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# A linearly polarized slotted rectangular microstrip patch antenna for WLAN application

**Mandeep Singh Heer and Vikrant Sharma***

GNA University, Phagwara, Punjab, India.

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**ABSTRACT**

A linearly polarized rectangular patch antenna having a small slotted geometry is discussed in this paper. The designed antenna can perform effectively from 3-4 GHz and the resonant frequency is a comparable find from 3.41 to 3.44 GHz, in which return loss is approximately -25 dB to -27 dB. The obtained bandwidth is approximately around 13%. The proposed antenna is designed on flame retardant FR-4 glass-reinforced epoxy dielectric material and fed by a simple coaxial probe feed method. In the patch, to design the desired path with suitable results like bandwidth, directivity and impedance matching a finite truncation ground technique is proposed. A 3.35 dB gain is obtained by providing a symmetric cut in a patch, which is quite an acceptable result obtained in such a frequency range. Further gain will be improved by varying the size material of the patch and substrate material. Various results due to ground truncation in plane or patch can be calculated and discussed in this paper, parameters like bandwidth, gain, efficiency and radiation characteristics. Mostly ground truncation is done to improve bandwidth parameters.

**Keywords:** LAN (local area network), WLAN (wireless local area network), MPA (microstrip patch antenna), NEMA (National Electrical Manufacturers Association), SAR (specific absorption rate), EMI (electromagnetic interference).

*Corresponding author. E-mail: vikrant.sharma@yahoo.com.

## INTRODUCTION

Equipment that are made in modern communication system nowadays is developed on wideband broadband and narrowband antenna designs which has the advantage of small size, lightweight low profile, high bandwidth which is used or designed for a vast and better communication field and equipment. Between portable devices, sensors, and computers, LAN techniques like Wireless local area network (WLAN) are more applicable and very soon replaced the short distance communication channels or links (Sharma et al., 2008). Various MPAs are used in various wireless applications and most commonly antennas are Rectangular MPA, Elliptical MPA and Circular MPA. Microstrip antennas have higher bandwidth and lower bandwidth, but due to various factors like narrow bandwidth, low gain and impedance mismatching, there is also various drawback in the field of communication. MPA can be easily fabricated by various techniques which include CVD, Lithography, etching techniques and more methods like PCB fabrication and printing masks on wafers. To remove various drawbacks different methods can be adopted such as addition or cuts of slots on patch, ground truncation, pin short methods, operating frequency change, the height of ground and substrate can be varied, and the material of patch is changed for improved and better results (Sharma et al., 2011a). When the surface wave fields or radiated signals from the radiator reflect the surface in a truncated ground or patch, that causes various effects on output such as input impedance, radiation pattern, axial ratio, gain and internal impedance of patch antennas can also be considerably changed.

A rectangular patch is most commonly used for better response in the communication field; mostly rectangular patch is chosen and linear polarization with required return loss can be easily obtained in a rectangular patch rather than any other shape and design of patches (Dua et al., 2012). With a 45 or 50 degree required to cut and truncation of the ground plane, a better bandwidth and an axial ratio, the gain can be achieved which is most commonly used in wireless applications like Wi-Max, Wi-Fi and WLAN applications. Due to the various properties and benefits of NEMA (Bhardwaj et al., 2008) based glass-reinforced based laminated epoxy resin, FR-4 material is used which has a 1.5 mm thickness according to the substrate and patch design (Gnanamurugan et al., 2019). Various effects and parameters like bandwidth, 2D pattern, 3D pattern, axial ratio and frequency responses are calculated (Heer and Sharma, 2018a).

