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Design of Micro strip Antenna in ISM Band with Polarization Diversity and Frequency Agility

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Abstract: **In the modern world especially during the last two decades, Wireless communications has been developed widely and rapidly. In future, development in personal communication devices will provide image, speech and data communications at any time, and anywhere around the world. It shows that the future communication terminal antennas must meet the requirements of multi-band or wideband operations to cover the frequency band of operation. Frequency agile antennas in ISM band (2.4-2.4835) GHz that support diversity polarization provides excellent performance for applications including multifunction radar, space-based platforms, wireless communications, and personal electronic devices. To reduce the transmission losses, matching in polarization in both the transmitter and receiver antennas is very much important. In this paper we will design two microstrip antenna one with linearly polarized and other with circularly polarized in 2.4 GHz ISM band with frequency agility in 2.4-2.4835 GHz. In both the design single feeding is used. This paper presents a new design for a linearly polarized antenna based on rectangular microstrip patch. Circular polarization is generated by truncating two opposite edges from a rectangular patch antenna. The truncation splits the field with equal magnitude and 90° phase shift into two orthogonal modes. Both the antennas are simulated with high frequency simulating software (HFSS)**.

Keywords: **Micro strip Patch, Coaxial Feed, Gain, VSWR, Radiation, S Parameter, Polarization, ISM Band, HFSS.**

I. INTRODUCTION

In wireless communication system, transmitting antenna gain is increased for increasing the wireless coverage range, decreases errors, increases achievable bit rates and decreases the battery consumption of wireless communication devices. This gain is increased for matching the polarization of the transmitting and receiving antenna. To achieve this polarization matching the transmitter and the receiver should have the same axial ratio, spatial orientation and the same sense of polarization. This paper is concerned with the design of two Microstrip Antenna in ISM band (2.4-2.4835) GHz one with linear polarization and other with circular polarization. In both the designs, the antennas can be design with any frequency as centre frequency in the given ISM band.

The industrial, scientific and medical (ISM) radio bands are radio bands (portions of the radio spectrum) reserved internationally for the use of radio frequency (RF) energy industrial, scientific and medical purposes other than telecommunications. The 2.4 GHz ISM band is used for many applications like for Wi-Fi family of standards (802.11 a,), cordless phones, wireless medical telemetry equipments and Bluetooth short range wireless applications.

With the low bandwidth, the applications of Microstrip patch designs are limited. Other drawbacks of patch antennas including low efficiency, limited power capacity, spurious feed radiation, poor polarization purity, narrow bandwidth, and

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manufacturing tolerance problems. For over two decades, research scientists have developed several methods to increase the bandwidth and low frequency ratio of a patch antenna. In this paper by designing two antenna most of the drawbacks of Microstrip patch Antenna has been overcomed

II. BASIC CHARACTERISTICS

A. Geometry: In its most fundamental form, a Microstrip Patch Antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown in Figure 1. The patch is generally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate.

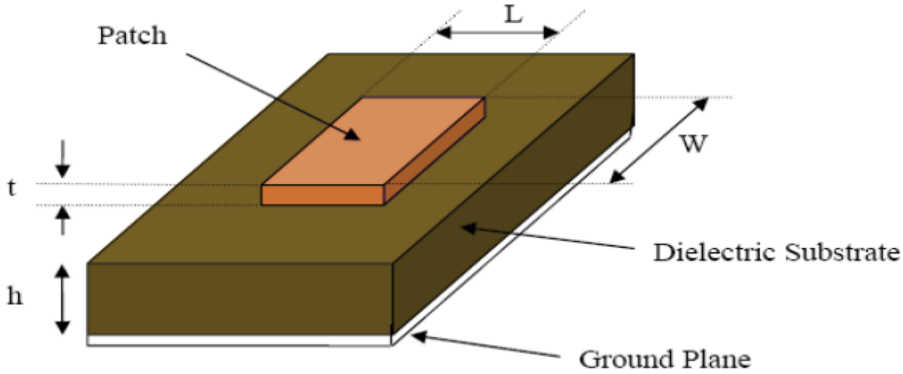

Fig 1 Structure of a microstrip patch antenna [1]

A Microstrip Antenna consists of conducting patch on a ground plane separated by dielectric substrate.

In order to simplify analysis and performance prediction, the patch is generally square, rectangular, circular, triangular, and elliptical or some other common shape as shown in figure 2. For a rectangular patch, the length L of the patch is usually $0.3333\lambda o < L < 0.5\ \lambda o$, where λo is the free-space wavelength. The patch is selected to be very thin such that $t << \lambda o$ (where t is the patch thickness). The height h of the dielectric substrate is usually $0.003\ \lambda o \leq h \leq 0.05\ \lambda o$. The dielectric constant of the substrate (εr) is typically in the range $2.2 \leq \varepsilon r \leq 12$.

