

## Performance Enhancement of Modified Multiband Stacked Microstrip Patch Antenna for Wireless Communication

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**Abstract:** This paper proposes a modified multilayer Aperture Coupled Stacked Microstrip patch antenna. The multiband Circular Polarization is achieved by corner truncation, embedding slits and introducing inclined slots. A good quality Circular Polarisation performance is achieved by varying the size of the inclined slots and four corner truncations. In the third layer, additional central sphere is introduced providing wide bandwidth. Optimization is achieved by variation of the patch parameters. Finally, a comparison is made with respect to the number of layers of the antenna. The proposed design provides good results with three layers, achieving optimization. The Stacked Patch antenna provides better mobility, better orientation between the transmitter and receiver than the Linearly Polarized Antenna. The Satellite Communication performs better in C band (4-8) GHz and in X band (8-12) GHz than in Ku band (12-18) GHz. The objective is to obtain low axial ratio at the desired frequencies.

**Key words:** Circular Polarisation • Axial ratio • Microstrip patch Antenna • Aperture Coupled feed

### INTRODUCTION

The microstrip antenna is one of the most commonly used antennas in applications that require circular polarization. Microstrip antennas are popular for wireless communication as far as they offer the benefits of low profile, low weight, compact, conformal to surfaces, easy fabrication. Microstrip antennas have inherent disadvantage of narrow bandwidth and low gain [1-3]. The techniques to increase impedance bandwidth of patch antennas such as aperture coupled feed, corner truncation, inclined slots and slits are proposed.

Circularly polarized (CP) antennas are increasingly important in wireless communications, since they allow signal reception irrespective of the orientation of the receive antenna with respect to transmit antenna [4, 5]. It also suppress Multipath Interference. CP antennas are widely used in portable devices. For example RFID reader antenna, WLAN, GPS and mobile phone etc [1].

The parameters for CP patch antennas are the VSWR < 2 or S<sub>11</sub> < -10dB and the axial ratio bandwidth (AR < 3dB) [6]. The use of CP antennas presents an attractive solution to achieve this polarization match. When receiving a CP wave, the antenna orientation is not

important to be in the direction perpendicular to the propagation direction allowing more probability [7]. In general microstrip antenna on its own doesn't generate circular polarization. Subsequently some changes should be done to the antenna [4]. In the proposed design, three layers is introduced where in the foam material is used as a substrate, with copper as the conducting ground.

The paper is organized as follows. In section II design parameters of the antenna is introduced. In section III detailed analysis of the design is done and results are observed. Section IV concludes the paper.

### Design Parameters

**Basic Patch Antenna Design and Geometry:** In its most basic form, a Micro strip 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 basic design of rectangular micro strip patch antenna is considered here.

**Antenna Design:** The conventional micro strip antenna design method is used here. Designing the patch antenna is to employ the following equations (1-4):

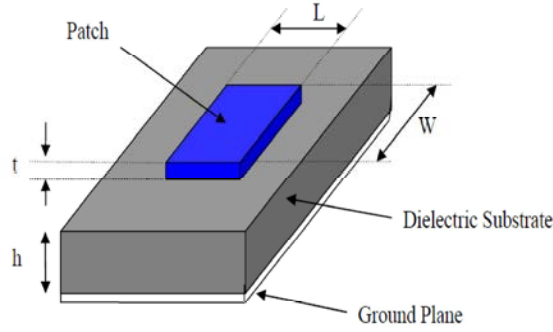


Fig. 1: Structure of Micro strip antenna

$$W = \frac{C}{2f_r} \sqrt{\frac{2}{\epsilon_r + 1}}$$

where;

c - Free space velocity of light,  $3 \times 10^8$  m/s

f<sub>r</sub> - Frequency of operation

$\epsilon_r$  - Dielectric constant

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left( 1 + \frac{12h}{W} \right)^{-0.5}$$

where,

$\epsilon_r$  - Dielectric constant

h - Height of dielectric substrate

W - Width of the patch

$\epsilon_{reff}$  - Effective dielectric constant

$$L_{eff} = L + 2\Delta L$$

where,

$L_{eff}$  - Effective length

$\Delta L$  - Change in length

Patch length extension ( $\Delta L$ ):

$$\Delta L = 0.412 \frac{h(\epsilon_{reff} + 0.3) \left( \frac{w}{h} + 0.264 \right)}{(\epsilon_{reff} - 0.258) \left( \frac{w}{h} + 0.8 \right)} \quad (4)$$

The Figure 2 shows the structure of proposed antenna developed with stacked patches consisting of three layers with foam substrate, aperture feeding technique and copper as conducting ground.

