EFFECT OF DIFFERENT SYMMETRIC SLITS ON MICROSTRIP PATCH ANTENNA

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ABSTRACT

In this paper, a basic linearly polarised microstrip square patch antenna operating at 2.4 GHz is proposed. We have modified the basic microstrip square patch antenna with rectangular shape slits, V shape slits and truncated corners to achieve circular polarization. Basically we have designed five different antennas to meet the specification. The various antennas have been simulated, fabricated and the performance has been tested on network analyser (Agilent Technologies: N9912A, SNMY51464189, ROHDE & SCHWARZ: ZVL13, 9 KHz to 13.6GHz,). The simulated and tested performance shows close agreement with each other. The various structures used in this study are microstrip square patch radiator, microstrip square patch radiator with truncated corner, rectangular slits, truncated corner with rectangular slits and V shape slits. The experiment results show rectangular slits with truncated corners in the main square patch and rectangular slits in the main square patch provide better performance with respect to the antenna parameters. Designed antenna is compact and provides circular polarization at the required operating frequency of 2.4GHz with improved bandwidth and gain. The use of circularly polarized antennas presents an attractive solution to achieve this polarization match which allows for more flexibility in the angle between transmitting and receiving antennas. It gives the following advantages such as reduction in the effect of multipath reflections, decrease in transmission losses, enhancement of weather penetration and allowing any orientation to the communication system.

KEYWORDS

Wireless, microstrip antenna, circular polarization, slit.

1. INTRODUCTION

Communication technology and the relevant techniques are changing drastically these days. Hence we require more sophisticated wireless communication equipment's. The radio frequency utilized by the system decides its range and the scalability [1, 2]. Different symmetric shaped slotted microstrip patch antennas are proposed for circular polarization for radio frequency identification applications [3]. Modern communication systems like cellular phones, personal computer cards for wireless local area networks (WLAN) prefer microstrip antennas over other radiators. These antennas provide advantages such as their light weight, low cost, low profile and uncomplicated integration with circuit components of portable personal equipment's.

Circularly polarized radiation can be generated with a symmetric slit on patch radiator having a compact size [1, 4-7]. Compact circularly polarized microstrip antennas (CPMAs) are fundamental requirement for applications such as cellular networks, radio-frequency identification (RFID) handheld readers, wireless LANs, receiver antennas for medical implants and portable wireless devices because the overall antenna size is a major consideration for such application [8-10]. Microstrip antennas are designed such that they have conducting patch

DOI:10.5121/Jmicro.2016.1403

printed on a grounded microwave substrate giving attractive features of low profile and conformability to mounting hosts.

CPMA using single feed technique does not require an external polarizer hence uses less board space than dual feed CPMA giving advantages of simple structure and compactness. Various reports in the literature have discussed many designs of single-feed, CPMAs with square or circular patches having compact size at a fixed frequency of operation [9-14]. In these designs, various compact CP techniques such as embedding a Y-shaped slot of unequal arm lengths, truncating patch corners or tips, inserting slits or spur lines at the patch boundary, embedding a cross slot of unequal arm lengths. These compact CP designs are fed by a probe feed or an edge-fed microstrip line. Designs applied to a corner-truncated square microstrip antenna are presented in detail [15, 16]. CP radiation of microstrip antenna operated at the TM11 mode has been accomplished for the case of a pair of slits. [16-17].

2. Structure and Design

2.1. Specifications of the design

Square microstrip patch antenna is designed with following procedure [16, 17].

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} = \frac{v_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (1)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{w}\right]^{-0.5} \qquad (2)$$

Where, v_0 show the free-space velocity of light. Effective dielectric constant of the microstrip antenna is determined using (2), Once W is calculated determine the extension of the length ΔL using

$$\Delta L = h\left[0.412\frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)}\right] \qquad (3)$$

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

2.2. Design Parameter

By introducing a perturbation in the form of truncating two opposite edges and also adding slits to a basic square patch antenna circular polarization is achieved. For square, elliptical and circular microstrip patch antenna, the use of truncated edges and slits gives circular polarization. Design structure for circular polarization with truncated corners and different slit shapes inserted in main square patch was obtained.

All the results are calculated using 3D software HFSS v.11 which is based on FEM (Finite Element Method). Results that are considered for analyses of these designed antennas are return loss, voltage standing wave ration (VSWR), axial ratio etc. These results are considered as reference for comparison with corresponding measured results of the fabricated antennas that has been designed in this work. The table 1 shows design parameter using the design procedure to construct the main square patch antenna on HFSS software.