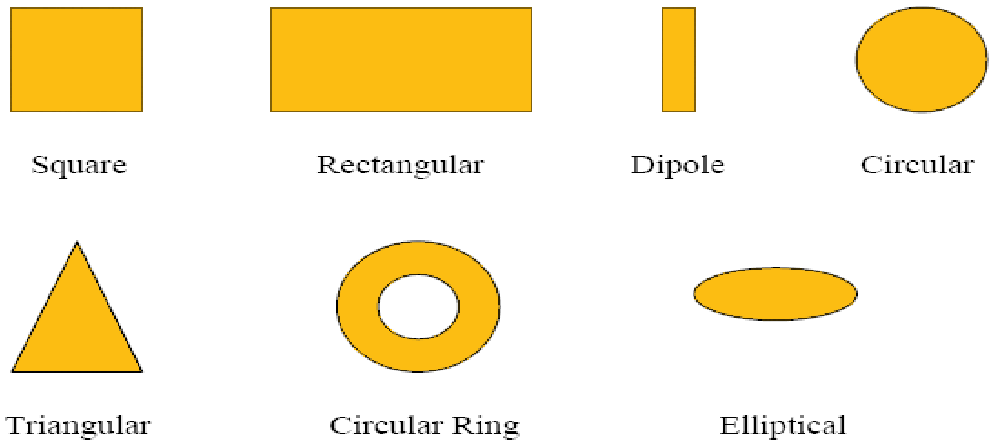

Fig 2 Common shapes of microstrip patch elements [1]

B. Feeding Technique: The four most popular feed techniques used are the microstrip line, coaxial probe (both contacting schemes), aperture coupling and proximity coupling (both non-contacting schemes). Here we use coaxial feeding for simplicity.

Coaxial Feed: The Coaxial feed or probe feed is a very common technique used for feeding Microstrip patch antennas. As seen from Figure 3 , the inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane.

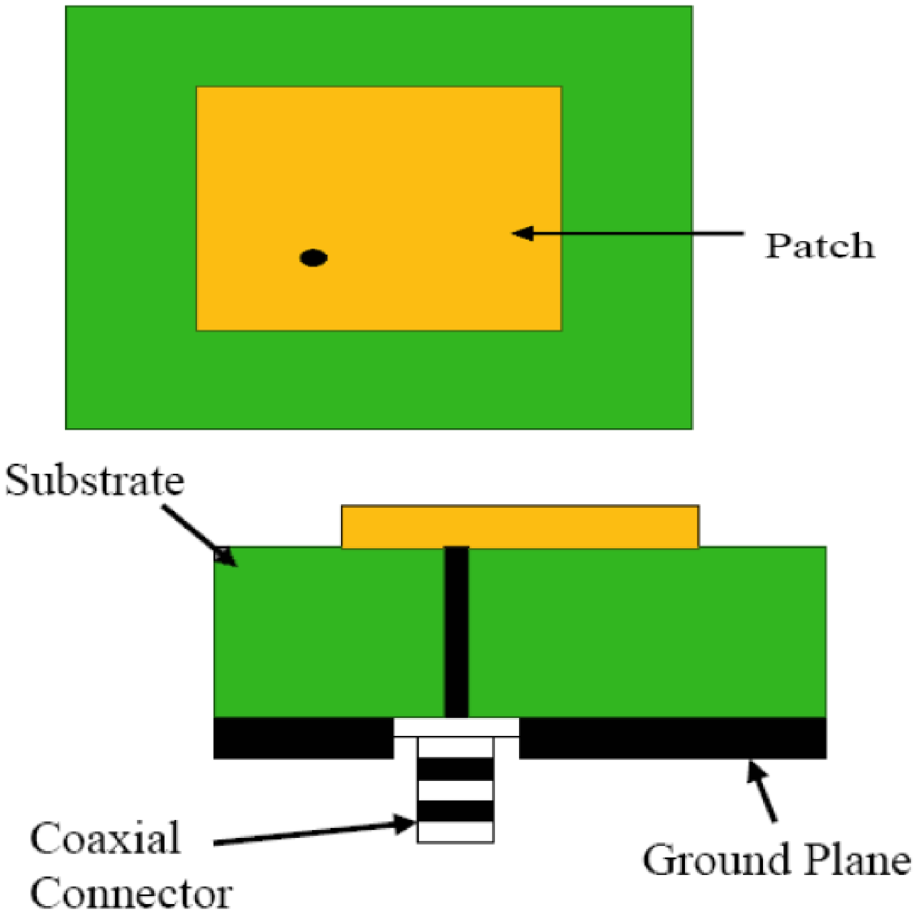

Fig 3. Probe fed Rectangular Microstrip Patch Antenna [1]