The optimization is obtained by truncating the corners of the patch and by introducing inclined slots and slits in the patches. Since the circular polarization cannot be obtained directly, the slits and subsequent slots has to be adjusted in accordance with the patch dimension.

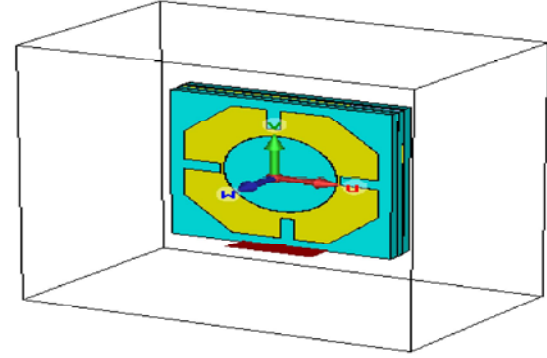


Fig. 2: Structure of proposed stacked patch antenna (three layers) using CST studio suite (perspective view)

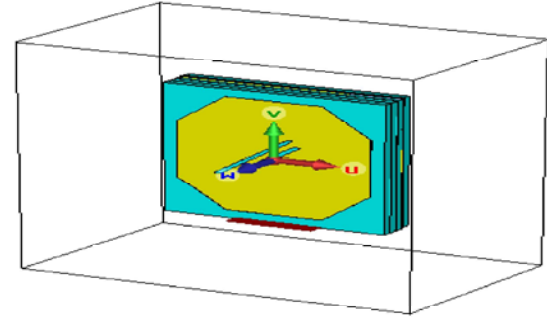


Fig. 3: Structure of proposed stacked patch antenna (four layers) using CST studio suite (perspective view)

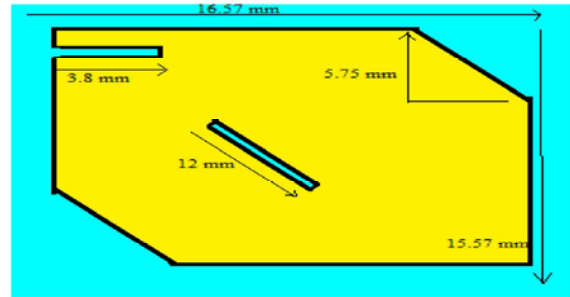


Fig 4: Bottom patch of the proposed (3 layer) stacked patch antenna

The Figure 4 shows the bottom patch of which the first patch is designed with two corners truncations, an inclined slots and a slit at the corner of the patch.

The Figure 5 shows the second layer patch which is designed with two corners alone truncated since it provides more optimization when truncated with two opposite corners. Embedding slits introduced in the first patch is increased to two slits in the second patch and the same dimensions are carried out as of patch 1. A central sphere is introduced with radius equal to 4.25 mm.

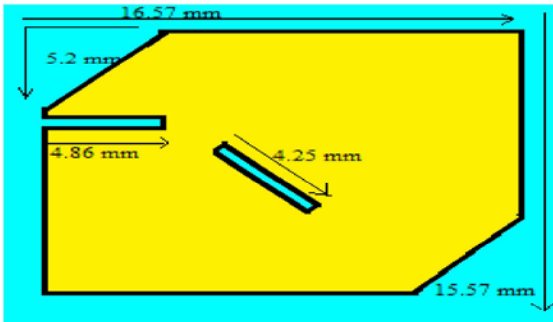


Fig 5: Second layer patch of the Proposed (3 layer) Stacked patch antenna

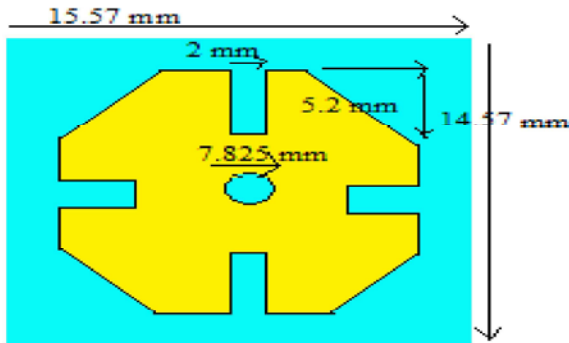


Fig 6: Middle patch of Proposed Stacked Patch antenna

The Figure 6 shows the third patch which is designed with embedding slits at the four edges and truncation is done on all the four corners. The same foam material is used as a substrate here. An additional central sphere introduced to the center with radius 7.825 mm.