Table 1. Design Parameter for main square patch antenna

Patch Parameter	Value
Shape	Square
Length	29.44
Length of Substrate	39.04
Height of substrate	1.6 mm
Center Frequency	2.4 GHz
Dielectric constant : FR4	4.4
Feeding method	Coaxial Probe Feed
Position of Probe Feed	7.6mm in Y direction

The square patch antenna is shown in figure 1 with their patch and substrate dimension; Figure 2 shows cross sectional view of antenna on HFSS software. Figure 3 shows top view of an antenna on HFSS as well as the fabricated version of the same.

Figure 1. Microstrip square Patch Radiator

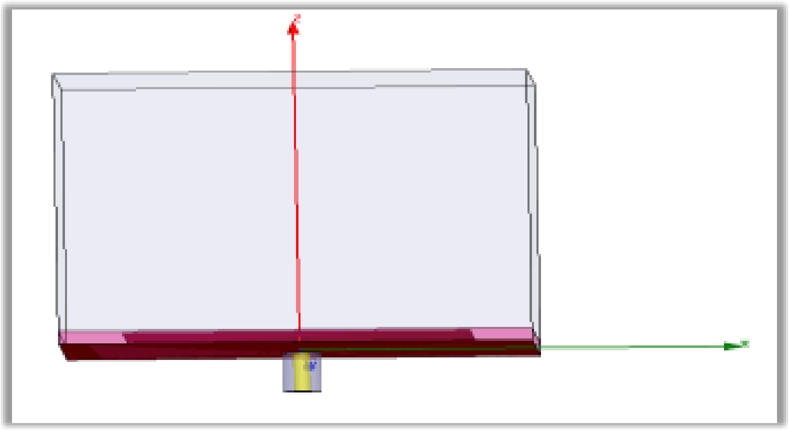

Figure 2. Cross Sectional View

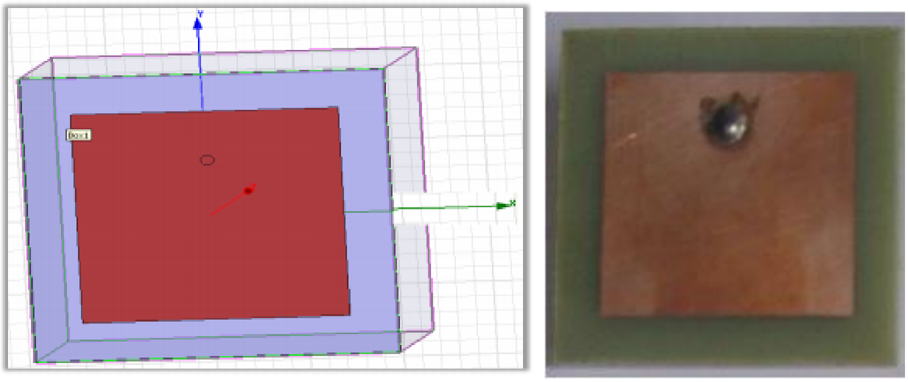

Figure 3. Microstrip square Patch Radiator

Finally we obtain the design structure for linear polarization with square patch antenna in simulated environment and in fabricated environment shown in figure 3 and for circular polarization with adding the different shaped slits shown in figure 4 to 7 in a main square patch antenna for the simulated and fabricated environment. Optimizing the truncated corner with one diagonal and also optimizing the different slit shape with one diagonal or both diagonals offer the best results.

