

Design and Study of Effects of Truncated Tip, Stacking With and Without Air Gap on The Patch Antenna

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Abstract

The study on triangular microstrip antenna with truncated tip, vertical stacking with and while not air gap for circular polarization is given during this article. The circular polarization of three antennas are obtained with 0.82% axial magnitude relation bandwidth for straightforward triangular patch with truncated tip, 1.31% axial magnitude relation bandwidth for vertically stacked patch while not air gap and 1.6% axial magnitude relation bandwidth for vertically patch with air gap. The impedance bandwidths of three antennas are achieved as 1.14% for straightforward triangular patch with truncated tip, 1.5% for vertically stacked patch with gap and 7.9% for vertically stacked patch with air gap. The gain and radiation efficiency of the complete three antennas are evaluated and compared. Details of simulated results are given and mentioned during this article.

Keywords— Microstrip patch antenna, Circularly polarization, Coaxial probe feed and parasitic elements.

I. INTRODUCTION

Microstrip antennas and arrays are wide utilized in recent years attributable to their sensible characteristics like low value, small size, light-weight conformable, simply fictitious and simply realizable. These options create the planar antenna very enticing to be used in vehicles, like space craft and satellites. However, these type of antennas have many drawbacks like narrow impedance bandwidth and high feed losses. These drawbacks can be reduced by using multilayer structures [1-5]. circular polarized microstrip patch antennas have become popular because they do not require orientation matching between transmitter and receiver. Circular polarized antennas are used in communication with satellite and aircraft which are situated above ionosphere [6-10].

CP can be achieved using the two feed and single feed. The generation of CP with two feed increases the overall size of antenna. But single feed permits a reduction in size and RF power loss of any feed. It has been reportable that regular geometrical formed patches with one feed purpose usually radiate LP wave. So for circular polarized wave it is necessary that there should be two orthogonal modes with 90-degree phase shift [11-15]. Easy microstrip with single feed provide the slender bandwidth. we are able to improve the bandwidth of antenna by introducing a parasitic component. The parasitic parts will be place in two geometrical patterns; in horizontal plane and vertical plane. once the parasitic component is placed in horizontal plane with driven component, it will increase the scale of antenna however once placed in vertical over the feed driven patch, it reduces the scale and becomes appropriate for wireless communication system. it's additionally reportable that bandwidth will be improved additional exploitation the multilayered structure like spaced insulator. This paper concentrates on the planning of single layer, parasitic and multilayer circularly polarized antennas. The impedance bandwidth, ARBW, average gain and η (radiation efficiency) of those antennas are calculated and compared [16-21].

II. DESIGN OF TRIANGULAR MICROSTRIP ANTENNA

The design expression for calculating the resonant frequency of equilateral triangular patch based on cavity model is given below;

$$f_{mn} = \frac{2c}{3a(\epsilon_r)^{\frac{1}{2}}} (m^2 + mn + n^2)^{\frac{1}{2}}$$

In the above expression, physical side length of triangular patch will be replaced by effective side length of triangular patch as given below;

$$a_{eff} = a + h(\epsilon_r)^{-\frac{1}{2}}$$

$$\epsilon_{eff} = \frac{1}{2}(\epsilon_r + 1) + \frac{1}{4}(\epsilon_r - 1)(1 + \frac{12h}{a})^{-\frac{1}{2}}$$

Where a ; side length of equilateral triangular patch antenna, h ; substrate thickness, a_{eff} ; effect side length of triangular patch, ϵ_r ; relative dielectric constant of substrate, ϵ_{eff} ; effective dielectric constant of substrate, and c ; speed of light.

III. ANTENNA DESIGN AND ANALYSIS

A. single patch antenna with truncated tip

The geometry of single layer triangular microstrip patch for CP is shown in Figure 1. This triangular has been design on FR4 of thickness 1.53mm and relativity permittivity 4.3. The triangular patch antenna with truncated tip is design for 3.76 GHz. The side length 24.63 mm for this center roughly calculated from the expression given above. The circular polarization is achieved by truncated tip of 4.16 mm. The tip length and coaxial feed position are optimized using 3D software HFSS. Truncated tip in patch is used to improve the ARBW of the antenna and it also shifts the resonant frequency at higher frequency side.

