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Comparative Study of Rectangular ,Circular and Corner Truncated Patch at 2.4 GHz

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***Abstract*— This paper presents a comparative study of rectangular, circular and corner truncated rectangular patch at 2.4 GHz. Microstrip antenna offers linear or circular polarization. Three different patches are designed and their results are compared. This comparison helps in deciding the best shape of the patch which can be chosen for designing the antenna array for RFID reader[1]. HFSS simulation software is used to design patch and compute the various antenna parameters like return loss(S11), directive gain, VSWR, axial ratio etc.**

***Keywords*— Patch Antenna,RFID, Polarization**

I. INTRODUCTION

Microstrip antennas have various advantages such as a planar configuration, can be made conformal to the host surface, ease of mass production using printed circuit technology which leads to low fabrication cost, are easier to integrate with other MICs on the same substrate, allow both linear polarization and circular polarization. Considering these advantages patch antenna is selected. A rectangular patch is linearly polarized. It may be easily converted into circularly polarized patch antenna with some modifications in the shape of structure[2]. The Radio Frequency Identification (RFID) technique is becoming one of the most popular wireless communication techniques in the world. Since RFID systems are based on a wireless radio link between the reader and the transponders (tags), antennas for both readers and tags are recognized to be crucial elements of the whole system.

RFID systems are used for tracking and personal identification purposes. So the antenna beam of the reader should be highly directional with narrow beamwidth to avoid interferences with neighbours. In this paper, three different patches are designed and compared on different parameters.

II. SELECTION OF SUBSTRATE

A. Substrate

For the patch antenna design, selection of substrate material is very important. Selection of substrate depends on thickness(h), dielectric constant (ε_r) and loss tangent. A patch antenna radiates due to the fringing fields. Smaller the permittivity (ε_r) of the substrate, more bowed the fringing fields become and they extend farther away from the patch. Therefore, using a smaller permittivity for the substrate yields better radiation. Dielectric constants should be in the range of $2.2<=\varepsilon_r<=12$.Thicker substrate provide better efficiency, larger bandwidth, loosely bound fields but lead to larger element size[2],[3]. In this design, substrate is chosen as FR 4 with dielectric constant as 4.4 as it is low cost and easily available.

B. Frequency

Frequency is selected as 2.4 GHz as it is in ISM band.

C. Feed

A patch can be end fed or inset fed. Study show that inset feed excitation technique provides more enhanced characteristics and perfect impedance matching as compared to the other feed techniques. Current is minimum at the end and maximum at the center. Thus as the feed point moves from the edge toward the center of the patch , the resonant input impedance decreases monotonically and reaches zero at the center. So inset feed element has lowest VSWR[4]. Also in inset feed best match can be obtained by properly locating the inset position. So all three designed patches are inset fed.

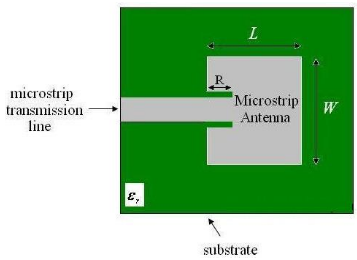

Fig 1.Inset fed patch

D. Selection of height of substrate(h)

With increase in h, the fringing fields from the edges increase, which increases the extension in length ΔL and hence the effective length, thereby decreasing the resonance frequency. Whereas with increase in h, W/h ratio reduces, which decreases ε_{eff} and hence increases the resonance frequency. But the effect of increase in ΔL is dominant over the decrease in ε_{eff}.. Thus more pronounced effect is decrease in resonant frequency. Study shows that efficiency reduces with increase in height and causes increase in surface waves[3]. Considering these factors height of substrate is chosen to be low i.e 1.5mm.

III. DESIGN PROCEDURE

A. Rectangular Patch Antenna

Following design equations are used for the rectangular patch[3],[5]

- The width of the Microstrip patch antenna is given as

$$W = \frac{c}{2f\sqrt{\frac{(\varepsilon r+1)}{2}}} \quad (1)$$

- Fringing makes the microstrip line look wider electrically compared to its physical dimensions. Since some of the waves travel in the substrate and some in air, an effective dielectric constant is introduced given as

$$\varepsilon_{reff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}[1+12\frac{h}{W}]^{1/2} \quad (2)$$

- The effective length due to fringing is

$$L_{eff} = \frac{c}{2f\sqrt{\varepsilon_{reff}}} \quad (3)$$

- Due to fringing the dimension of the patch as increased by ΔL on both the sides