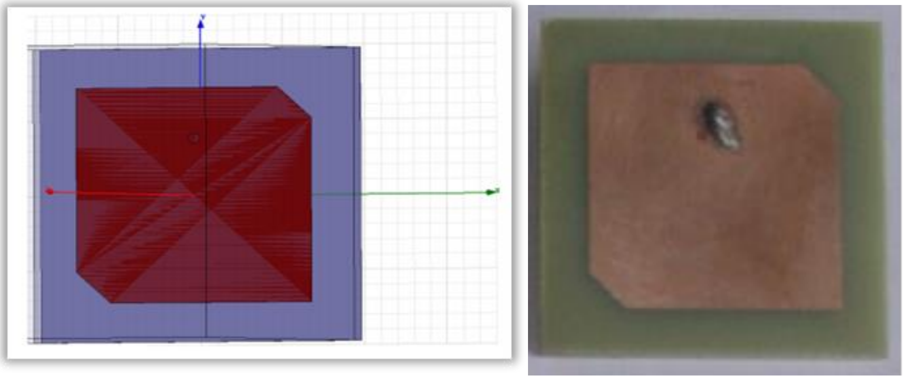

Figure 4. Truncated Corner

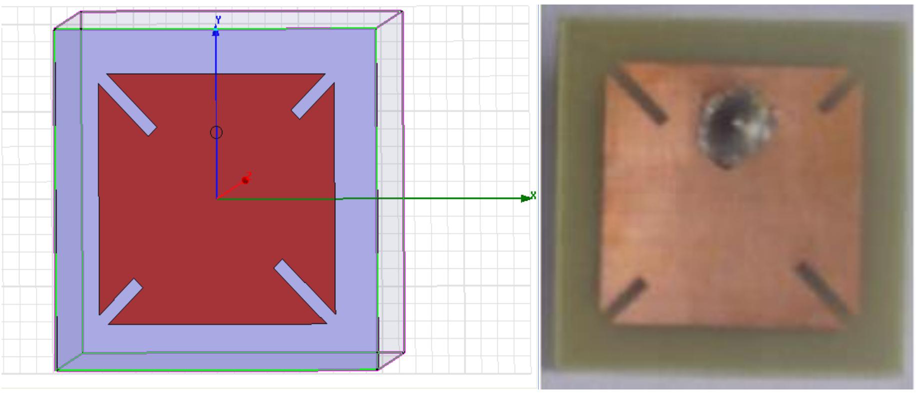

Figure 5. Rectangular Slits

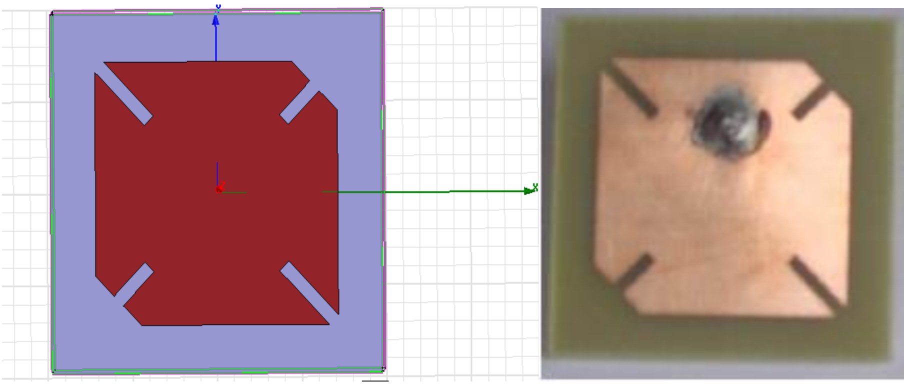

Figure 6. Truncated Corner with Rectangular Slits

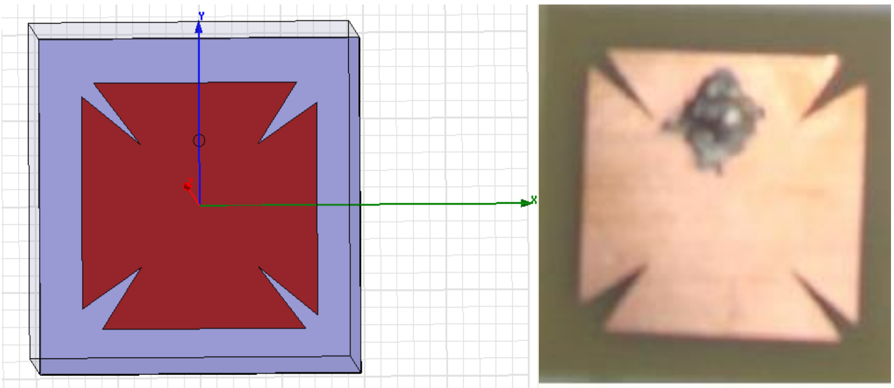

Figure 7. V shape Slits

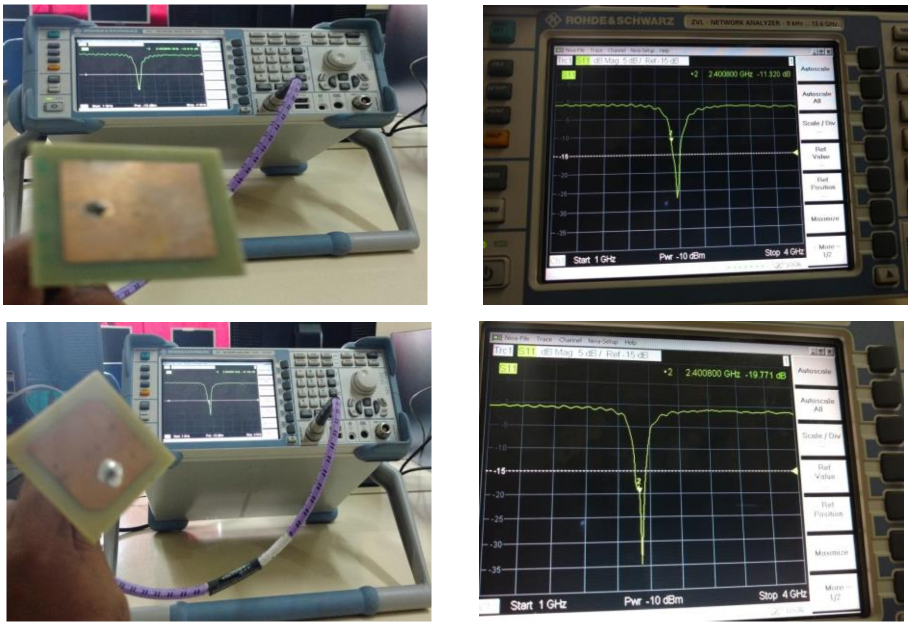

Figure 8. Tesing of antennas on VNA

We tested all the antennas on vector network analyser ZVL 13 9KHz to 13.6GHz (ROHDE & SCHWARZ) for parameters such as return loss and VSWR as shown in figure 8.

3. DESIGN METHODOLOGY

1. Ansoft HFSS was used to simulate and verify following design steps:

   - The slit circumference along one of the diagonal axes with respect to the other diagonal axis on a patch radiator was varied to achieve circularly polarized radiation with compact size.
   - After comparison of the performance of the antennas based on fixed overall antenna size and patch radiator size, circularly polarized microstrip antennas based on larger-perimeter types of slits are more compact.
   - Different slit shapes embedded microstrip square patch radiators are studied as follows:
     i) Truncated corners ii) Truncated corners and slits
     iii) V-shaped slits iv) Rectangular slits
   - Two resonant modes which are equal in magnitudes and orthogonal to each other are obtained through excitation of the slit along the diagonal direction of the patch. The circumference of the slits in the diagonal directions is changed in order to obtained two orthogonal resonant modes for the circularly polarized radiation.

2. Using HFSS simulation the following parameters were observed: Gain, Return Loss, Radiation Pattern, VSWR, Directivity and Bandwidth.

3. The circularly polarized microstrip patch antenna was fabricated using symmetric slit on FR4 substrate, tested and verified using network analyser for the specified parameters of the antenna.

4. Comparison of hardware results and simulated results.

4. SIMULATION AND RESULTS

The simulated results of return loss, VSWR, axial ratio, radiation pattern of proposed circularly polarized symmetric-slit microstrip antenna operating at 2.4 GHz for the above mentioned dimension is given below:

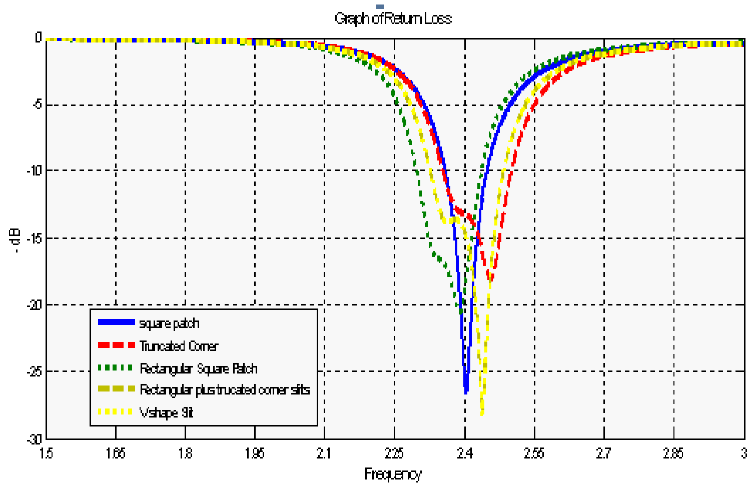

Figure 9. (a) Simulated Return loss Vs Frequency for different antenna structures