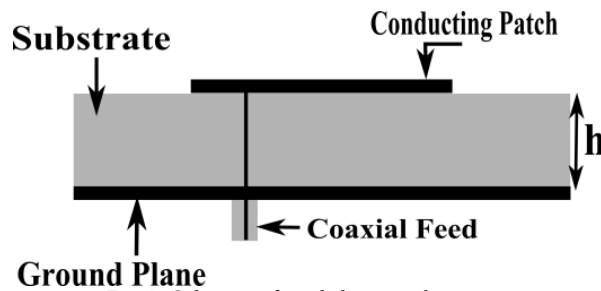


Fig. 1a Side view of single layer patch antenna.

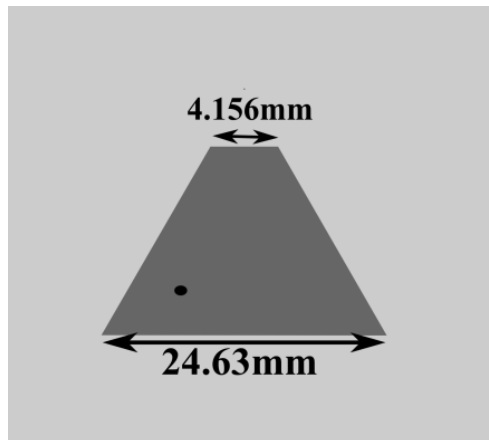
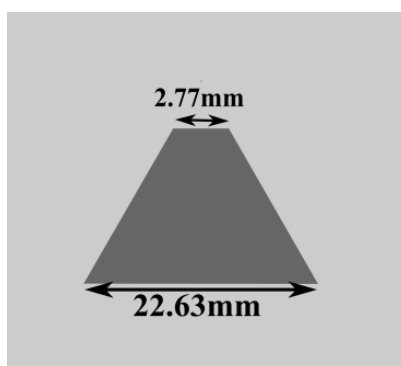
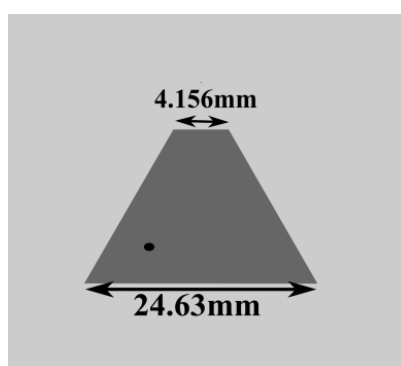
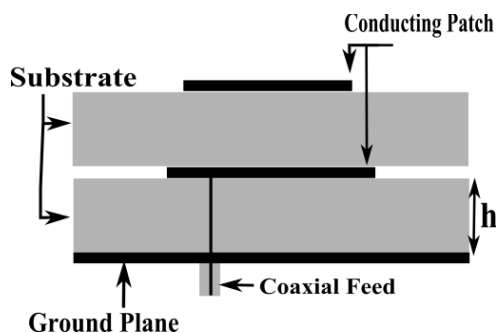


Fig. 1b Top view of Single layer patch antenna.

B. Patch antenna with parasitic patch

The geometry of a side view of the proposed antenna is shown in the Figure 2a. In this, vertically stacked structure contains two coupled cavities one under each patch. The size of parasitic patch is less than the driven patch. Parasitic patch will resonate at high frequency with respect to that of driven patch. The dimension of driven patch is taken with side length of 24.63 mm and truncated tip of 4.16 mm as shown in Figure 2b. The dimension of parasitic patch is taken 22.63 side length and truncated tip of 2.77 mm as shown in Figure 2c. The feed location of driven patch and truncated tip length is optimized

for good impedance and axial ratio bandwidth. The center frequency of antenna is shifted towards lower frequency 3.35 GHz with the improvement in bandwidth.



C. Multilayer patch antenna with air gap

Figure three(a) shows the side view of multilayer patch antenna with air gap. The central frequency is 3.59GHz for this multilayer antenna. The side length of feeding patch is 24.63mm for the central frequency as shown in Figure 3b. Parasitic patch of the 3rd antenna structure has side length of 22.62mm as depicted in Figure 3c. The space between the patches is 0.8mm. As air-gap increases the center frequency shifts towards higher frequency side and bandwidth also increase. For the good return loss and axial ratio bandwidth the combination of size, feed location and air gap is optimized.

