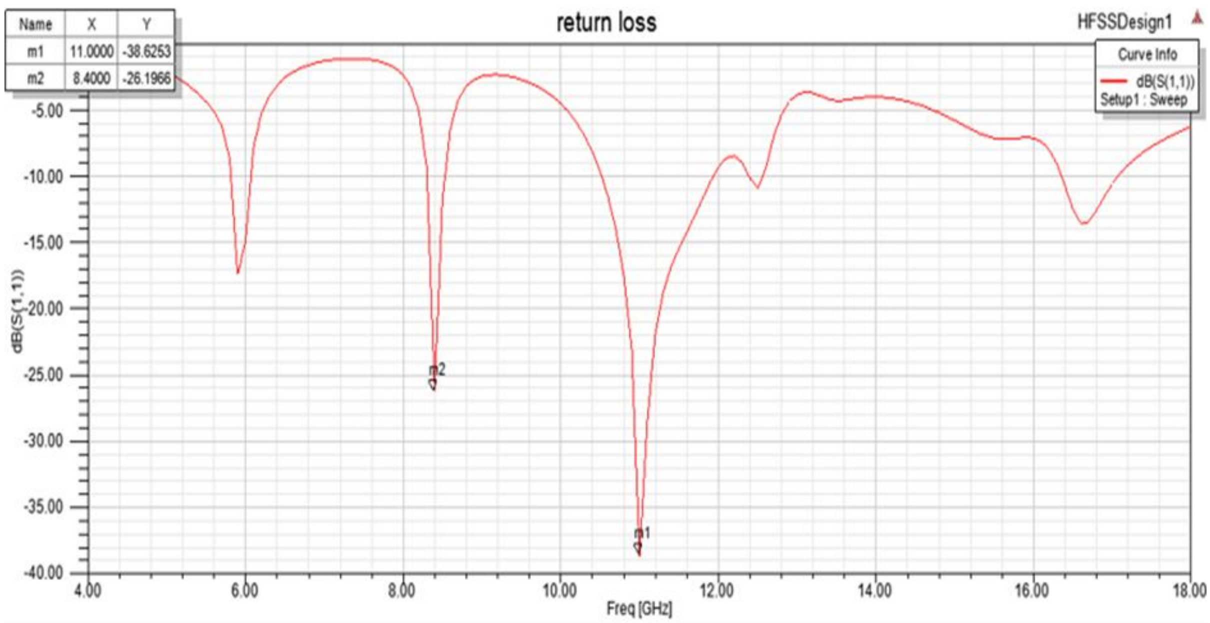


Figure 2 shows S11 return loss of the proposed antenna

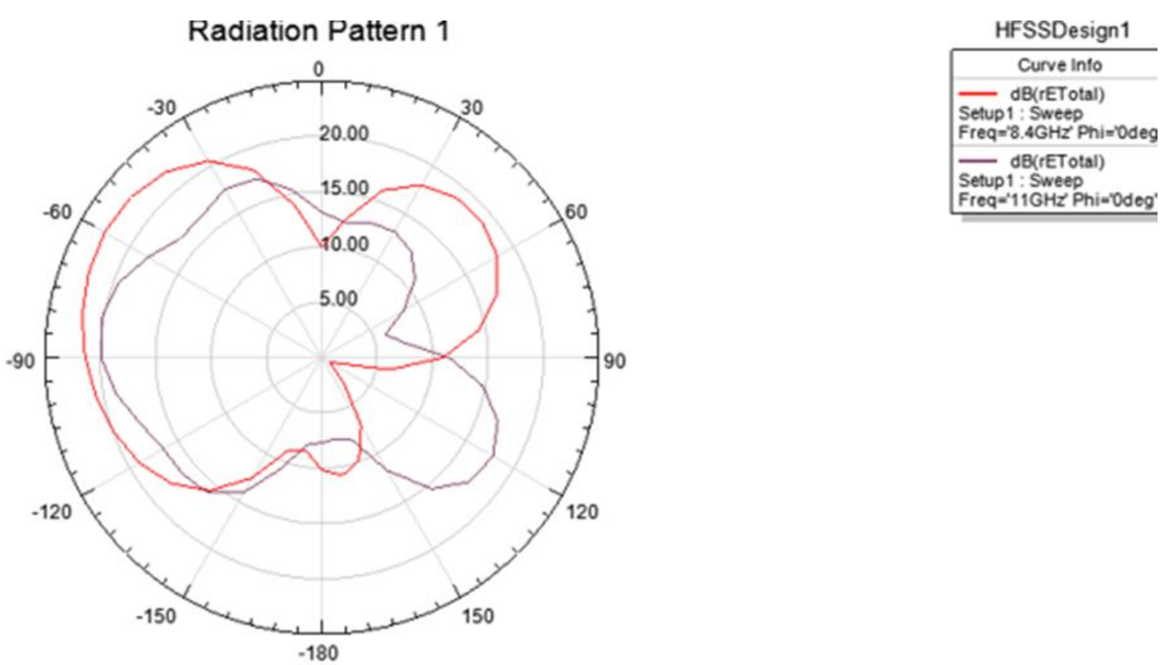
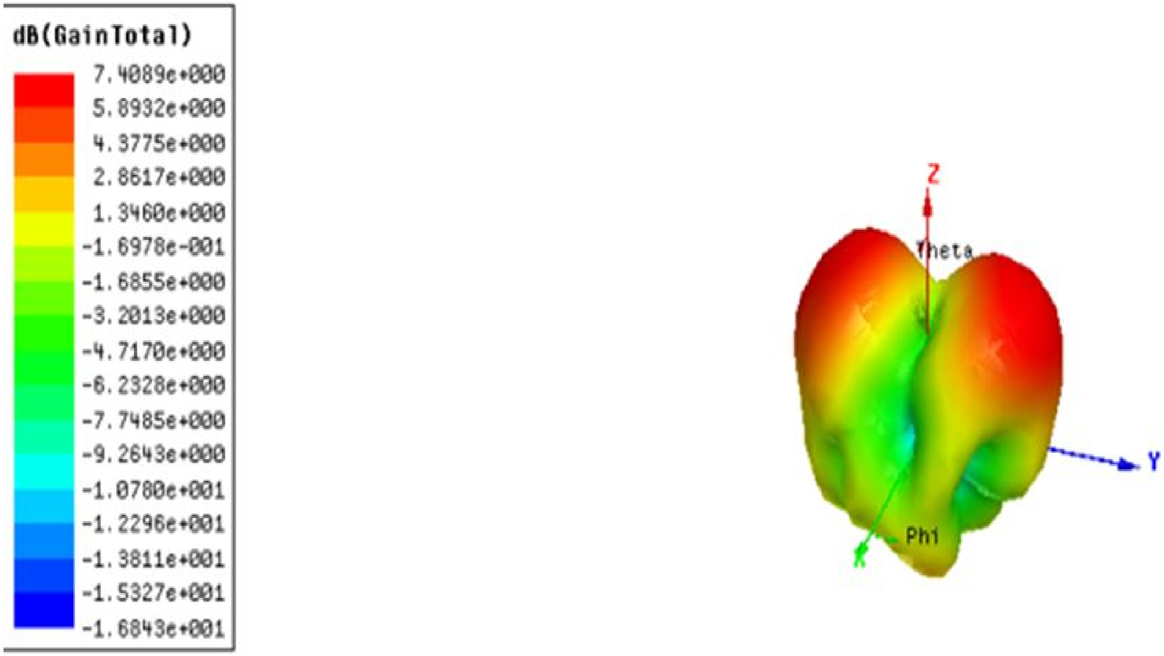


Figure 3 shows the radiation pattern of the proposed antenna.

The 3D radiation pattern was observed as shown in figure 3. This is a 2D radiation pattern for the elevation and azimuthal plane respectively. Radiation Pattern is a graphical representation of the radiation properties of the antenna as a function of space. Radiation Pattern describes the pattern of energy radiated into the space.



