Novel Microstrip Patch Antenna with Modified Ground Plane for 5G Wideband Applications

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Abstract

For high speed data communication, the latest 5G wireless technology has the capacity to fulfil the requirements of broadcasting live events, high definition video streaming, autonomous driving, robotics and so on. Instead of conventional low-gain narrow bandwidth antennas, high-gain wide-band antennas are needed for reliable 5G wireless communication. In this paper, we proposed a novel slot-loaded microstrip patch antenna (MPA) with helipad like ground modification for lower 5G frequency spectrum at around 3GHz. The antenna is designed and fabricated on FR-4 substrate. The bandwidth obtained from simulation is about 1.78 GHz which is 18 times larger than that of a conventional MPA with full ground plane. The magnitudes of the simulated and measured return losses are found -46.51 dB and -36.48 dB, respectively. The measured radiation patterns of the conventional and the proposed MPA are found hemispherical and bi-directional, respectively. Such bidirectional antenna is suitable for mobile base stations, WLAN, intra-satellite communication and beam forming applications.

Index terms— 5G wide-band wireless communication, rectangular slot-loaded microstrip patch antenna, ground modified bi-directional antenna.

revolution has occurred in the world of wireless communication systems with the introduction of 5G network. It provides high speed data transmission rates more than 1Gbps to broadcast live events, high definition video streaming, autonomous driving, robotics, aviation, health care applications, etc. This 5G wireless technology is nearly capable of the wired fiber optic internet connection. Another feature of 5G is that it can transfer both voice and high-speed data at the same time more efficiently than the other conventional mobile cellular technologies. Depending on the implementation policy of 5G in various countries, the lower and higher end of the fifth generation frequency spectrum are approximately 3-5 GHz and 24-71 GHz, respectively **??**1]. To interconnect the existing mobile devices and various sensors, sub-6 GHz frequencies are being used by 5G technology. For maintaining high speed transmission and reception, high-gain wideband antennas are needed for reliable wireless communication. Recently use of a wideband antenna for multichannel transmission and reception has become more popular.

Besides, low-profile antennas are preferable for mobile base station, intrasatellite communication purposes, missiles and so on. For these application areas, microstrip patch antennas (MPAs) are better choice over the other types of antennas. Some of the advantages of MPA are light weight, smaller size, low fabrication cost, easy installation, mechanical robustness and freedom of design [2][3].They also minimize the excitation of other undesired modes [4]. Due to the miniaturized structure of MPAs, they feasibly can be used in smaller electronic gain, narrow bandwidth, low directivity, low power handling capacity, distorted radiation pattern and multiple resonances [6][7].So the target of the research on MPA is to increase the bandwidth, gain, and desired radiation pattern for various sorts of 5G applications. Antenna characteristics can be improved by introducing slots of different shapes, defected ground plane, metamaterial, and shorting pins. etc. [7][8][9][10]. Besides by increasing the substrate height, and lowering the dielectric constant, antenna characteristics can also be increased [11]. Moreover feeding techniques affect some important antenna parameters such as bandwidth, return loss, VSWR etc. **??**12].

In this paper we proposed a microstrip patch antenna having 6 rectangular slots placed symmetrically on both sides the feed line. The introduction of slots on the patch changes the resonance characteristics from conventional multiband to a single resonant one. The ground plane is modified with a new structure to increase bandwidth. The bandwidth of the slot loaded MPA with modified ground plane is increased approximately 18 times than that of the conventional MPA. The design and simulation process of the MPA are done by CST software. The radiation pattern and ?? 11 of the fabricated antenna are measured using Vector Network Analyser (Rohde & Schwarz-ZVH8) and Wave and Antenna Training System (Man and TEL Co.).

1 Introduction II.

Keywords: 5G wide-band wireless communication, rectangular slot-loaded microstrip patch antenna, ground modified bi-directional antenna.

The slots are denoted by '??', '??' and '?? ' as shown in Fig. 1(b). The widths and lengths of slots are each slot is very sensitive to the patch characteristics. For example, the distances of slot 'c' from the bottom edge, side edge and top edge of the patch are denoted by ?? 1 , ?? 2 and ?? 3 , respectively (see Fig. 1(b)). Similarly the positions of slot '??' and '??' are taken as ?? ?? and ?? ?? (?? = 1, 2, 3).