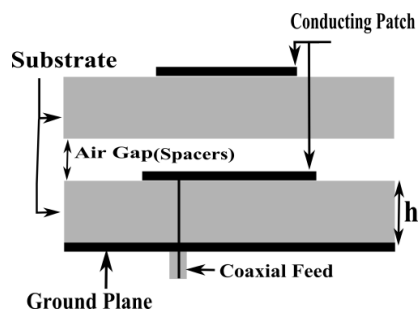


Figure 3a Side view of Multilayer patch antenna with air gap

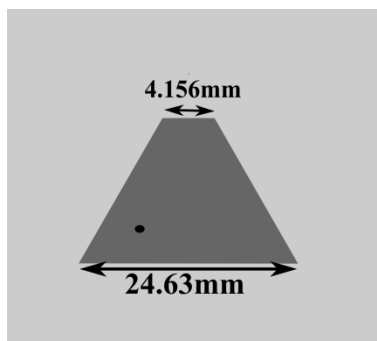


Figure 3b Top view of microstrip driven patch

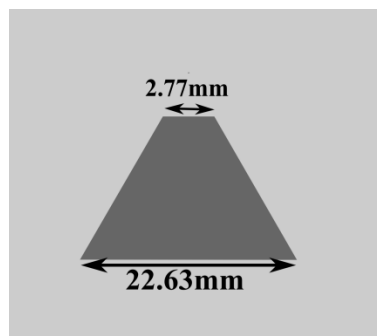


Figure 3c Top view of parasitic patch

IV. RESULTS AND DISCUSSIONS

The simple truncated tip triangular patch is shown in Figure 1b with optimized dimension. This simple truncated tip triangular patch is design for central frequency f_0 of 3.89 GHz. The feed position is optimized for best impedance matching. The impedance bandwidth is achieved 44.3MHz from 3.8742GHz to 3.9185 GHz at VSWR 2:1. This is 1.14 % bandwidth with center frequency of 3.89 GHz. The result of this antenna is shown in Figure 4.

Similarly, second antenna; a vertically stacked patch antenna without air-gap is shown in Figure 2 with optimized dimensions. The antenna is simulated for optimum impedance matching with respect to feed location and truncated tip. The side length and truncated tip length of parasitic patch is obtained 22.63mm and 2.77 mm respectively. The impedance bandwidth is achieved 52.5MHz from frequency 3.575GHz to 3.6275GHz. This is about 1.5% bandwidth with central frequency of 3.6GHz. This bandwidth is 0.36% more in comparison to simple triangular patch with truncated tip.

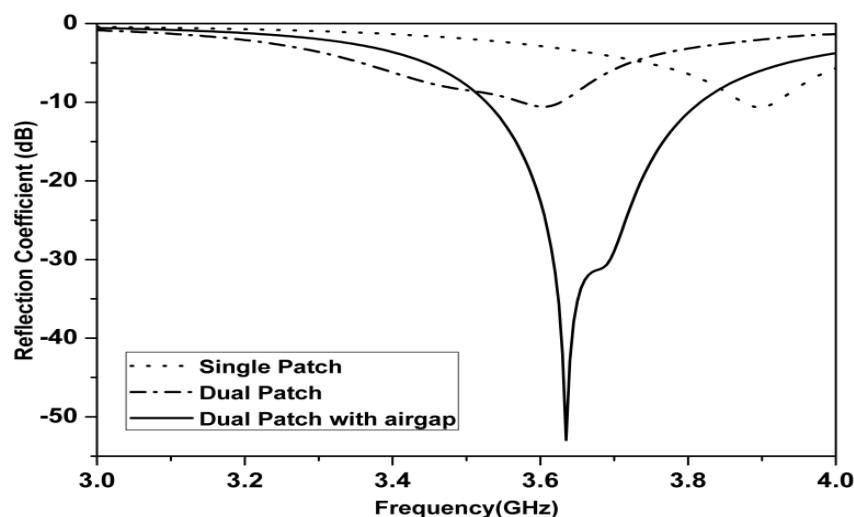


Fig. 4 Return loss(dB) bandwidth of simple, dual patches with and without airgap.