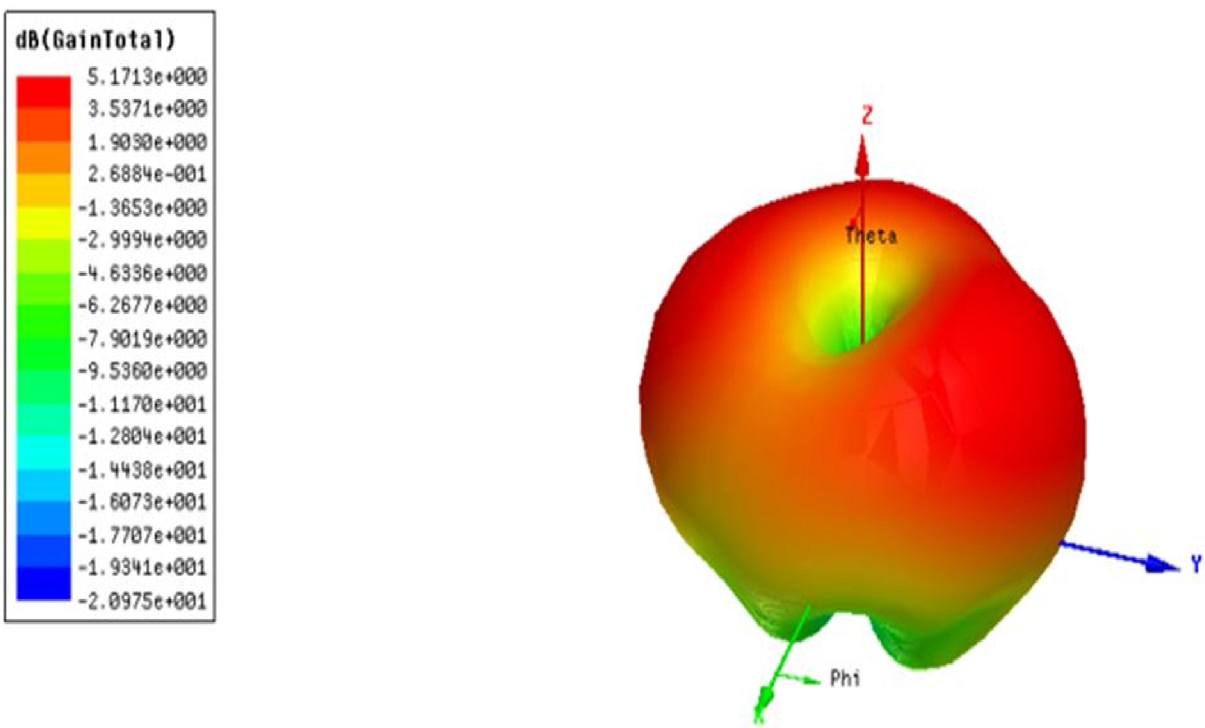


Figure 4 shows total gain of the proposed antenna.

The 3D Polar Plot was observed as shown in figure 4, which shows the radiation pattern in all the three planes. Gain in the broadside direction can be found out observing the 3D polar plot which will be against theta and phi.

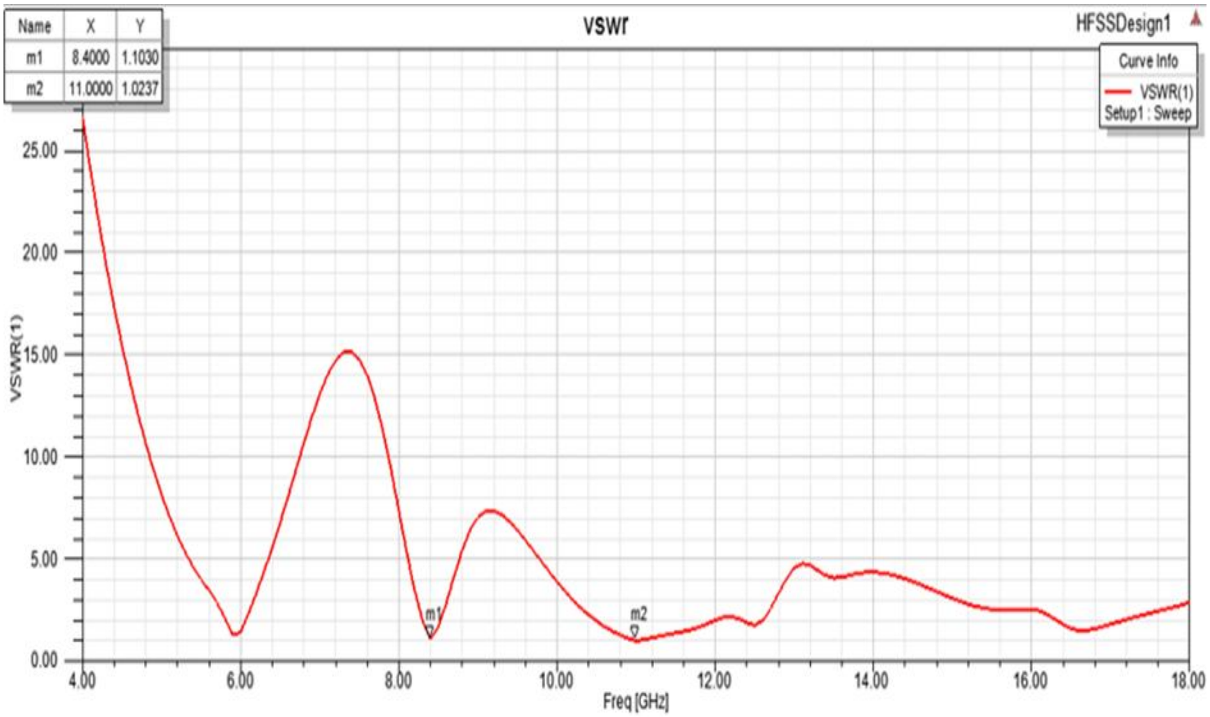


Figure 5 shows VSWR of the proposed antenna.

Figure 5 shows the voltage standing wave ratio (VSWR) of the proposed X-band antenna. The evaluation of VSWR is below 2 that are noticed from the graph clearly. It is observed that the value of VSWR at 11 GHz & 8.4 GHz was < 2 i.e., 1.10 & 1.02 as shown in figure 5. It is a wanted value. VSWR value implies the impedance matching between the source and the feed is good which is an essential requirement for the proper working of the antenna.