## DESIGN ANALYSIS

The proposed design of rectangular MPA and its geometry is represented in Figure 1. As per requirement, an antenna is designed on FR-4 glass-reinforced epoxy dielectric material, followed by a simple coaxial probe feed method, in which the dielectric substrate has a thickness of 1.5 mm (Siddik et al., 2019). In the coaxial transmission line system, this feed technique is used in the antenna. Using commercial software i.e., IE3D v 12.1 the proposed design is synthesised and analysed (Heer and Sharma, 2018b). A rectangular patch antenna will simulate resonant frequency, the condition is that the conventional rectangular patch does not have any reduced ground and addition of the cut in the patch is about 4.22 GHz, and the resonant frequency has corresponded to dominant mode i.e., TM-11 mode as discussed in transmission lines (Dafalla et al., 2004). By exciting a simple rectangular patch, linear polarization and other parameters can be easily obtained. While the cut introduced is 4.7 mm in length at an elevation of 45 degrees; linear polarization is achieved (Chung et al., 2004). With the cut of 4.7 mm in the proposed rectangular patch antenna, the antenna gain is increased from 3.10 dB to 3.40 dB, which is considerable for the proposed design. To design a rectangular patch antenna, a finite ground is chosen having a width of 100 mm and a length of 50 mm is taken (Islam et al., 2019). For a patch in the proposed microstrip patch antenna, the dimension of the patch has a width of 30 mm and a length of 20 mm. The dimension of the antenna is given as W1 = 100 mm, L1 = 50 mm, W2 = 30 mm, L2 = 20 mm, h = 1.6 mm, $\varepsilon_r$ = 4.4. The dimensions of the ground and patch can be varied according to the design and application area of the antenna (Siddik et al., 2019). After selecting a feed location for a coaxial feed line transmission system, the suitable feed location can be selected for finite ground and truncated or cut gradually to find different responses (Yuan et al., 2006). So, when the ground area is reduced up to 50% of its original dimensions, the efficiency of the antenna is improved with a gain of 3.30 dB and having suitable VSWR with up to 30% of improved bandwidth (Sharma et al., 2011a; Lin et al., 2015).

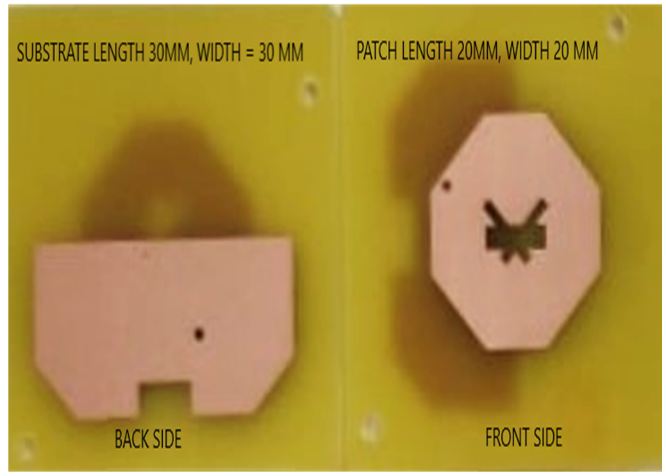



**Figure 1.** Antenna design.

## RESULTS

At the initial stage, we choose a finite ground length which is selected as a width of 100 mm and length of 50 mm without any truncation in the ground and cut in a patch. The resonant frequency at the initial stage is around 2 to 3.5 GHz frequency and has a very narrow bandwidth of 2 to 4% of bandwidth. When we reduce the finite length and width of ground up to 5 mm (approximately), a cut is introduced to get a suitable impedance with improved bandwidth, also the dimensions of the ground are adjusted accordingly as the size of the patch is introduced (Sekra et al., 2009). With this truncation in the ground, the patch is supposed to be a defected one also. The patch will become a suspended type, with the proposed design as the ground is truncated along with the width of the proposed design (Bhattacharyya, 1991). In Figure 2, the finalized proposed antenna geometry is shown, where the width is reduced to 46 mm and the length is 50 mm. As we know suspended patch means the dielectric used is air instead of a circuit board, and it can be broadly used for improving the bandwidth of the antenna (Dubey et al., 2011). In this design when we use the patch as a suspended type patch, it will act as a radiator which reduces various parasitic and impedance parameters, also it can improve the return loss and enhance the bandwidth.