For the 3rd design, multilayer patch antenna with gap is shown in Figure 3 with optimized dimensions. This antenna is optimized for air-gap, truncated tip of parasitic patch, side length of patch and feed position. The optimum impedance matching is obtained for side length of parasitic patch 22.63 mm with truncated tip of 2.77 mm. The air gap between driven and parasitic patches are obtained 0.8mm. With these optimized dimensions, the impedance bandwidth is obtained 289.7MHz from frequency 3.5269GHz to 3.8166GHz. This corresponds to impedance bandwidth of 7.89% with central frequency of 3.672GHz. This is 6.75% more in comparison to 1st antenna structure and 6.39% more in comparison to 2nd antenna structure. The return loss bandwidth of this antenna is shown in Figure 4. It is observed from the all three designs that the return loss bandwidth increases and central frequency decreases for second and third structures in comparison to the 1st structure as shown in Figure 4. The optimized dimensions of all the three antenna structures are tabulated in Table -1 & 2.

S No	Types of patch	Side Length(mm)	Truncated Tip Length (mm)	Resonant freq. f_0 (GHz)
1	Simple Patch	Feeding Patch-24.63mm	Feeding Patch-4.16mm	3.89
2	Dual Patch	Feeding Patch-24.63mm Parasitic Patch-22.63mm	Feeding Patch-4.16mm Parasitic Patch-2.77mm	3.6
3	Dual Patch with Air Gap	Feeding Patch-24.63mm Parasitic Patch-22.63mm	Feeding Patch-4.16mm Parasitic Patch-2.77mm	3.67

Table 1; Optimum dimension & resonant frequency of simple triangular truncated tip microstrip patch, stacked without & with airgap.

S No	Impedance Bandwidth (MHz)	Axial Ratio Bandwidth (MHz)	Average Gain(dB)	Efficiency η (%)
1	44.3MHz	32MHz	4.69dB	53.92%
2	52.5MHz	47.3MHz	3.97dB	55.96%
3	289.7MHz	58.8MHz	5.082dB	67.38%

Table 2; shows Return loss bandwidth(MHz), Axial Ratio bandwidth(MHz), Average Gain(dB) & Efficiency(%)

All the three circular polarized antennas are presented for wide axial ratio bandwidth. The axial ratios of all three antenna structures are shown in Figure 5. It is observed from the axial ratio for the simple triangular patch with truncated tip is achieved 32MHz from frequency 3.8765GHz to 3.9085GHz at 3 dB axial ratio. This is about 0.82% axial bandwidth with f_0 of 3.89GHz. For 2nd antenna structure, the ARBW is 47.3MHz from frequency 3.5841GHz to 3.6314GHz. This is about 1.31%. For vertically stacked patch air gap 0.78 mm between driven patch and parasitic, the ARBW is 66.8MHz from range of frequency 3.6313GHz

to 3.6898GHz. This is about 1.6% ARBW with f_0 of 3.66GHz. The ARBW increase in case of stacking with & without air gap in comparison to 1st antenna structure.

The average gain in dB versus frequency are also presented for all the three antennas. The average of simple truncated tip triangular patch at center frequency is 4.69dB. The average gain for parasitic element with and without air-gap is 3.97 and 5.085dB respectively. The average gain of three antenna are shown in Figure 6. It is observed that average gain is better for multilayer antenna structure with air-gap.

The radiation efficiency of these three antennas are also plotted in figure 7. It is observed from results that radiation efficiency of multilayer antenna with space dielectric is better than without air-gap and simple truncated tip triangular patch. This is because the air-gap effect reduces the dielectric loss of antenna which increase the radiation efficiency.

