ISSN: 2096-3246
Volume 55, Issue 09, September, 2023

# Design And Development Of Enhanced Gain Stacked Patch Antenna

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**Keywords:**
Inset feed, microstrip, slots, stacked, X-band

**ABSTRACT**

This paper includes design and development of patch antenna for X-band communication. Overall substrate dimension is 35 x 30 x 4.7mm3. The simulated results show that the bandwidth obtained is 9.41-11.54GHz.due to application of stacking their overall gain is found to be 7.40 dB. Thenatennais printed on FR4 and Arlon CuClad 233 with a dielectric constant of 4.4 and 2.33 respectively with a gap of 1.5mm are introduced.



## 1. INTRODUCTION

In the era of rapid growth in the wireless communication, there is requirement of constant update in the case of antenna technology. The microstrip patch antennas have attractive features of light weight, low profile, ease of fabrication and conformal to mounting surface. These advantages lead to application of microstrip patch antenna in variety of fields like aircraft, missiles, mobile communication, satellite communication, GPS systems, remote sensing, etc. The microstrip antenna has a major drawback of narrow bandwidth [1]. In order to overcome this problem, various methods have been introduced and implemented by researchers. One of the methods of improving the bandwidth is stacking of the antenna, i.e. using a parasitic layer and a patch [2].

In stacked configuration [3- 6], two or more patches are vertically placed upon on another and built like a multilayer printed circuit board (PCB). This configuration leads to increase in the overall height of the antenna, but the size in the planar direction remains the same as that of a single patch. The lower patch is called driven patch or feeding patch and the other patch is called parasitic patch or radiating patch. The other patches are excited through electromagnetic coupling from the bottom patch [7]. The patches can be fabricated on either same or different substrate. If the dielectric constant of lower layer is higher than the top layer, then the magnitude of the first order mode on the lower patch is greater than on the top patch. Thus, broadest bandwidth can be obtained. The stacked antenna configuration can also be used to create a dual band antenna [8].

Locker has proposed two stacked bow-tie patch configuration for stacking and overall bandwidth of 9.56-12GHz is observed. The simple structure of antenna is fed through 50 ohm microstrip feed line and it has an efficiency of about 85% [9]. Further, [10] described an antenna in stacked configuration for multiband operation. The dimension of the antenna is 30x30mm$^2$. A H-shaped parasitic patch is shown in the paper, placed above the feeding patch. The antenna is fed through 50 ohm microstrip feed line. 4 resonant frequencies are obtained through this antenna. FR4 and Rogers RT/duroid 5880 are used as substrates. As given in [11], stacked antenna provides a bandwidth of 38% having peak gain of 5.9 dB. F-probe fed stacked antenna [12] where wide bandwidth is achieved at the expense of increase in antenna volume.

In this paper, an antenna with H-shaped slot in the bottom patch for X-band communication is presented. The antenna yields a wideband as well as good gain is achieved. The paper is categorized into different sections, where antenna structure is discussed in Section II, performance parameters of the antenna is elaborated in Section III and Section IV states the conclusion and future scope of the following antenna is proposed.

## 2. ANTENNA OVERVIEW

Fig. 1, Fig. 2, Fig. 3, Fig. 4, illustrates the overall geometry of the proposed antenna. FR4 and Arlon CuClad 233 have been used as substrate. The bottom patch is fabricated on substrate with a high dielectric constant, while top patch is fabricated on substrate which has a low dielectric constant [13], [14]. Thickness of both substrates is 1.6mm (h1 = h2). Distance (ha) between the substrates is 1.5mm. The space between the feeding patch and parasitic patch forms two types of resonators, which depends on distance. Fig. 1 shows the dimension of the bottom patch. The bottom patch has length of 25mm and width of 20mm. Slots on both sides of the patch are made, having length of 14mm and width of 1mm. A H-shaped slot is made whose dimension is shown in figure. A parametric study has been shown for the slots below. Variable a, b, c, d, e, f, g and h represent slots which have been studied below.