C. Equations for calculations of Designing Parameters:

The expression for εreff is given in [1] as:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \qquad \text{-------(1)}$$

Where *εreff* = Effective dielectric constant *εr* = Dielectric constant of substrate *h* = Height of dielectric substrate

W = Width of the patch

The dimensions of the patch along its length have now been extended on each end by a distance Δ*L*, which is given empirically in [1] as:

$$\Delta L = 0.412h\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \qquad \text{------------(2)}$$

The effective length of the patch Leff now becomes

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$$L_{eff} = L + 2\Delta L \quad \text{---------(3)}$$

For a given resonance frequency f0 , the effective length is given by

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{re}}} \quad \text{---------(4)}$$

For efficient radiation, the width of patch is given by [1]

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r+1)}{2}}} \quad \text{------------(5)}$$

III. DESIGN AND SIMULATION OF MICROSTRIP ANTENNA IN ISM BAND WITH LINEAR POLARISATION WITH ANSOFT HFSS

A. Simulating Software Ansoft HFSS:

In order to calculate the full three-dimensional electromagnetic field inside a structure and the corresponding S-parameters, HFSS employs the finite element method (FEM). FEM is a very powerful tool for solving complex engineering problems, the mathematical formulation of which is not only challenging but also tedious. The basic approach of this method is to divide a complex structure into smaller sections of finite dimensions known as elements. These elements are connected to each other via joints called nodes. Each unique element is then solved independently of the others thereby drastically reducing the solution complexity. The final solution is then computed by reconnecting all the elements and combining their solutions. These processes are named assembly and solution respectively in the FEM. FEM finds applications not only in electromagnetic but also in other branches of engineering such as plane stress problems in mechanical engineering, vehicle aerodynamics and heat transfer.

B. Steps for Antenna analysis using HFSS:

1. Create a parametric solid model for geometry.
2. Specify material property.
3. Specify boundary condition and excitations
4. Specify analysis and frequency sweep setup Information
5. Perform the analysis
6. Examine the results.
7. Examine the fields.

C. Design Procedure:

The resonant frequency used in this paper is 2.4 GHz ISM band. Any frequency in ISM band can be selected as resonant frequency according to the designer’s choice. For designing microstrip patch antenna, first of all we have to calculate width and length of the patch.

The width of the microstrip patch can be calculated by equation (5) and the length of the patch can be calculated by equation (3).

Determination of Feed Point Location is done by adjusting the position and fixed where VSWR is minimum and antenna gain is maximum.

D. Antenna Geometry for Probe feed:

The geometry of proposed Microstrip Patch Antenna in Shown in Fig 4.. In this design following parameters are taking into account. Choosing of substrate, dielectric constant, resonant frequency, patch length and patch width. The detailed dimensions are given in the table 1 and table 2. Various parameters are considered while doing the simulation. Substrate material as Rogers RT/ duroid 5880 (tm) is used. The relative permittivity of the substrate is 2.2.

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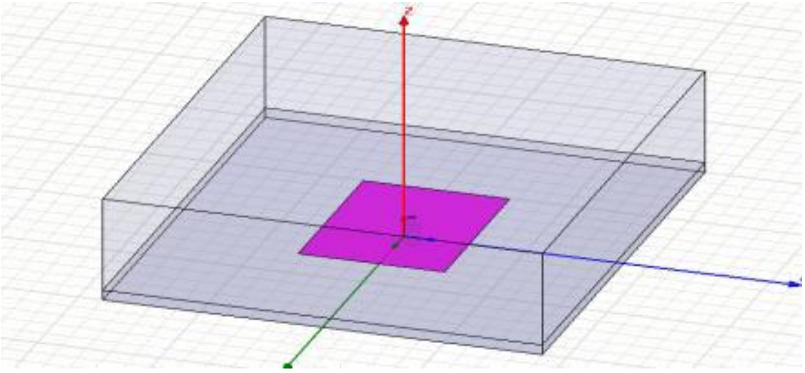

Fig 4 Geometry of designed Antenna

Table 1

	Length(L)	Width(W)	Height(h)	ξr
Patch	**40.0**	**30.0**	**3.2**	**2.2**
Substrate	**100.0**	**90.0**	**3.2**	**2.2**

Dimension of rectangular patch and substrate in mm

For providing execution Probe Feed technique will be used. For that coaxial cable of material pic with dielectric constant 1 is used. The detailed description of coax and probe is given in table 2.