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{W}{h}+0.8)} \quad (4)$$

- Hence the length the of the patch is

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

For this feed would be given L/4 distance

TABLE I : SPECIFICATIONS OF RECTANGULAR PATCH

Length	28.4 mm
Width	38.22mm
Feed Length	21.5mm
Inset Position	7.5mm

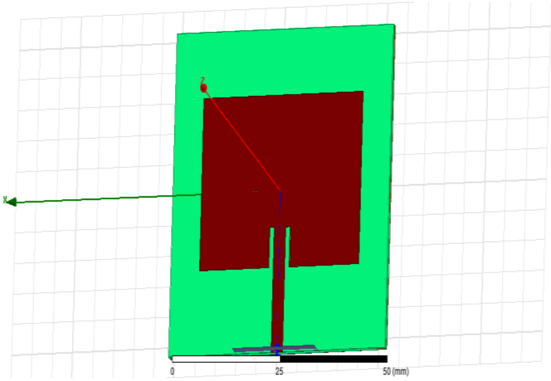

Fig. 2.Rectangular Patch

B. Circular Patch Antenna

Following design equations are used for the circular patch[3],[6]

- Since the dimension of the patch is a circular loop, the actual radius of the patch is given by

$$a = \frac{F}{\{1+\frac{2h}{\pi\varepsilon_r F}[\ln(\frac{\pi F}{2h})+1.7726]\}^{1/2}} \quad (6)$$

$$F = \frac{8.791\times10^9}{f\sqrt{\varepsilon_r}} \quad (7)$$

- The above equation does not take into consideration fringing effect. Since fringing effects makes the patch electrically larger the effective radius of patch is used and is given by

$$a_e = a\{1+\frac{2h}{\pi\varepsilon_r a}\left[\ln\left(\frac{\pi a}{2h}\right)+1.7726\right]\}^{1/2} \quad (8)$$

TABLE II : SPECIFICATIONS OF CIRCULAR PATCH

Radius	19.8mm
Effective radius	17.5mm
Feed Length	18.5mm
Inset Position	7.5mm

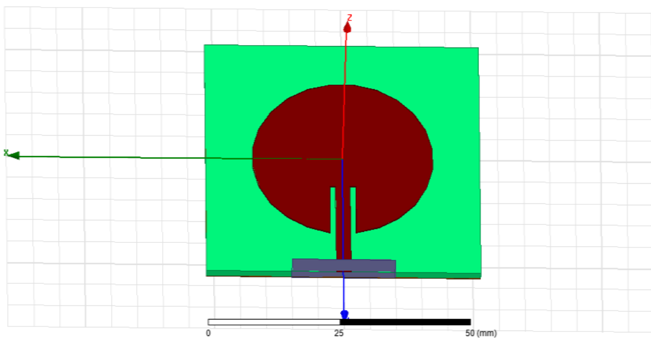

Fig. 3. Circular Patch

C. Corner Truncated Rectangular Patch

A patch antenna can be circularly polarized by using two feeds at orthogonal positions that are fed by 0^o and 90^o 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.

The design equation for truncated length are given as[3],[7]

$$Qo = \frac{c\sqrt{\varepsilon r}}{4foh} \quad (9)$$

$$\frac{\Delta s}{s} = \frac{1}{2Qo} \quad (10)$$

$$a = L\sqrt{\frac{\Delta s}{s}} \quad (11)$$

Where Q_o = Unloaded quality factor

$\frac{\Delta s}{s}$ = Truncation Ratio.

a= truncated length.

TABLE III : SPECIFICATIONS OF RECTANGULAR PATCH WITH TRUNCATED CORNER

Length	28.4mm
Width	38.2mm
Truncated Length	3.03mm
Inset feed	7.5mm

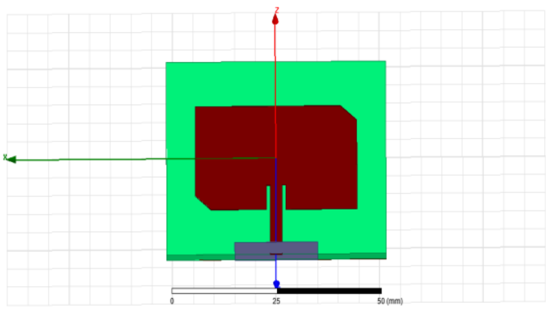

Fig. 4. Corner Truncated Rectangular Patch

IV. RESULTS

Once the dimensions of the antenna are computed, the antenna is designed. Various parameters plots like return loss, polar plot, VSWR axial ratio etc.

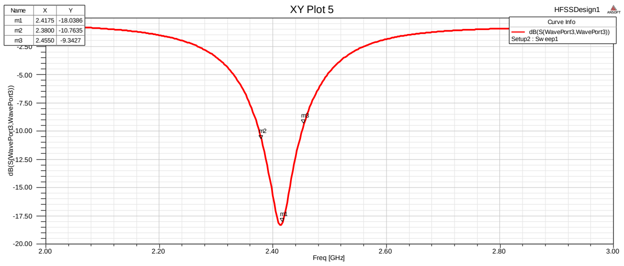

Fig.5. Return loss of rectangular patch

The above figure shows that the antenna resonates at around 2.41 GHz, return loss being -18.03 dB. It provides a bandwidth of 75 MHz.