After the simulation, the calculated input impedance of the following design is shown here in Figure 3(a). The centre of the Smith chart implies an impedance matching of an antenna in a 2D pattern (Naidu et al., 2019), the concentric circle passes through the center of the Smith chart and shows it has wide impedance and bandwidth. The bandwidth of the antenna is varied from 3.2 GHz to 3.7 GHz and with improved bandwidth of 13.4% bandwidth, a 2:1 VSWR, around -23.00 dB return loss (approx.) and up to 54% of efficiency (Liu et al., 2012). The return loss is -44.04 dB at 3.5 GHz of the designed

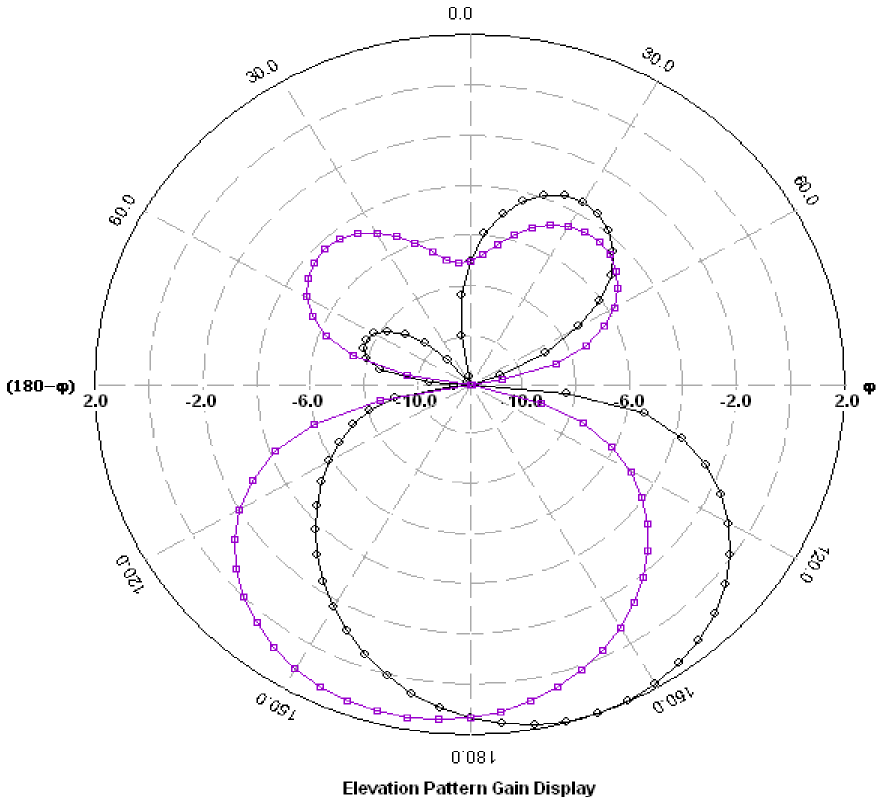
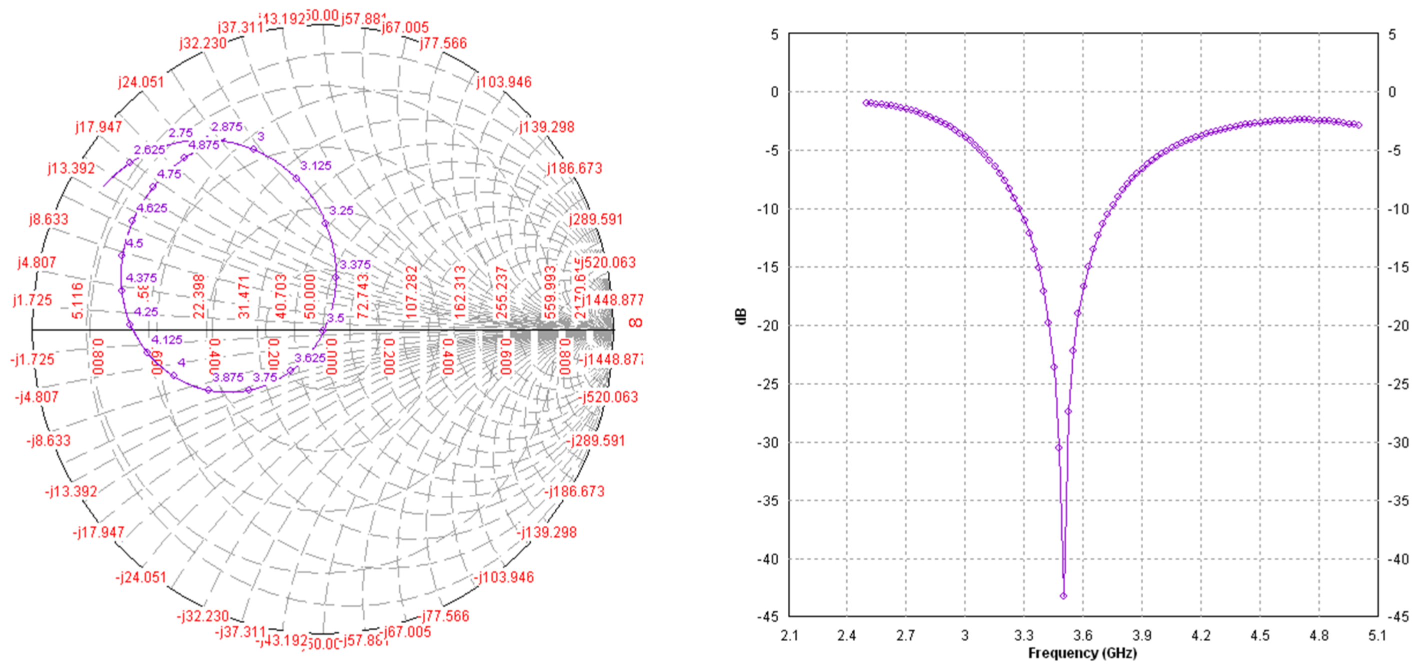