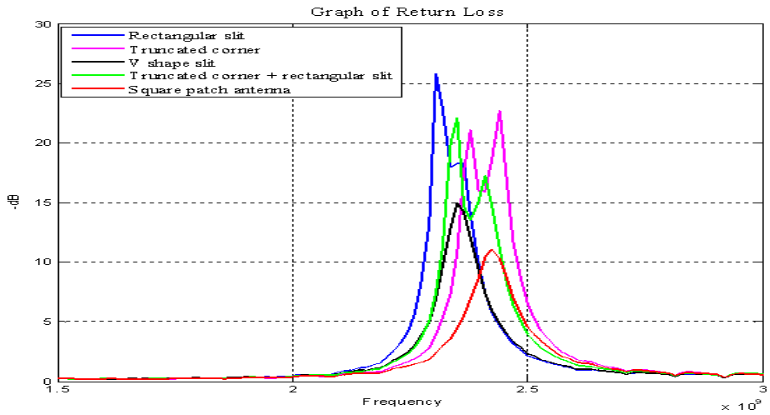

Figure 9. (b) Measured Return loss Vs Frequency for different antenna structures

Figure 9-(a) shows simulated and Figure 9-(b) shows measured results of a return loss with different slit shapes added in main square patch antenna at resonant frequency of 2.4 GHz. The bandwidth of rectangular slit with the truncated corner is 158 MHz. The improvement in bandwidth of rectangular slit with the truncated corner in comparison with the main square patch is the result of reduction in width of the patch. This reduction of width has resulted in reduced resistance and Q factor hence the bandwidth is improved.

$$Q = \frac{R}{\omega_0 L} \quad (5)$$

$$BW = \frac{1}{Q\sqrt{2}} \quad (6)$$

The simulated results of the various slit shape structures designed in this paper shows good agreement with the fabricated results. There are various wireless applications working in this frequency band. Figure 10 and 11 show simulated VSWR and axial ratio respectively for different antenna structures, here VSWR below 2 and axial ratio below 3dB.

Figure 11 shows radiation pattern of different structures antenna. Also from figure 11, it is clear that radiation pattern of the antennas showing omni directional.