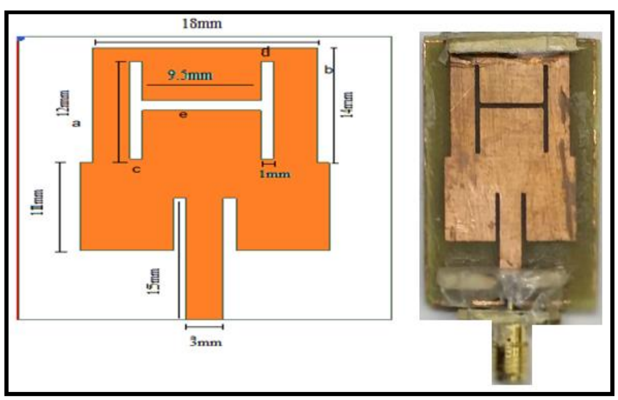



**Fig.1.** Lower (feeding) patch geometry

Fig. 2 shows the gap between two substrates. Fig. 3 shows the top patch dimensions of the proposed design and Fig. 4 shows the ground plane. 50 ohm inset feeding has been used to provide to the antenna.

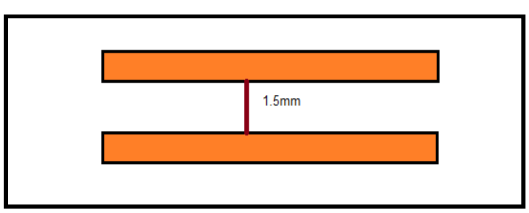



**Fig.2.** Gap between the stacked antennas.

ISSN: 2096-3246
Volume 55, Issue 09, September, 2023

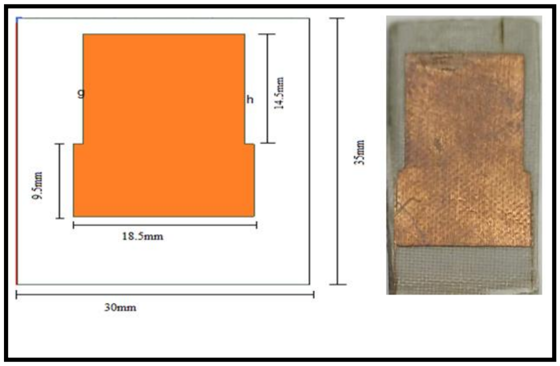


**Fig.3.** Top patch dimensions.

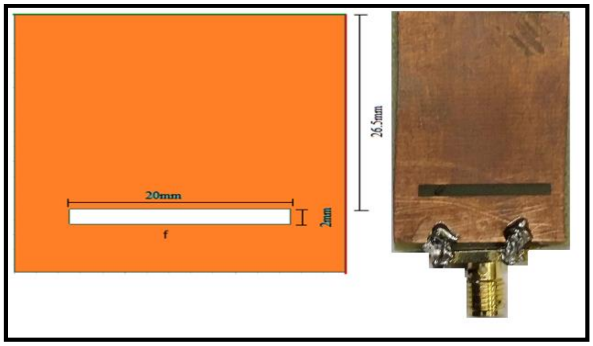


**Fig.4.** Ground plane dimension

## 3. RESULT AND DISCUSSIONS

The main motive is to design a microstrip stacked patch antenna with improved bandwidth and gain, which satisfies various parameters. The simulation work of the prototype antenna has been done using HFSS software. A parametric study has been presented in this paper. The characteristic of stacked antenna depend strongly upon the distance between the parasitic patch and the feeding patch. When parasitic patch is close to the bottom patch, the antenna in stacked configuration has two resonant frequencies close to one another. This happens because resonant mode of the parasitic patch is almost the same as the primary mode of feeding patch. These patches lead to formation of a leaky resonator when distance between the patches is approximately half the wavelength. As a result, this resonant field enhances the antenna gain.