The feed technique used is the aperture coupled feeding. The advantage of stacked patch antenna is such that when a feed is connected to one. The patches are all excited with a common aperture coupled feed with the view of tolerating the changes in the polarization signal. The introduction of gap between the substrate and the patch shows the variation in bandwidth. This type of antennas are designed to provide improved bandwidth and axial ratio < 3 dB.

## RESULTS AND DISCUSSIONS

Various parameters are obtained using the design analysis using CST Studio suite.

The Figure 7 shows the S-parameter plot of the antenna design developed with four layers. S-parameter refers to the ratio of voltage out versus voltage in. S-parameters are a frequency domain description of the electrical behavior of a network. The return loss is also observed to be -11.1, -20.2 and -15.2 for the multiband frequencies obtained at 4.4 GHz, 8.2 GHz and at 10.1 GHz.

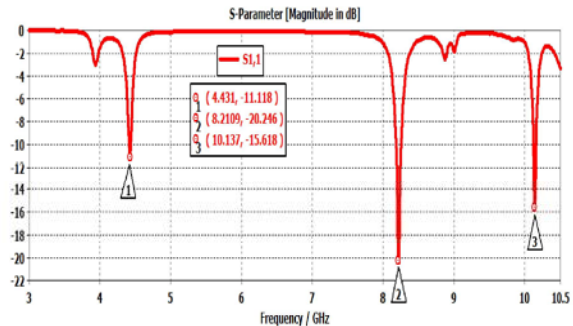


Fig 7: S-parameter plot of the four layered Stacked Patch antenna

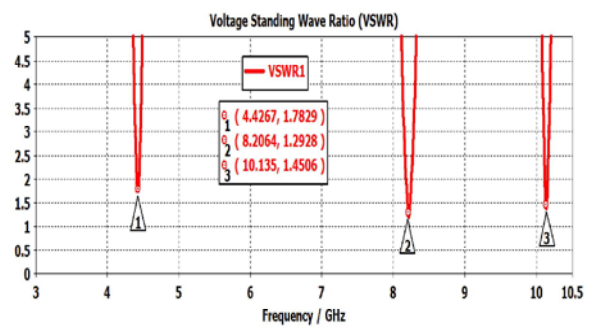


Fig 8: Voltage Standing Wave Ratio plot of the four layered Stacked Patch Antenna

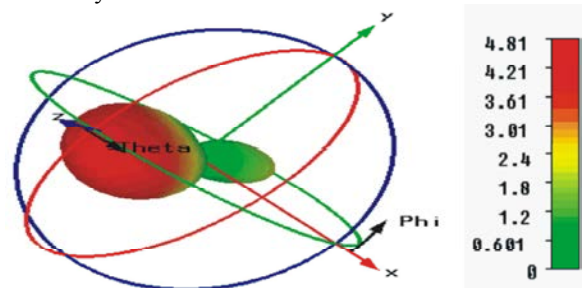


Fig 9: Directional radiation pattern of the four layered stacked patch antenna at 4.4 GHz

The Figure 8 shows the Voltage Standing Wave Ratio plot. VSWR plot is a measure that conveys how well the system is matched and how much of energy is getting into the antenna. If the VSWR is low, it says the how well the antenna is matched. The VSWR, when it is observed to be low also conveys that it is good for amplifier load effects. The VSWR is observed to be 1.7 for 4.4 GHz, 1.2 and 1.4 for 8.2 and 10.1 GHz respectively.

The Figure 9, 10 and 11 shows the Directional radiation pattern of the antenna designed with four layers. Directivity is a Figure of merit of an antenna. Here the directivity is observed to be around 4.81 dB for the frequency 4.4 GHz, 3.45 dB for 8.2 GHz and 4.06 dB for 10.1 GHz respectively.