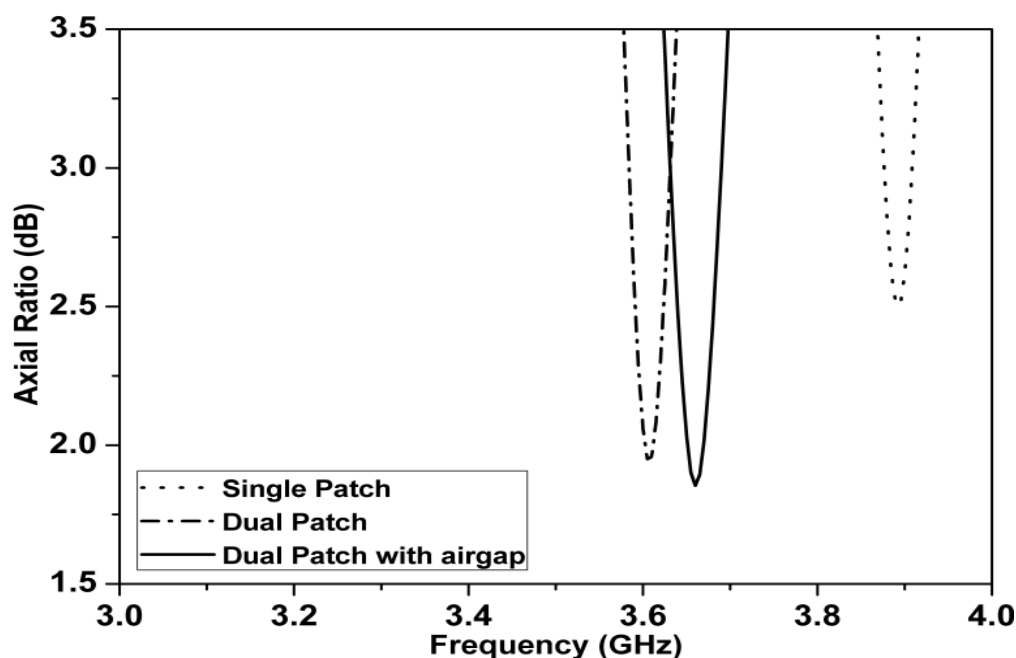


Fig. 5 Axial ratio of simple, dual patches with and without airgap.

The antennas' radiation patterns of 1st, 2nd and 3rd structure are shown in figure 8. It is observed that all antenna structure radiated left hand circular polarized wave in upper hemisphere (+z direction). All these antennas have cross polarization more than 20dB. It is also observed from the figure 8(b) and (c) that the beam width of radiation patterns decreases due to the effect of multilayer structure. Figure 9 shows the photograph of the printed antenna structures.