Table 2

	Radius	Height	ξr
Coax Cable	**1.6**	**5**	**1**
Coax Pin	**0.7**	**5**	**1**
Probe	**0.7**	**3.2**	**1**

Dimension of coaxial probe cable in mm

E. Design Result:

The simulation is done in HFSS (High Frequency Structural Simulator). The return loss of Rectangular patch antenna is shown in fig.5 which shows that it resonates at 2.37 GHz frequency and Return loss is -31.4402 dB. These resonant frequencies give the measure of the impedance bandwidth characteristic of the patch Antenna and band width is 48 MHz(2.396-2.346 GHz).

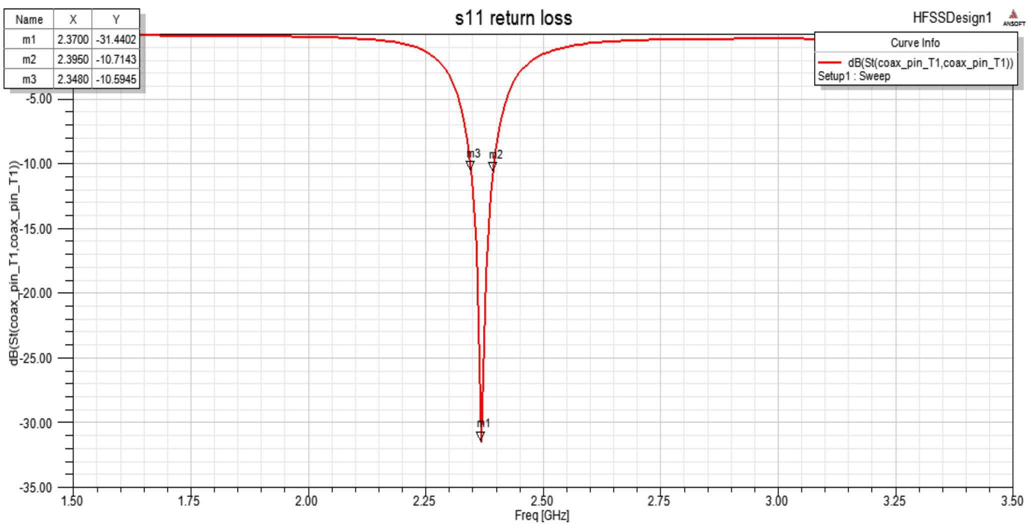

Fig 5 Scattering parameter or return loss at different frequencies of patch

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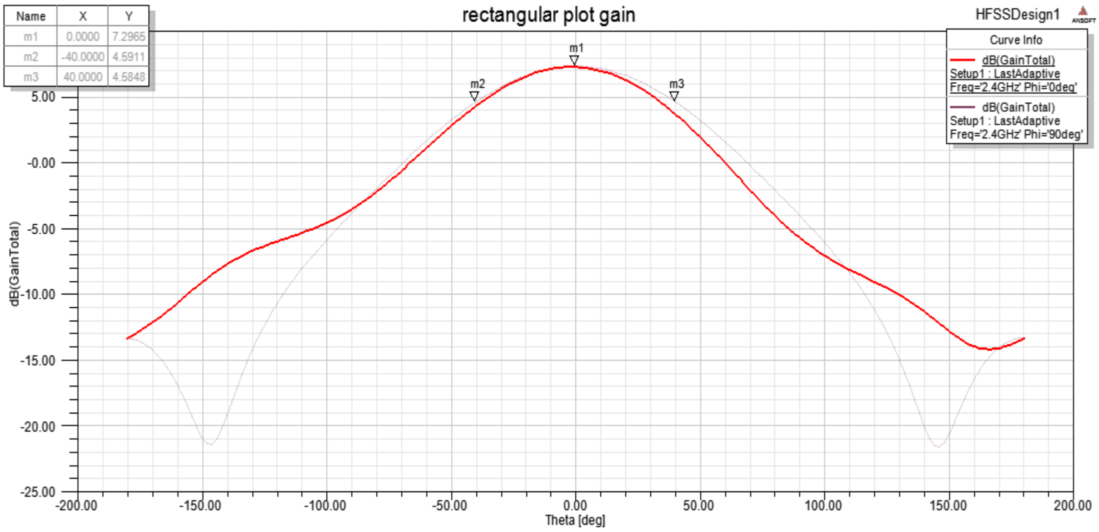

Fig 6 Rectangular plot gain of the patch antenna

Fig 6 shows the Rectangular plot gain of the patch antenna and Fig 7 shows the radiation pattern.From figure 6 &7 it is found that the gain of Antenna is 7.2964 dB. The resulting VSWR characteristic is plotted and found that it will have lowest VSWR (0.4666) at 2.37 GHz and shown in Fig 8.