IV. CONCLUSIONS

The proposed rectangular microstrip patch antenna with triple slot for X band with microstrip feeding technique show a good broad bandwidth of 463 MHz. It also shows a high reflection coefficient of -38.62 dB & -26.19 dB with the substrate height of 1.6 mm. This is validating in all the designed form of the different structure of the antenna. The broadening of the antenna is obtained by the proper impedance matching by microstrip feeding at the source point of the antenna. This good bandwidth and high return loss might be convenient for many wireless applications. The simple antenna would find considerable for good wide band wireless application. The outcome parameters of microstrip patch antenna design is simple and its performances have fulfilled the requirement set by X band communication. For further studies on this rectangular patch, different substrate with different dielectric constants can be used to enhance the results. We can also vary the height of the substrate to achieve better gain of the circular shaped microstrip patch antenna.

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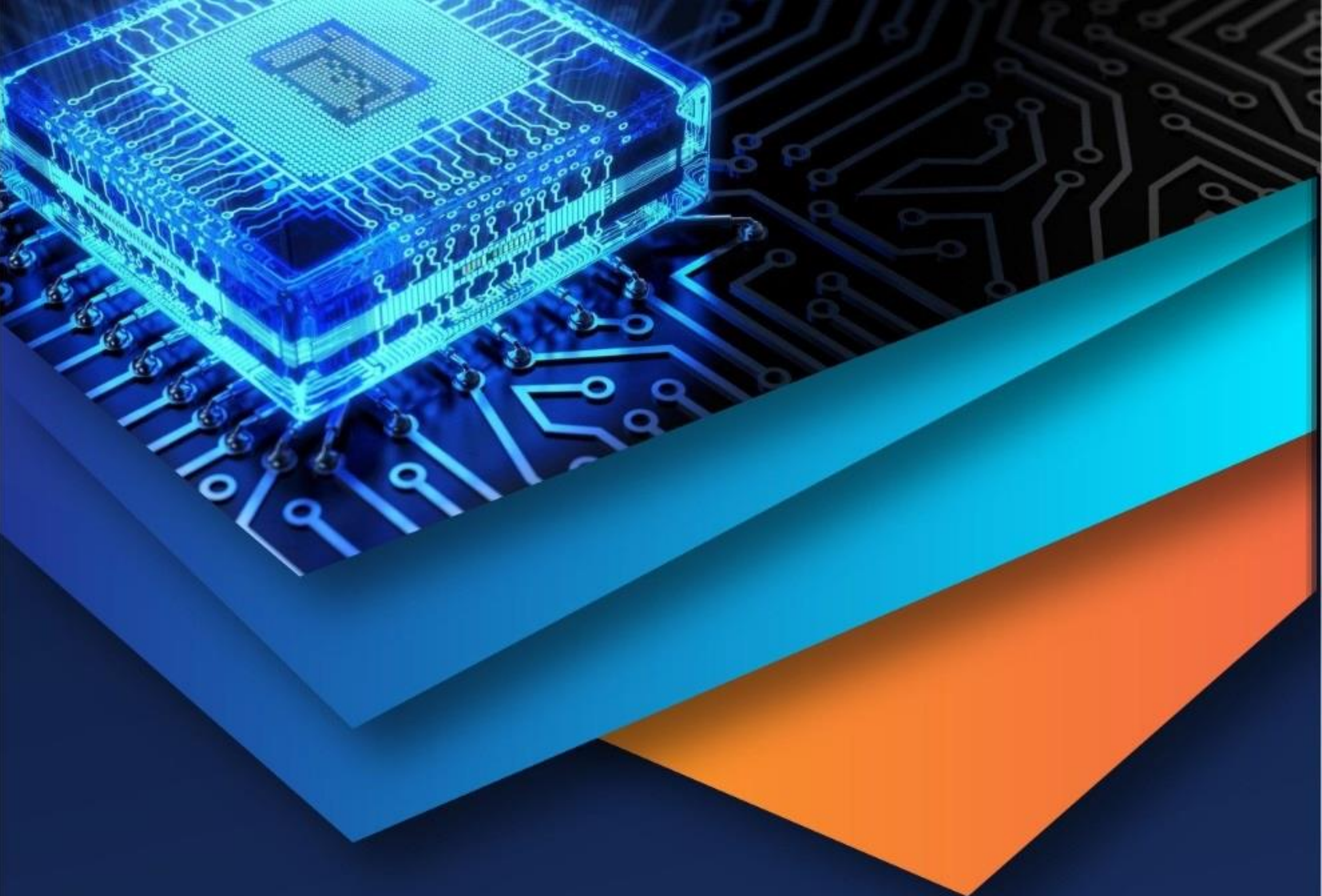

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