**Figure 2.** 2-D pattern.




**a** **b**

**Figure 3.** (a) Input impedance, (b) Return loss.

antenna as shown in Figure 3(b). At the edge of the slots of the patch, the concentrated and distributed currents can be calculated. 3.55dB is the peak gain, which is obtained at the resonant frequency of 3.41 GHz as shown in Figure 4. The 2D radiation pattern of the design without truncating ground is shown in Figure 5, its radiation pattern is changed with the desired changes in the dimensions of the ground and patch (Sharma et al., 2011b).

Various effects after the ground and patch truncation like gain, return loss, bandwidth and efficiency are shown in Figure 6. Changing the ground truncation, and its elevation i.e., changing the cut length and width of the patch does not affect the resultant parameters properly (Islam et al., 2019).

Figure 2 shows that with the reduced size up to a width of 45 mm and length of 50 mm, the antenna will become a suspended type after the ground truncation at finite dimensions, which results in a small size or say a size reduction, and also it gives a miniature size application with lightweight, compactness and reduced cost (Rowley and Waterhouse, 1999).

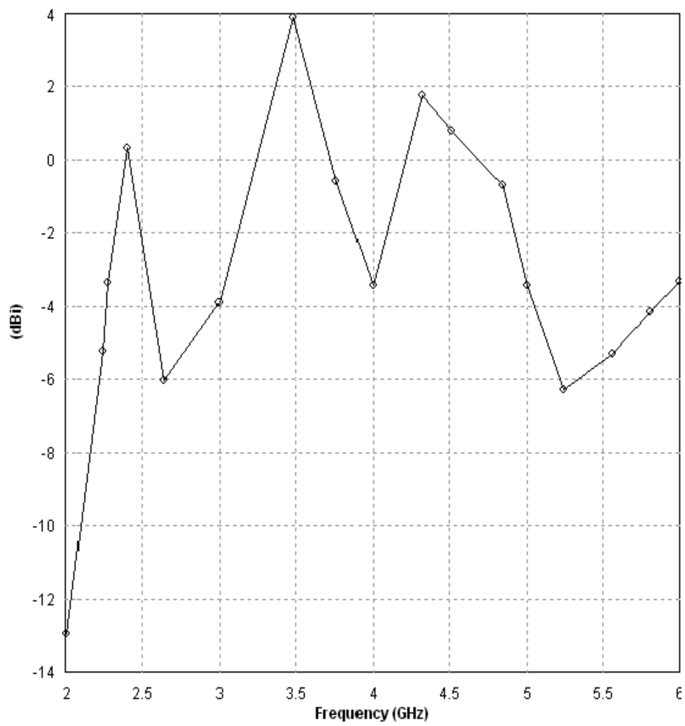



**Figure 4.** Gain vs. frequency.

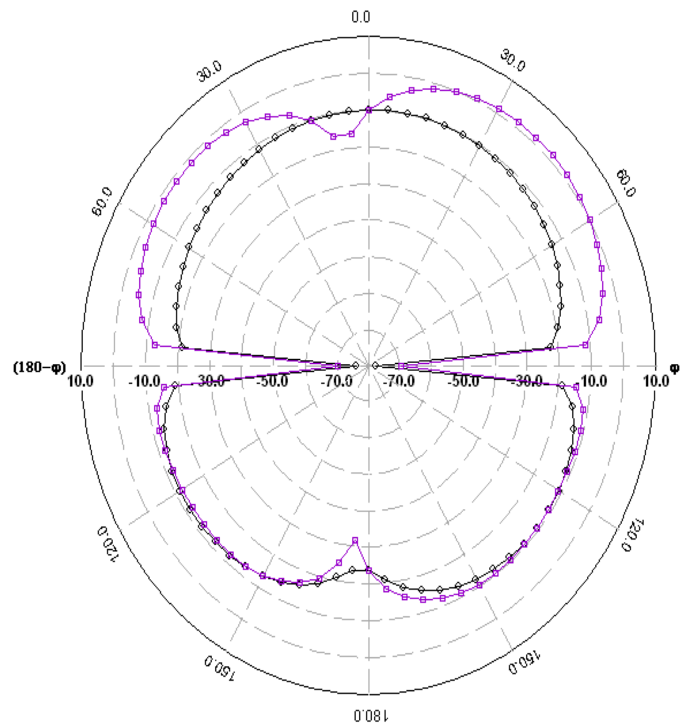



**Figure 5.** 2D radiation pattern without ground truncation.

In Figure 3a and b, the Smith chart and return loss graph are shown, and the concentric circles of the Smith chart show the matched input impedance with the coaxial fed transmission line system (Yuan et al., 2006). The approximate value of impedance from the Smith chart is about 22.36 + j17.94. Figure 3(b) shows a graph between the Return loss (in dB) on the y-axis with the desired frequency (in GHz). It shows that the desired microstrip patch antenna design perfectly resonates at 3.5 GHz frequency with a perfect return loss of -44dB or -45 dB i.e. at this point a maximum power will radiate from the radiator at the calculated resonant frequency of 3.5 GHz (Robinson et al., 1996). The improved wide bandwidth is about 13.4% with a good impedance matching as shown by the Smith chart, which is achieved by ground truncation.

The graph between Gain (in dB) is on the y-axis and frequency (in GHz) on the x-axis is shown in Figure 4, which shows the gain of approx. 3.5 dB at 3.5 GHz frequency (Heer and Rawat, 2017). The gain was achieved through the proposed design with the help of ground and truncation.

Taking the ground dimension of the length of 50 mm and width of 46 mm, to observe the effect on the design we adopt defected ground technique. At (0, -50) co-ordinate point we defect or cut the ground plane by introducing a rectangular hole (Abdelaziz and Nashaat, 2007). By changing the width and length of the rectangular hole, effects on the various antenna responses are shown in Table 1.