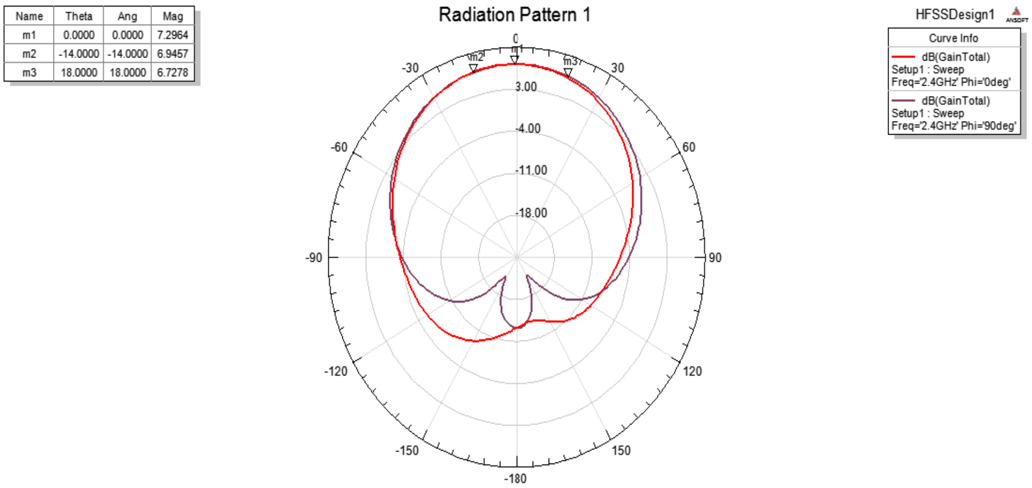

Fig 7 Radiation Pattern of designed Antenna

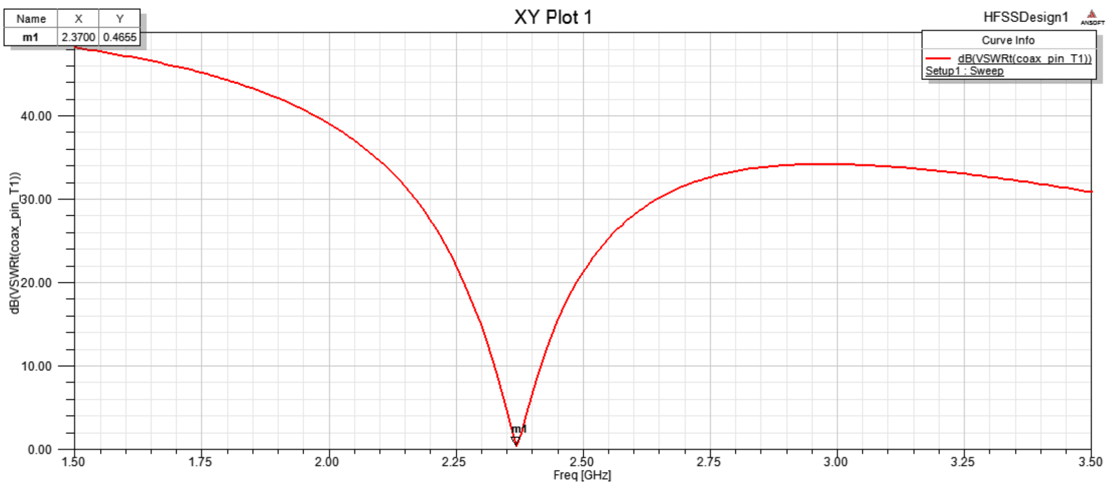

Fig 8 VSWR of designed Antenna

IV. DESIGN AND SIMULATION OF MICROSTRIP ANTENNA IN ISM BAND WITH CIRCULAR POLARISATION USING TRUNCATED CORNER

A. Geometry of proposed Antenna: Patch antenna can be circularly polarized by using two feeds at orthogonal positions that are fed by 0º and 90º with the help of power divider. When two feeds are placed orthogonal to each other, the input impedance and resonance frequency remain unaffected as the two feeds are at null location of the orthogonal mode. But in this method of dual feeding, an external power divider with quadrature phase difference is required to generate the two orthogonal modes. Circular polarization can also be obtained by modifying the corners of rectangular patch antenna. Small isosceles right angle triangular patches are removed from the diagonally opposite corners of the rectangular patch. Truncating the two opposite corners make the resonance frequency of the mode along this diagonal to be higher than that for the mode along the unchopped diagonal.