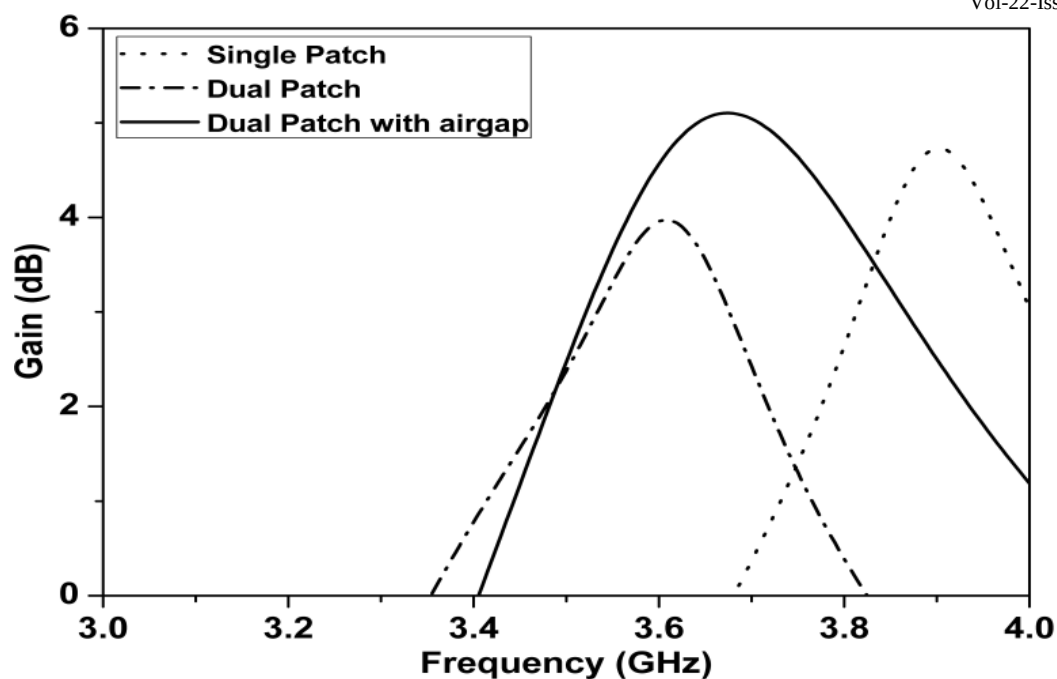


Fig. 6 Average gain (dB) of simple, dual patches with and without airgap.