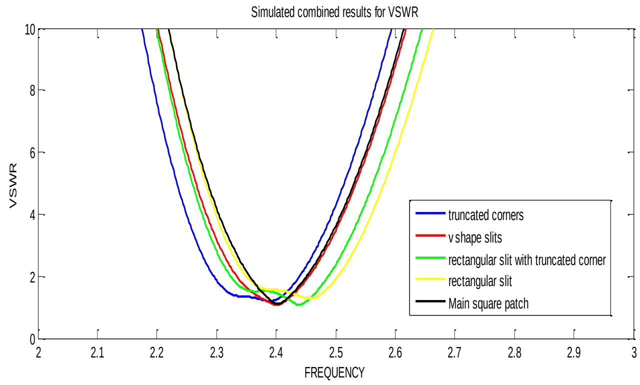

Figure 10. Simulated VSWR Vs Frequency for different antenna structures

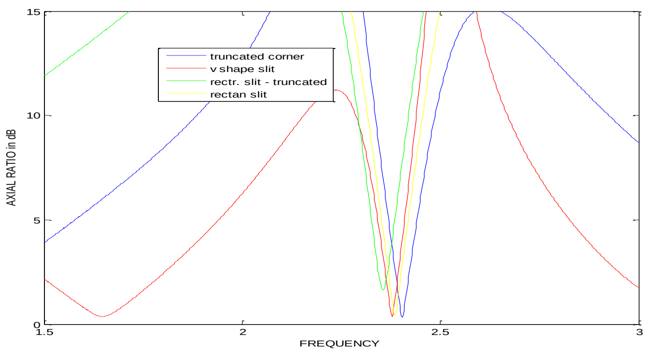

Figure 11. Simulated Axial Ratio Vs Frequency for different antenna structures

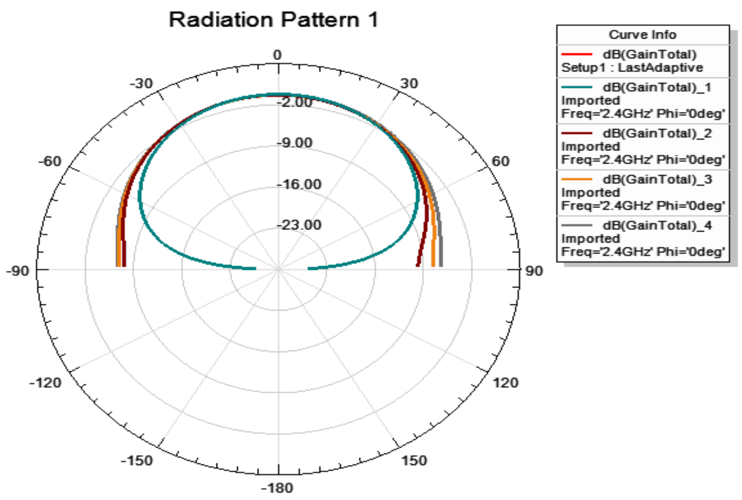

Figure 12: Simulated Radiation Pattern Vs Frequency for different antenna structures

4.1 Comparison of the antenna parameters

Table 2 shows the comparison between simulated results and measured results of fabricated main square patch antenna and other configurations with slits. The table 2 clarifies that there is excellent correlation between simulated and measured parameters of the antenna.

Table 2. Comparison for various antenna parameters

Type	Frequency (GHz)		S_{11} (dB)		VSWR	
	Simulated	Measured	Simulated	Measured	Simulated	Measured
Main Square Patch	2.40	2.40	-26.3	-11.320	1.09	1.79
Truncated Corner	2.44	2.40	-17.9	-19.77	1.55	1.06
Rectangular Slit simulated	2.38	2.30	-20.4	-25.6	1.24	1.35
Rectangular Slit with Truncated corner simulated	2.42	2.38	-28.1	-21.5	1.44	1.40
V shape Slit simulated	2.40	2.35	-31.2	-14.9	1.06	1.43

The parameters in the above table show the improved performance with all added slits compared to the main microstrip patch antenna. From the table 2 it is clear that return loss of rectangular slit with truncated corner is -28.1dB.

Table 3 shows the comparison of various parameters of the designed antennas with respect to the following antenna parameters: radiation intensity, bandwidth, directivity and gain. From the table 3 it is clear that rectangular slit added in the main square patch gives best antenna results for radiation intensity, radiated power, accepted and incident power as compared to other slit structures. Rectangular slit with truncated corner structure gives the best results as compared to other slit structures with respect to bandwidth, gain and directivity.

Table 3. Combined results of proposed antennas

Variables	Main square patch	Truncated Corner	Rectangular slit	Rectangular slit with truncated corner	V Shape slit
Radiation Intensity (µW/sr)	653.2	753.44	946.5	733.95	717.74
Directivity	1.227	1.4247	1.472	1.5103	1.493
Radiated Power (mW)	6.417	6.6456	8.07	6.10	6.03
Accepted Power (mW)	10.06	10.244	12.8	9.8562	9.74

Incident Power (mW)	10.06	10.079	12.98	10.21	9.75
Gain	0.815	0.924	0.928	0.935	0.925
Radiation Efficiency	63.76	67.87	63.08	61.959	61.95
Bandwidth (MHz)	90	150	140	158	116

5. CONCLUSIONS

In this work circular polarization has been achieved in all the configurations of added slits except for the main square patch. The main square patch antenna provides a linear polarization. All the measured parameters have shown an excellent improvement with respect to main square patch antenna. The compactness in the structure has also been achieved. The rectangular slit with main square patch and the rectangular slit with truncated corners give the best results with respect to various parameters. When the rectangular slits are added to the main square patch the bandwidth is improved by 55%. The bandwidth provided by rectangular slit with truncated corners is 75 % more than that of the main square patch. The gain in the rectangular slit with truncated corner antenna is also improved by 14 % compared to main square patch antenna.

The other parameters such as radiation intensity, radiated power, accepted and incident power are improved in the rectangular slits added to the main square patch. Thus it can be concluded that the addition of the rectangular slits and truncated corners have enhanced the performance of main square patch antenna. Thus we have proposed highly efficient circularly polarized antennas with modified slits added to the main square patch antenna which will be useful to the wireless communication applications fulfilling the requirements of light weight, low cost, small size and low power consumption along with better bandwidth.

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