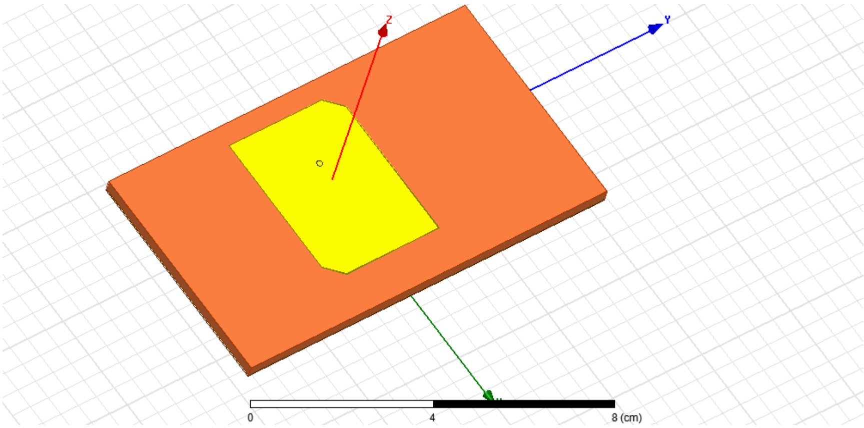

Fig 9 Gemetry of truncated corner rectangular patch microstrip Antenna

B. Design of proposed Antenna:

This Design achieves circular polarization by introducing a perturbation in the form of truncating two opposite edges of a basic rectangular patch antenna. Truncated edges have been used to achieve circular polarization in square, elliptical and circular patch also. Finally we obtain the design structure for circular polarization with truncated corners of a basic rectangular patch antenna.

Table 3:

Patch Shape	rectangular
Patch Length	40
Substrate Length	55
Height of the Substrate	3.2 mm
Frequency	2.4 Ghz
Dielectric Constant of Substrate	2.2
Feeding method	Coaxial probe feed
Probe Feed Position	7.6 mm in Y direction
Truncated Length	4.0 mm

Design parameters of rectangular patch antenna in mm

We have constructed rectangular Microstrip patch Antenna. We obtain the following design parameters using the designing equations to construct the proposed antenna and simulated with Ansoft HFSS software. The good results are obtained by optimizing the truncated corner with one diagonal.

C. Simulation and Results:

Using HFSS simulation we can observe following parameters: Return Loss, Gain, Bandwidth, VSWR ,Directivity, and Radiation Pattern.

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The proposed circularly polarized micro strip antenna is optimized at around 2.4 GHz for the above mentioned dimensions. The simulated results of return loss, VSWR, radiation pattern are as plotted below. Figure 9 shows the geometry of truncated corner rectangular patch microstrip antenna.

Fig 10 shows simulated results of return loss of the proposed circularly polarized microstrip antenna at resonant frequency of 2.4 GHz and band width is 100 MHz(2.35-2.45 GHz). From the figure 10 it is found that the Return loss at resonant frequency is – 26.05 dB.