### A. RETURN LOSS

The return loss for the corresponding prototype antenna has been illustrated in Fig. 5. It can be seen that two resonating frequencies and bandwidth are obtained in different cases. These two resonating frequencies are generated due to two patches which have been used in the prototype design. The final design shows a wideband which has been obtained after proper optimizations. The resonant frequencies are close to one another, which results in creation of wideband. Generally resonance frequency of top patch is more than the bottom patch. The effect of slots is seen in the figure. Table I illustrates the resonant frequencies and bandwidth obtained when different slots were made in order to reach the final prototype antenna. The shape and size of top patch also plays an important role in stacked configuration.

Fig. 6 shows the effect of change in gap between the substrates. Return loss gives the idea of how much efficiently antenna is transmitting power. It is generally measured in dB. The variation in return loss is observed with shifting the gap between the two substrates. Good matching is obtained at h= 1.5mm, where two resonant frequencies 9.8 GHz and 10.3 GHz with return loss of 35.98 dB and 49.57 dB respectively could be observed. The simulated impedance bandwidth (VSWR<=2) is 21.73% from 9.41 to 11.54 GHz has been achieved.

**Table-I** Estimated Performances of Prototype Antenna

| Parameters | Resonating Frequency (GHz) | Return loss (dB) | Bandwidth (GHz) |
|---|---|---|---|
| No slots | 9.006 | 10.1 | 0.03 |
| Slot f | 9.92 | 15.91 | 0.9 |
| | 11.20 | 28.49 | 0.55 |
| Slots f, a and b | 9.98 | 16.40 | 1.02 |
| | 11.32 | 37.13 | 0.57 |
| Slots f, a, b, g, h and e | 9.86 | 16.54 | 0.9 |
| | 11.16 | 28.22 | 0.98 |
| Slots f, a, b, g, h and c | 10 | 41.89 | 2.01 |
| | | 14 | |
| All slots | 9.8 | 35.98 | 2.13 |
| | 10.3 | 49.57 | |

**Table-II** Estimated Performances of Prototype Antenna

| Parameters | Values |
|---|---|
| Bandwidth Range | 9.41-11.54 GHz |
| Gain | 7.40 dB |
| Resonating Frequency | 9.8 GHz and 10.3 GHz |
| Gap between two substrate | 1.5mm(proposed) |
| Efficiency | 85.23% |

Empirical dielectric constant can be calculated using (1).

$$\epsilon_{reff} = \frac{h_1 + h_a + h_2}{\frac{h_1}{\epsilon_{r_1}} + \frac{h_a}{\epsilon_{r_a}} + \frac{h_2}{\epsilon_{r_2}}} \quad (1)$$

The calculated empirical dielectric constant is found to be 1.8147. It is known that bandwidth can be enhanced by increasing the height of the substrate and decreasing effective dielectric constant. The patch on Arlon CuClad 233substrate is place on its upside position and introduction of air gap with $\epsilon_r$= 1.0006 leads to further increase in overall height and decrease in net dielectric constant which has been calculated using (1). The two patches and gap is acting as a capacitor and its value should be kept low which can be done by decreasing dielectric constant of the material or increasing the gap. This air gap controls the coupling [15].

These slots are cut into the bottom patch leading to change in current distribution, making current to cover extra patch along the slots. Thus, the fundamental mode of antenna is overlapped and a higher mode is created which overlaps the original bandwidth.