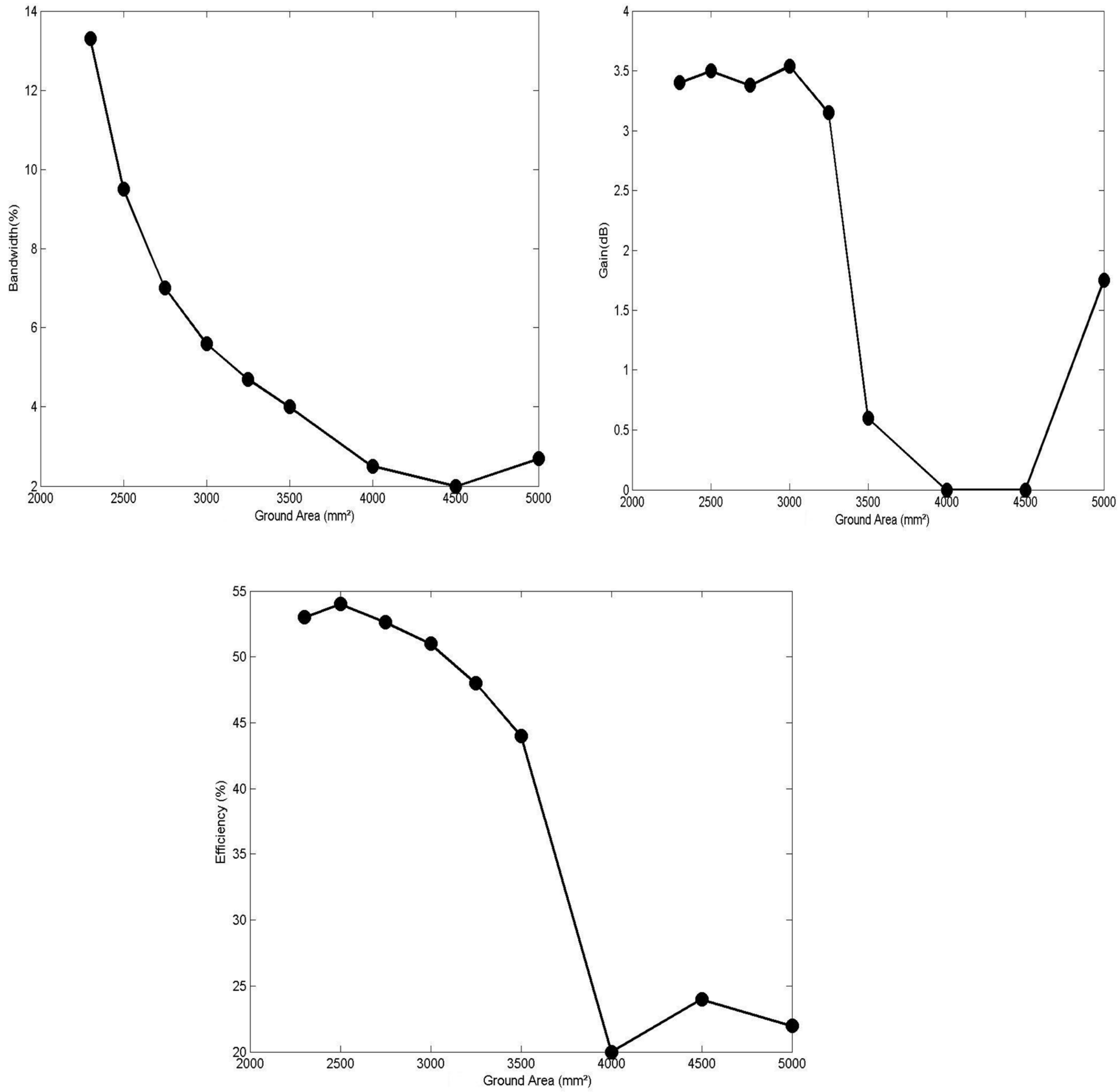



**Figure 6. (a)** Ground area (mm$^2$) vs. bandwidth (%). **(b)** Ground area (mm$^2$) vs. Gain (dB). (c). Ground area (mm$^2$) vs. efficiency.

**Table 1.** Different feed points on the patch to obtain various antenna parameters.

| S. no. | Rect length | Rect width | Resonant frequency | Return loss | Bandwidth | Frequency bandwidth | Impedance matching | Gain | Efficiency | Axial ratio |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | 14 | 6 | 3.445 | -27.16 | 13 | 3.21-3.67 | (53-3.4j) | 3.17 | 53 | 9.81 |
| 2. | 16 | 8 | 3.445 | -27.31 | 13 | 3.23-3.68 | (53-2.8j) | 3.23 | 53 | 9.6 |