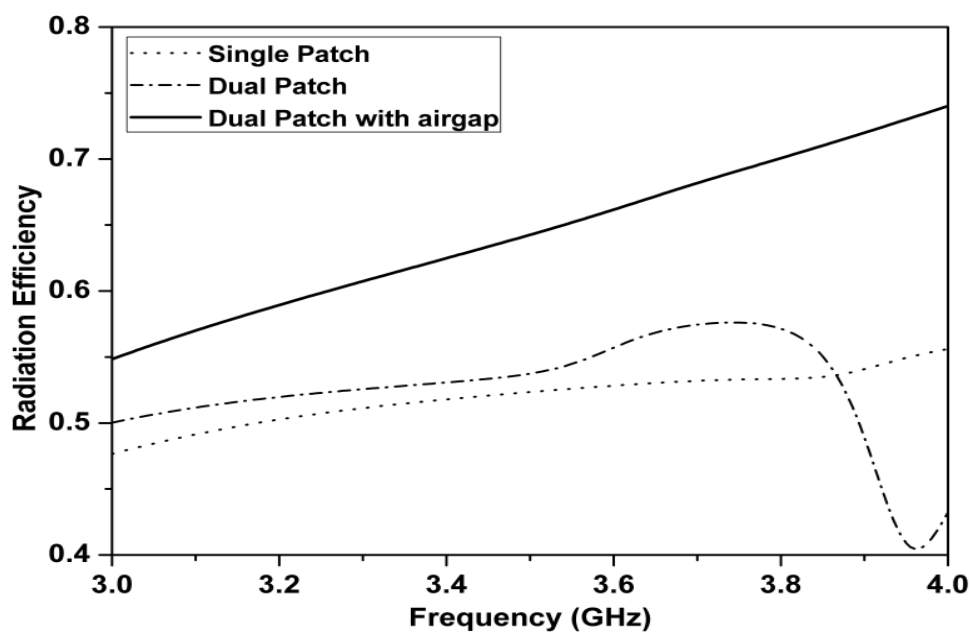


Fig. 7 Radiation efficiency of simple, dual patches with and without airgap

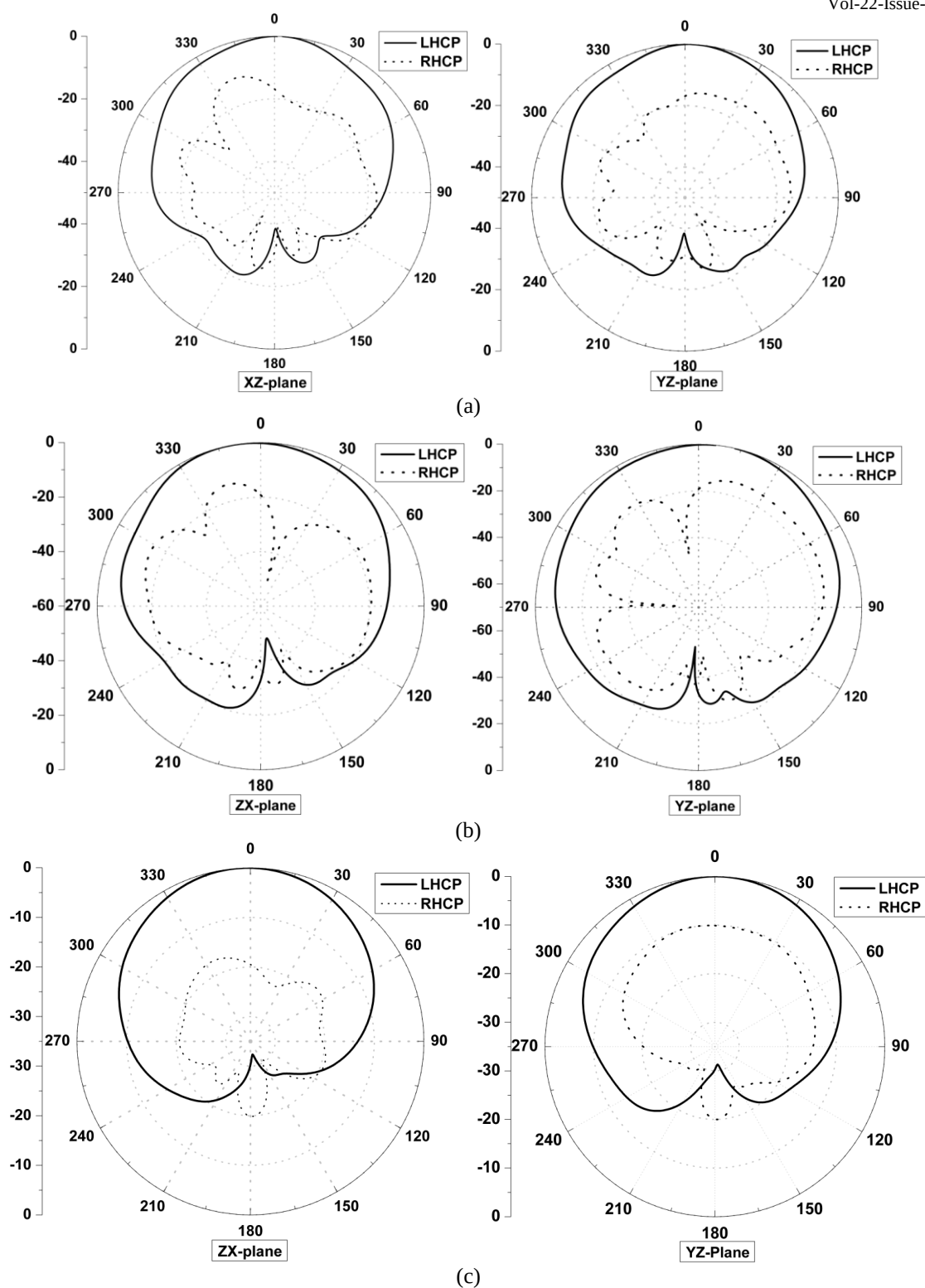


Fig. 8 Radiation patterns in XZ- and YZ-plane of: (a) 1st antenna structure at 3.89 GHz, (b) 2nd antenna structure at 3.61GHz and (c) 3rd antenna structure at 3.66GHz

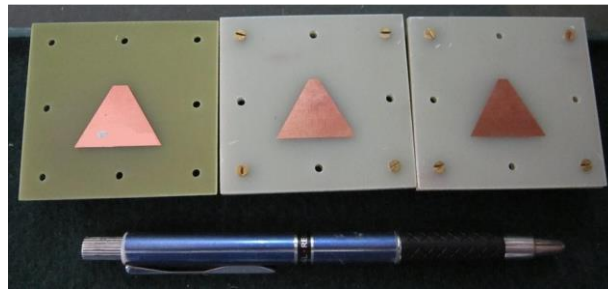


Fig. 9 Photograph of the fabricated antenna structures

V. CONCLUSION

In this paper, comparative study of simple truncated tip patch is vertically stacked with parasitic patch with & without air gap is presented. The impedance bandwidth of 3rd antenna structure is achieved more than 1st and 2nd antenna structures. The axial ratio bandwidth of 3rd antenna structure is obtained is 0.39% more than 2nd antenna structure & 0.62% more in comparison of 1st antenna structure. The average gain & efficiency has been achieved more for 3rd antenna structure. The radiation pattern of XZ and YZ-plane also studied. It is observed that 3rd antenna structure gives the best performance in terms of impedance bandwidth, axial ratio bandwidth, gain, radiation, efficacy and beam width in comparison to 1st and 2nd antenna structures. These antennas structure are easy to fabricate and can be used in wireless communications.

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