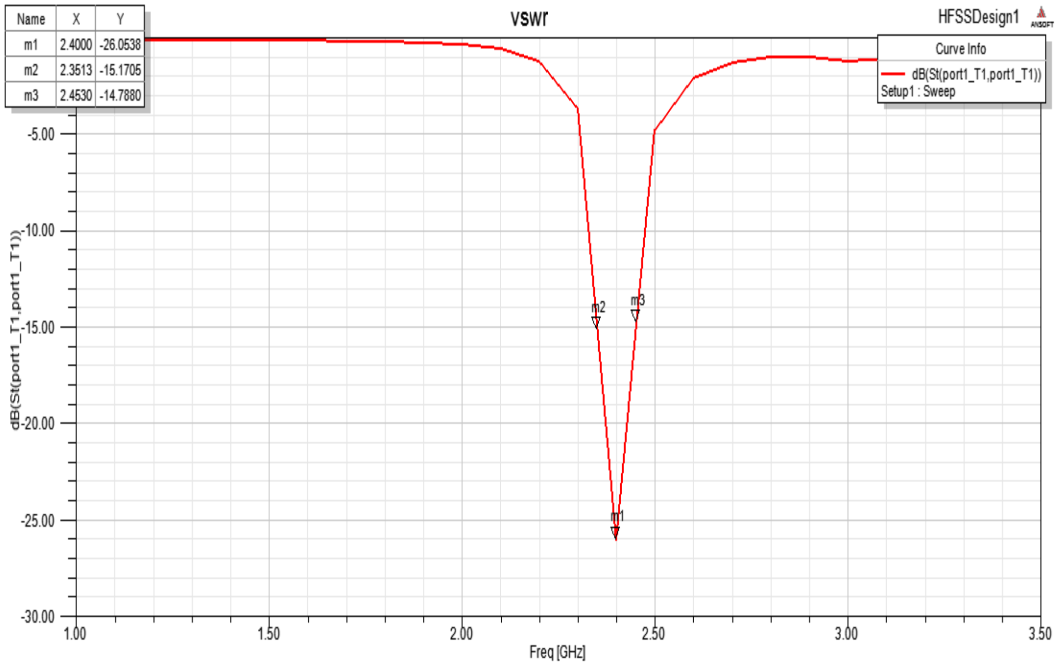

Fig 10 simulated return loss

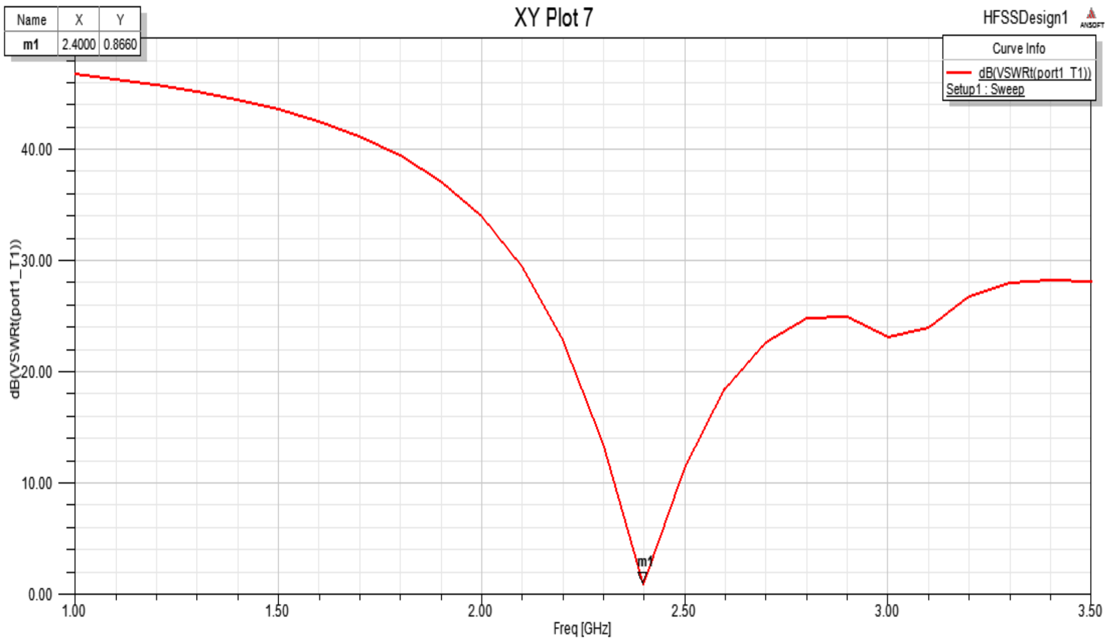

Fig 11 simulated VSWR

Fig 11 shows simulated result of VSWR is 0.86 for the truncated corner antenna at 2.4 GHz.

Radiation pattern is shown in Fig 12. For resonant frequency 2.4 GHz the gain of the Antenna is 4.66 dB. The radiation pattern is copolarized in H plane.