| 3. | 18 | 9 | 3.41 | -25 | 13 | 3.21-3.65 | (55.3+0) | 3.43 | 53 | 9.2 |
| 4. | 20 | 10 | 3.41 | -25.94 | 13 | 3.21-3.65 | (55.2+0) | 3.37 | 53 | 9.3 |
| 5. | 22 | 11 | 3.41 | -26 | 13 | 3.21-3.65 | (55.3+0.4j) | 3.4 | 53 | 9.2 |
| 6. | 22 | 14 | 3.42 | -25.7 | 13 | 3.21-3.66 | (54.7-1.2j) | 3.45 | 54 | 9.5 |
| 7. | 24 | 16 | 3.45 | -27.12 | 13 | 3.22-3.66 | (53.3-3j) | 3.42 | 54 | 9.9 |
| 7. | 24 | 20 | 3.41 | -25.45 | 13 | 3.21-3.65 | (55.3+.5J) | 3.53 | 55 | 9.8 |
| 8. | 24 | 24 | 3.41 | -25.2 | 13 | 3.21-3.65 | (55.3+0) | 3.55 | 55 | 10 |
| 9. | 24 | 26 | 3.445 | -25.67 | 12.56 | 3.23-3.6 | (55.2-5j) | 3.46 | 55 | 10.8 |
| 10. | 24 | 28 | 3.445 | -25.69 | 12.8 | 3.2-3.7 | (55.3-4.0j) | 3.45 | 55 | 11 |