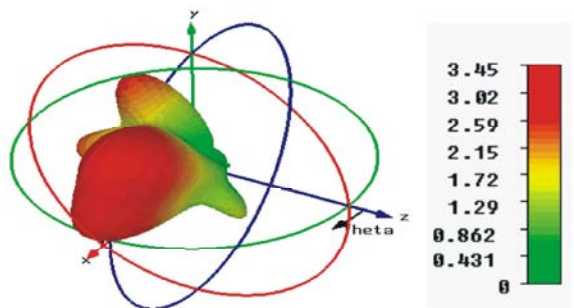


Fig 10: Directional radiation pattern of the four layered stacked patch antenna at 8.2 GHz.

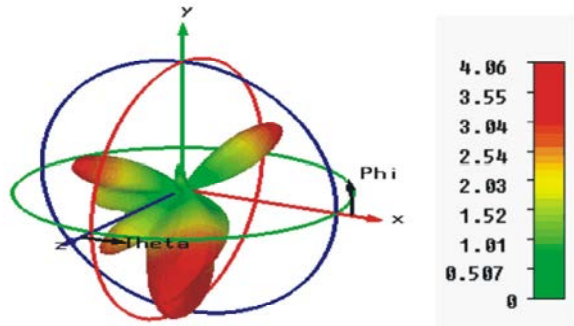


Fig 11: Directional radiation pattern of the four layered Stacked Patch antenna at 10.1 GHz

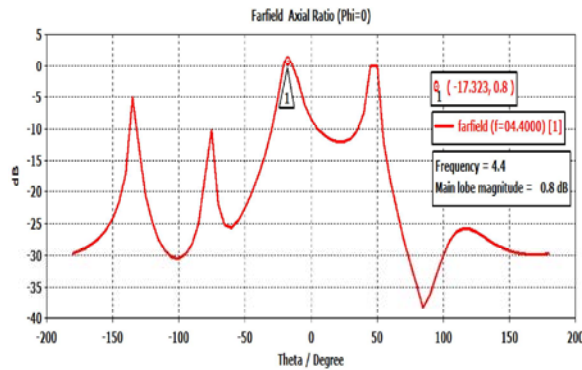


Fig 12: Axial Ratio of the four layered Stacked Patch antenna at 4.4 GHz

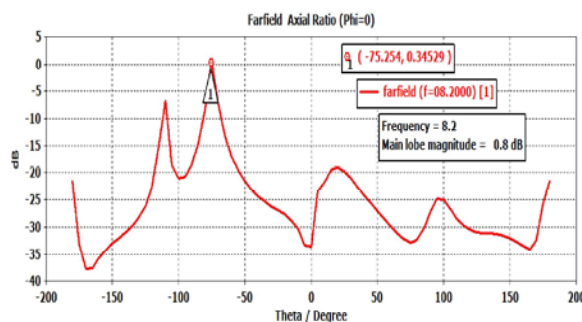


Fig 13: Axial Ratio of the four layered Stacked Patch antenna at 8.2 GHz

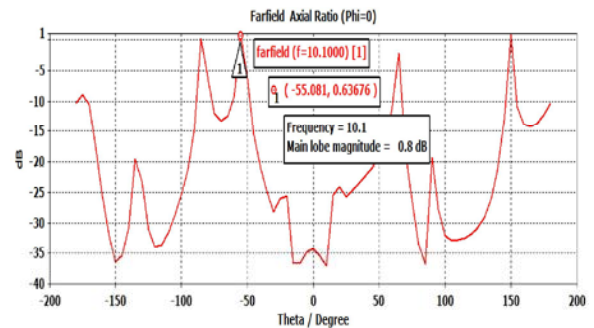


Fig 14: Axial Ratio of the four layered stacked patch antenna at 10.1 GHz

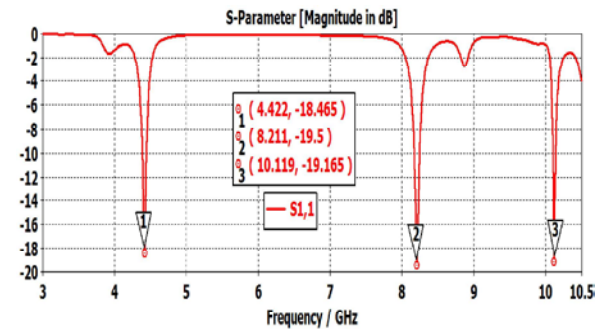


Fig 15: S parameter plot of the proposed three layered stacked patch design

The Figure 12, 13 and 14 shows the axial ratio of the three layered stacked patch antenna. For circular polarization, it should be 1 or 0 dB. The measures of axial ratio for particular frequencies are 0.8 dB, 0.8 dB and 0.8 dB for 4.4 GHz, 8.2 GHz and 10.1 GHz respectively.