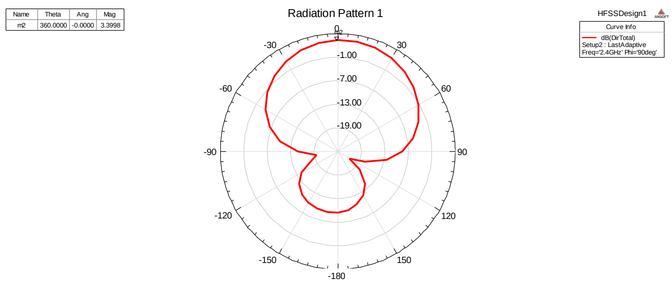

Fig.6. Directivity of rectangular patch

The above figure shows that the rectangular patch antenna provides a gain of around 3.39 dB.

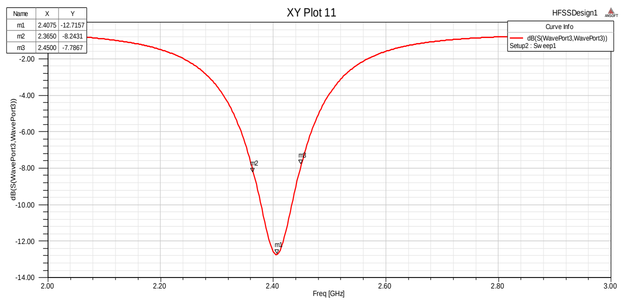

Fig.7. Return loss of circular patch

The above figure shows that the antenna resonates at around 2.41 GHz, return loss being -12.63 dB. It provides a bandwidth of 80 MHz.

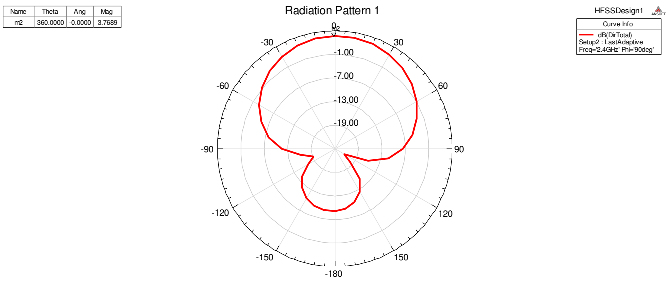

Fig.8. Directivity of circular patch

The above figure shows that the circular patch antenna provides a gain of around 3.76 dB.

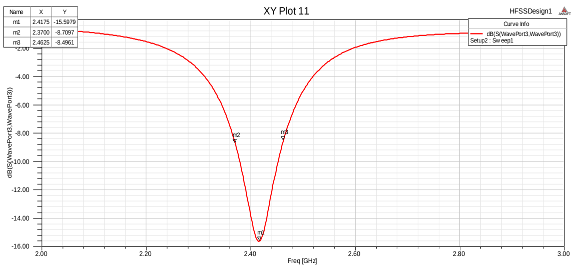

Fig.9. Return loss of corner truncated patch

The above figure shows that the antenna resonates at around 2.41 GHz, return loss being -15.59 dB. It provides a bandwidth of 90 MHz.

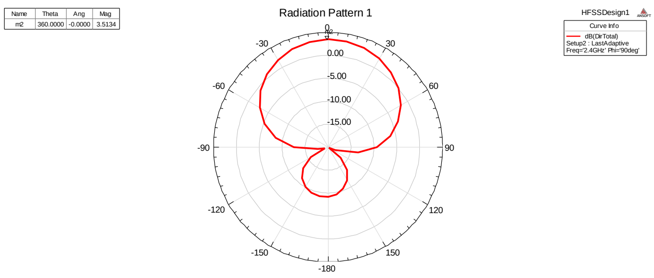

Fig.10. Directivity of corner truncated patch

The above figure shows that corner truncated patch antenna provides a gain of around 3.51dB.

TABLE IV: COMPARISON OF RESULTS

	Freq (GHz)	Return loss(dB)	Directivity (dB)	BW (MHz)
Rectangular Patch	2.41	-18.03	3.39	75.0
Circular Patch	2.41	-12.63	3.76	80.0
Corner Truncated Patch	2.41	-15.59	3.51	90.0

V CONCLUSION

All three antennas resonant at around same frequency. Return loss is highest for rectangular patch but it suffers from poor gain and bandwidth. For perfect circular patch gain is highest but has lowest return loss and medium bandwidth. Corner truncated patch has medium gain, medium return loss and highest bandwidth. The results show that the corner truncated patch antenna gives better results as compared to rectangular patch and circular patch .So it can be selected as the patch element for the array.

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