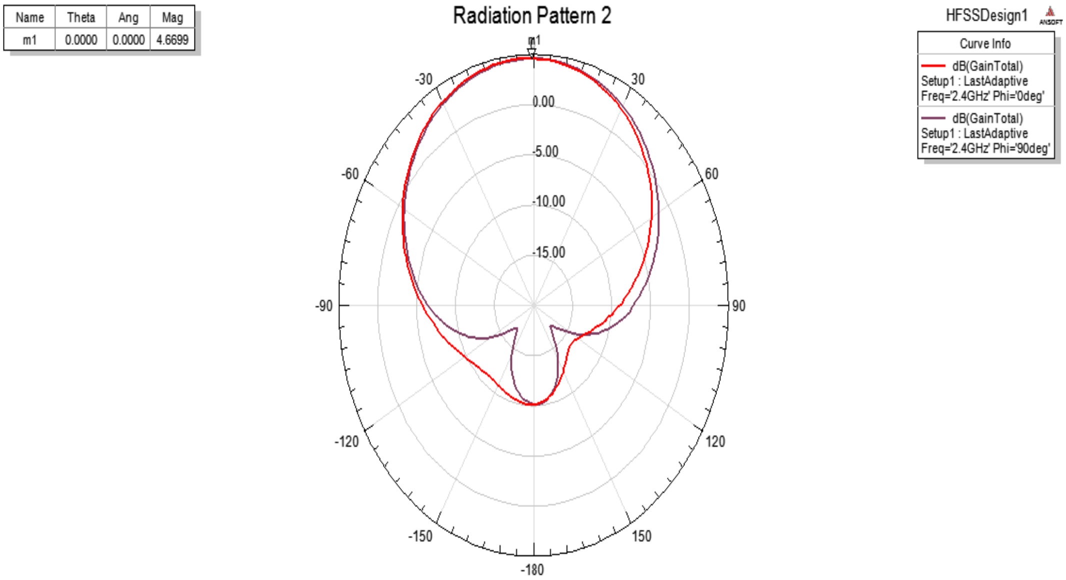

Fig 12 Radiation pattern in truncated edge rectangular patch antenna.

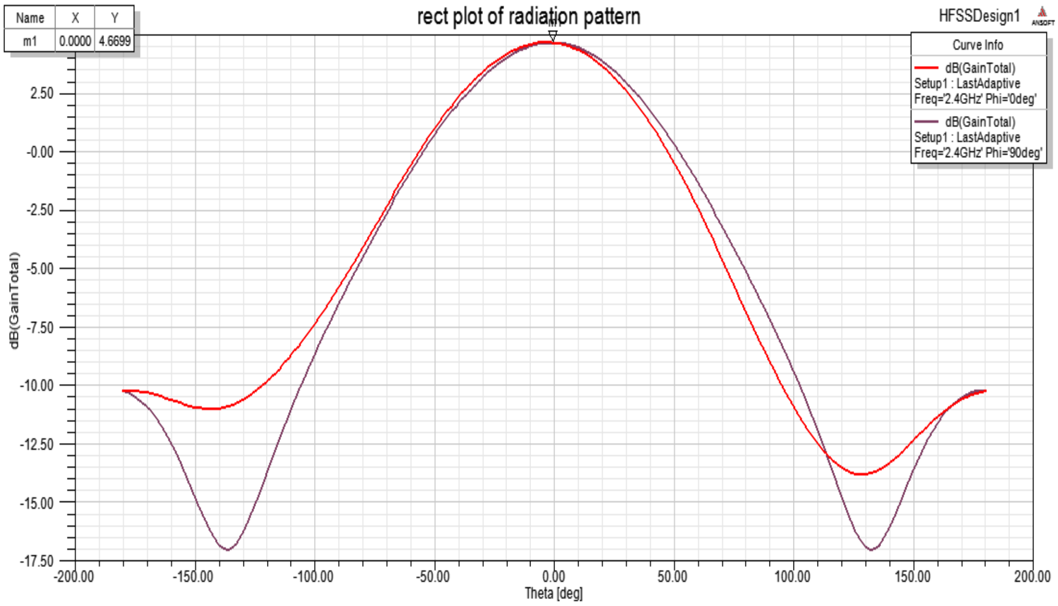

Fig 13 Rectangular plot of radiation pattern in truncated edge rectangular patch antenna

V. CONCLUSION

In first design, the simulated far field pattern is most suitable for WLAN application. From the design (fig. 14-16) it is found that for antenna operating at almost resonant frequencies, the resulting far - field patterns in the horizontal plane were as expected from a typical Microstrip Antenna and is most suitable for WLAN application. This proposed Microstrip Antenna enhanced the impedance bandwidth and provides good matching. The simulation is done by Ansoft HFSS.

In second design, circular polarization is obtained by truncated two opposite corner of a rectangular microstrip patch antenna. It also provided an improved performance with respect to Return Loss, Bandwidth, VSWR, Gain, and Radiation Pattern. This technology can provide a range of benefits with the ability to support wireless communication. With the two designs, the antenna can be designed either for linear polarization or for circular polarization. Hence the diversity polarization is achieved.

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In both the design, the resonant frequency can be selected any of the ISM band frequency (2.4-2.4835 GHz). So, frequency agility is achieved.

In this paper parameters are optimized manually. Parameters can be optimized by writing the programme using MATLAB. Both the designed Microstrip patch Antennas have small value of gain and it can be enhanced by using photogenic band gap (PBG) structure. In both the design single feeding is used. These designs can be extended in the production of antenna array.

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