The same set of parameters are observed with three layers of stacked patch design using aperture coupling technique and it is inferred that it provides good performance parameters than the four layered stacked patch design. It is validated by the simulation results carried out providing minimized return loss, improved bandwidth and d

The Figure 15 shows the S parameter plot of the antenna design carried out with three layers, at same frequencies as that of four layers. This design produces good return loss of -18.4, -19.5 and -19.165 for 4.4 GHz, 8.2 GHz and 10.1 GHz respectively.

The Figure 16 shows the Voltage Standing wave ratio plot of the proposed three layered stacked patch structure. It is found to be 1.271, 1.238 and 1.2578 for three different frequencies.

The Figure 17, 18 and 19 shows the directional radiation pattern of the proposed three layered stacked patch design which provides better directivity of 5.39 dB, 3.45 dB, 5.07 dB at 4.4 GHz, 8.2 GHz and at 10.1 GHz respectively.

Table 1: Comparison between three layer and four layer stacked patch antenna

Parameters	Frequency					
	4.4 Ghz		8.2 Ghz		10.1 Ghz	
	Three Layers	Four layers	Three layers	Four layers	Three layers	Four layers
AXIAL RATIO	0 dB	0.8 dB	0 dB	0.8 dB	0 dB	0.8 dB
RETURN LOSS	-18.465	-11.2	-19.5	-20	-19.16	-15
DIRECTIVITY	5.39 dB	4.81 dB	3.45 dB	3.45 dB	5.07 dB	4.06 dB
VSWR	1.271	1.238	1.257	1.78	1.29	1.45
BANDWIDTH	283 MHz	191 MHz	276 MHz	214 MHz	207 MHz	168 MHz

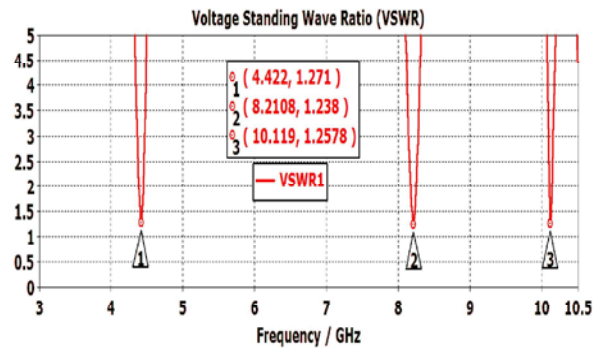


Fig 16: Voltage Standing wave ratio plot of the proposed three layer stacked patch design

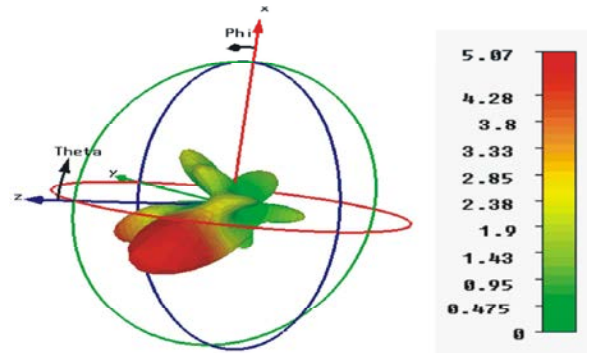


Fig 19: Directional Radiation pattern of the proposed three layer stacked patch design at 10.1 Ghz

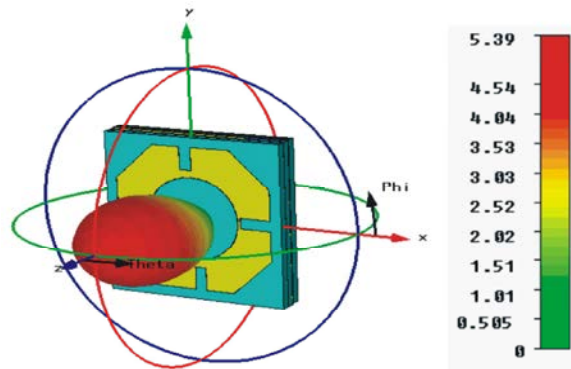


Fig 17: Directional Radiation pattern of the proposed three layer stacked patch design at 4.4 Ghz