Based on the above experimental data in Table 1, the graphs will be plotted as per shown in Figure 6a, b, c. Figure 6a shows that with ground truncation how the bandwidth of the proposed design varies with ground truncation. Along the width the ground of the antenna is also reduced, when the width changes to W = 46 mm then the proposed design bandwidth is extending from 3.10 GHz to 3.44 GHz i.e., 13.4% bandwidth (Sekra et al., 2009). Figure 6(b) shows due to ground truncation there is a change in the gain which varies from 3.17 dB to 3.55 dB. In a previous study, we found that in patch antennas when we truncate ground planes and vary the patch size, the antenna parameters changes accordingly (Bhattacharyya, 1991). Past research has shown the resonant frequency, directivity and input resistance of a rectangular microstrip patch antenna change as we cut the patch and truncate the ground (Sharma et al., 2011a). In the Microstrip patch antenna, various feeding techniques are used such as microstrip feed line system, coaxial feed or probe feed system, aperture coupled feed and proximity coupled feed techniques (Robinson et al., 1996; Psychoudakis et al., 2004). Mostly, the coaxial feed or probe feed is commonly used to provide a feed point in feeding patch antennas through a simple copper wire or say coaxial cable (Heer and Sharma, 2020). By coaxial feed technique, the desired conductor is placed on a patch which will find an excitation point from which point the antenna is radiated, so based on signal strength we calculated the desired gain and bandwidth of the antenna. For low spurious radiation or radiated signal of frequency, the coaxial feed technique is easy to fabricate and desired results will be obtained. Narrow bandwidth is the major disadvantage of this technique, the main reason is that the hole is drilled in the substrate and the connector connects or protrudes from outside the ground plane, so it does not make it completely planar for the thick substrate (Bird, 2015). With an increase in probe length, where the substrate is thicker by selecting suitable material of substrate, the input impedance will become more inductive which led to the impedance matching problems and the value of the Smith chart is affected. With the thick dielectric substrate (which proves broader bandwidth), the feed line system such as microstrip line feed and coaxial feed technique has several disadvantages (Singh et al., 2016). A ground plane is connected by the outer conductor, while the radiating patch is soldered by an inner conductor of coaxial connector through the dielectric (polarized electrical insulators). To match the feed with its input impedance the feed can be placed at any calculated or experimental location inside the patch and after that done meshing to achieve desired value, that the main advantage of the coaxial feed technique. This feed method is easy to design, fabricate and calculated the desired parameters (Heer and Rawat, 2017). Figure 6(c) shows that due to a change in the ground area the efficiency is increased according to that ground area (Chung et al., 2004).

## CONCLUSION

As we concluded there are two techniques to improve various antenna parameters like enhanced bandwidth, improved gain and efficiency with desired resonant operating frequency. The first technique is depending on the resonant frequency that has corresponded to the dominant mode i.e., TM-11 mode as discussed in transmission lines (Pirinoli et al., 2004). In improved parameters, the main problem resolved is SAR and EMI radiations, which are mainly focused on human health and environmental radiations (Andújar et al., 2012; Gosselin et al., 2011). Those parameters will be achieved by using a low-frequency range and suitable bandwidth at that frequency. To reduce the antenna size with improved parameters are discussed in this technique, in which at desired elevation angle the patch is truncated and the second technique is truncated the finite ground (Joseph et al., 2006). With the first technique, we will be able to do size reduction along with the desired length and width of the patch, which will also double the bandwidth of the antenna and the efficiency of the antenna will be improved (Chung et al., 2004). The resonant frequency will be changed approximately from 4.4 GHz to 3.5 GHz after ground truncation. With the help of the second technique, there is a reduction in the size of the antenna which is about 50% reduced and the bandwidth will be enhanced by up to three times as its values are compared to the conventional or fabricated rectangular microstrip patch antenna (Singh et al., 2016).

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