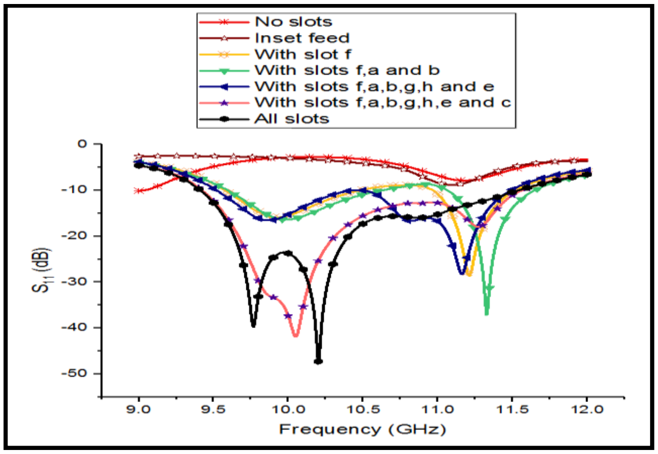



**Fig.5.** Effect of slots on the proposed antenna

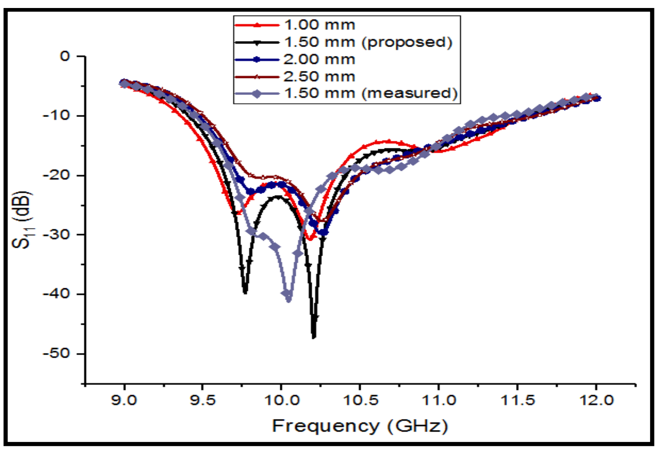



**Fig.6.** Effect of gap on the proposed antenna

**Fig.7.** Measurement of the fabricated antenna using VNA

**B. RADIATION EFFICIENCY, CURRENT DISTRIBUTION, GAIN AND RADIATION PATTERN**

The simulated radiation efficiency of 85.23% is achieved for the proposed design. It has been illustrated in Fig. 8. Fig. 9 shows the current distribution for the antenna. It can be seen that current is flowing though the microstrip line which has been used for the feeding. The top patch is excited through electromagnetic coupling from the bottom patch. 7.62 dB of gain is achieved for the proposed design, as shown in Fig. 10. Radiation pattern shows the variation of power which is radiated by the antenna in different direction far from the antenna. The radiation pattern of the prototype antenna for X-band application at resonant frequencies 9.8 GHz is displayed in Fig. 11 and 10.3 GHz is displayed in Fig. 12. The ripples in the radiation pattern is mainly due to finite metallic ground plane. In all the cases, intensity of co-polarised antenna is maximum in comparison with cross-polarised antenna [16- 18].