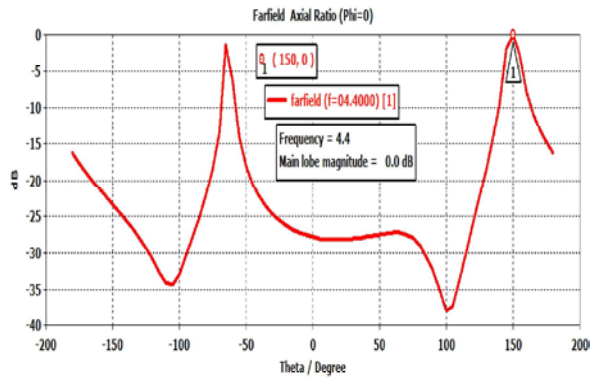


Fig. 20: Axial Ratio of the proposed three layered stacked patch antenna at 4.4 Ghz

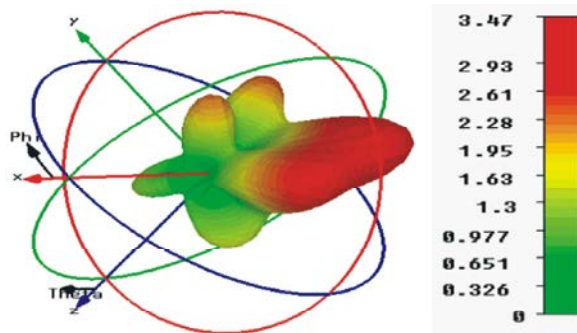


Fig 18: Directional Radiation pattern of the proposed three layer stacked patch design at 8.2 Ghz

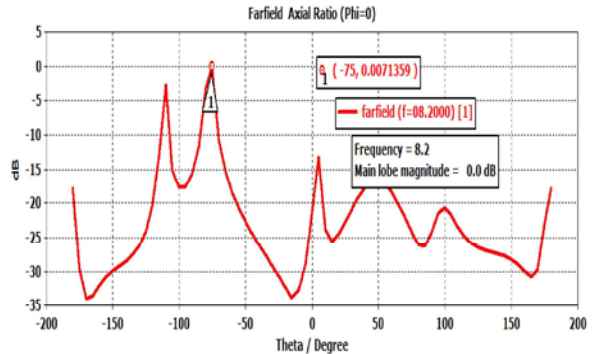


Fig. 21: Axial Ratio of the proposed three layered stacked patch antenna at 8.2 Ghz



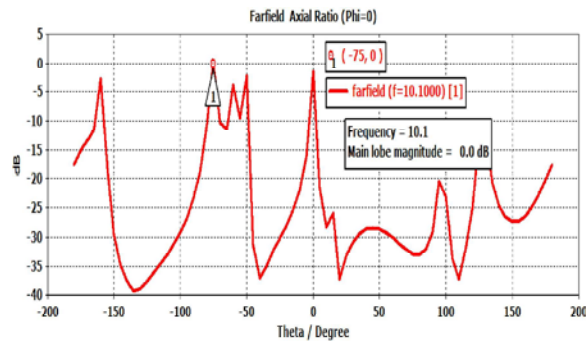


Fig. 22: Axial Ratio of the proposed three layered stacked patch antenna at 10.1 Ghz

Therefore the performance parameters are compared for the three layered and four layered design and it is found that better results are obtained using three layered stacked patch antenna providing miniaturization. The results are tabulated in the Table 1.

## CONCLUSION

In this paper a modified multilayer Aperture Coupled Stacked Microstrip patch antenna is proposed. It is observed that the return loss is reduced and good performance parameters are obtained like wide bandwidth in a three layered structure than four layer, thereby miniaturization is achieved. The axial ratio equal to 0 dB is obtained for circular polarization condition. The proposed antenna designed for C band and X band performs well in satellite downlink than in Ku band under adverse weather conditions. The Circularly Polarized stacked patches are substantially gaining importance in wireless communications.

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