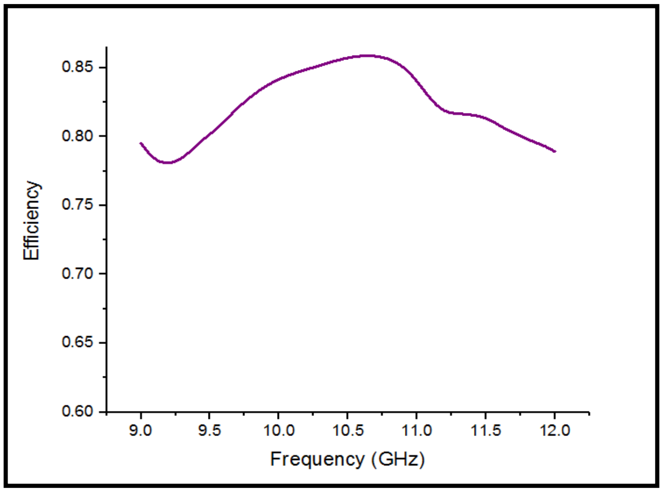
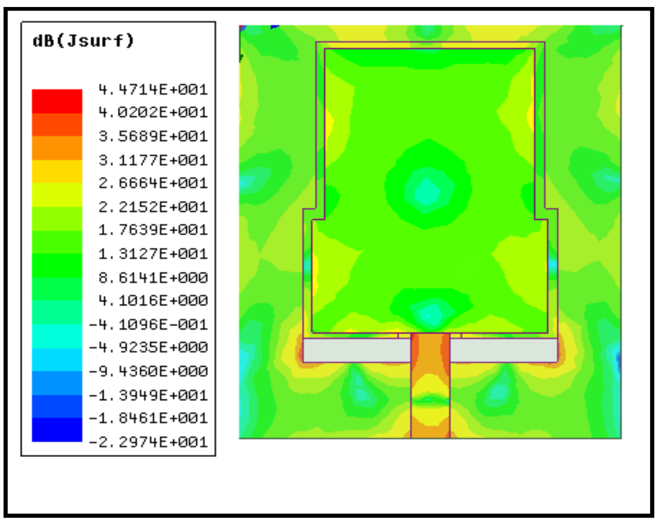
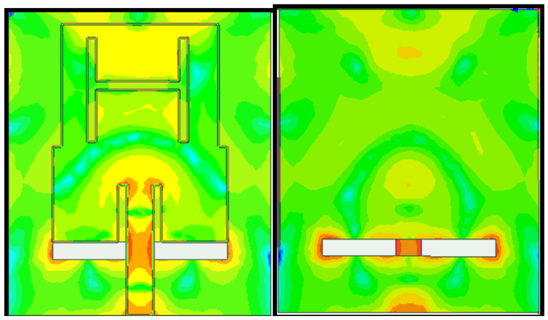



**Fig.8.** Efficiency of the proposed antenna.




(a) Top patch



(b) Bottom patch (c)Ground

**Fig.9.** Current distribution of the prototype antenna

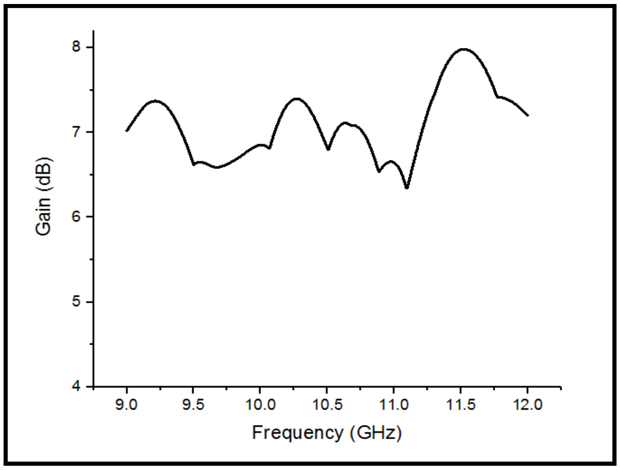
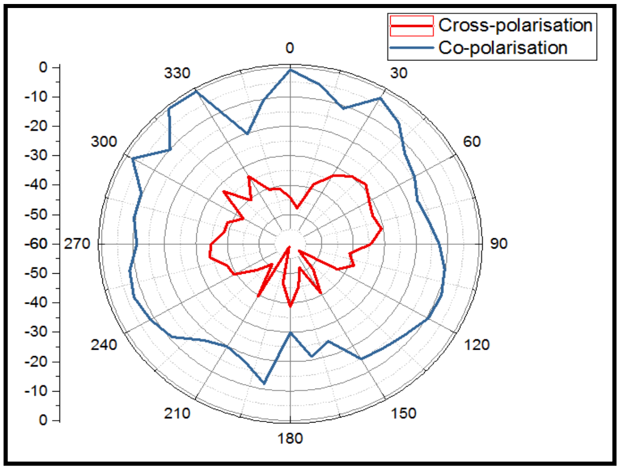
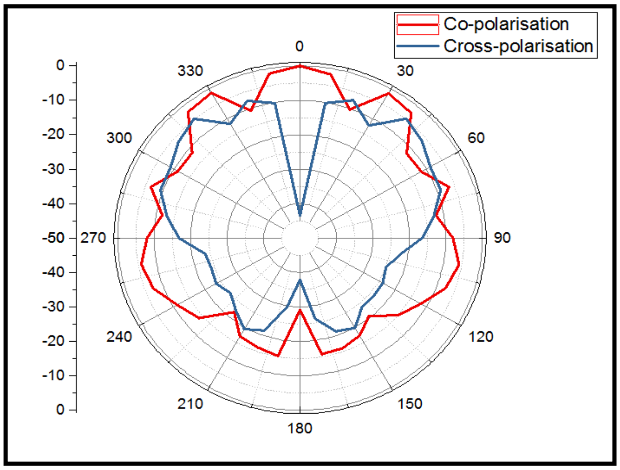



**Fig.10.** Gain of the proposed antenna.

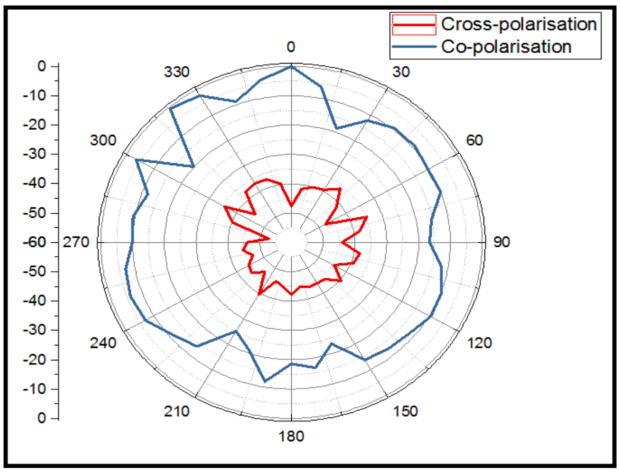



(a)

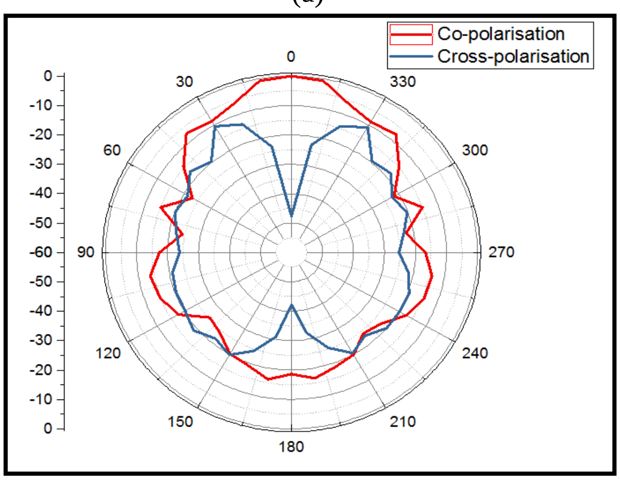



(b)

**Fig.11.** Radiation pattern at 9.8 GHz (a) E- plane (b) H-plane.




(a)




(b)

**Fig.12.** Radiation pattern at 10.3 GHz (a) E- plane (b) H-plane.

## 4. CONCLUSION

An inset fed stacked antenna was proposed. The antenna allows efficient operation over the frequency range with a relative bandwidth of 21.73%. The layout is simple and easy for fabrication. Return loss of 35.98 dB and 49.57 dB for 9.8 GHz and 10.3 GHz respectively is achieved with a gain of 7.4dB and efficiency of

85.23%. The proposed antenna has utilisation in satellite communication, radar technology, terrestrial broadband communication, etc.

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