Figure 1 (c) shows the modified ground structure of the proposed MPA. To increase the bandwidth of patch antenna, the ground side is modified to form a helipad-like structure. Three English letter 'I' are made along the length of patch. All 3 Istructures are connected at the middle. The middle I has larger width than the other two Is. This middle I also has a rectangular slot in the middle and two side-slots at the top and bottom edges. The hatched part in ground plane represents the existence of copper layer and the rest regions are etched out. The widths of the side I and central I are expressed by ?? 1 and ?? 2 , respectively. The distance between the outer edges of 2 side I's is denoted by ?? 3 which is taken 10 times of the width of each side I i.e. ?? 3 = 10 × ?? 1 .The whole ground plane has been finally appeared as a helipad-like structure.

For the analysis, the substrate is considered FR4 whose dielectric constant,?? ?? is 4.3 with a thickness?? ????ð ??"ð ??"ð ??"ð ??" = ? r +1 2 + ? ? ?? ?1 2 ? ?(1 + 12? ??) ? 1 2 ? (1)

The width ?? of the patch is calculated for the resonant frequency ð ??"ð ??" ?? at 3 GHz using the following equation?? = ?? 0 2×ð ??"ð ??" ?? × ? 2 Ñ?" ?? +1 (2)

where ?? 0 is the speed of light in free space.

The relation between the actual length ?? and the effective length ?? ??ð ??"ð ??"ð ??"ð ??" is?? = ?? ??ð ??"ð ??"ð ??"ð ??" ? 2??? (**3**)

Where ??? is the fringing correction factor and is expressed as??? = 0.412? × ??? ????ð ??"ð ??"ð ??"ð ??" + 0.3?(?? ? + 0.264) ?? ????ð ??"ð ??"ð ??"ð ??" ? 0.258 ?(?? ? + 0.8) (4)

The expression for the effective length ?? ??ð ??"ð ??"ð ??"ð ??" is?? ??ð ??"ð ??"ð ??"ð ??" = ?? 0 2×ð ??"ð ??" ?? × ? ? ?? ??ð ??"ð ??"ð ??"ð ??" (5)

Microstrip transmission line width ?? ð ??"ð ??" has been varied from W/5 to W/15 to achieve the best result through simulation. The value is found to be 3.06 mm for the best antenna characteristics.

The equation used for determining the exact length of inset feed ?? ?? for thin dielectric substrate to achieve an input impedance of 50? is as follows [13]:

Where ?? ??7 = 0.001699, ?? ??6 = 0.13761, ?? ??5 = 6.1783, ?? ??4 = 93 . 187, ?? ??3 = 682.93, ?? ??2 = 2561.9, ?? ??1 = 4043 and?? ??0 = 6697,respectively.

Using the above stated equations, all the parameters (such as ?? ????ð ??"ð ??"ð ??"ð ??" , ??, ??, ?? ??) are calculated for ð ??"ð ??" ?? = 3 GHz. These calculated values are used to design a conventional MPA as well as the proposed MPA using CST software. It is found that the calculated values of different parameters are slightly modified to obtain the optimized values which give better antenna characteristics. The gap between the patch and the inset-feed microstrip line ?? ð ??"ð ??" has been changed from 0.5 to 3.5 mm to get the best result. It is found that ?? ð ??"ð ??" = 0. 95 mm gives the satisfactory result. ?? ?? = 10 ?4 ??? ??7 ? ?? 7 + ?? ??6 ? ?? 6 ? ?? ??5 ? ?? 5 + ?? ??4 ? ?? 4 ? ?? ??3 ? ?? 3 + ?? ??2 ? ?? 2 ? ?? ??1 ? ?? + ?? ??0)L/2(**6**)

resonance characteristics at a single frequency, slots are introduced in the patch (see Fig. 1 The length ?? 3 and width ?? 3 of the smallest '??' slot are found 3.2 mm and 1.9 mm, respectively. Two smallest 'c' slots are placed symmetrically on both sides of the feed line. Each smallest 'c' slot is positioned at distances ?? 1 = 14.605 mm, ?? 2 = 2.745 mm and ?? 3 = 5.205 mm away from the bottom edge, side edge and top edge of the patch antenna, respectively. The dimensions of medium type '??' pair of slots are ?? 2 = 5mm and ?? 2 = 1.9mm.These' ??' slots are positioned at ?? 1 = 13.505 mm, ?? 2 = 5.345 mm and ?? 3 = 4.505 mm apart from the bottom edge, side edge and top edge of the patch, respectively.The length and width of the biggest two symmetrical rectangular '??' slots are ?? 1 = 6.5 mm and ?? 1 = 2.2mm, respectively. The slots are positioned at ?? 3 = 3.805 mm, ?? 2 = 8.245 mm and ?? 1 = 12.705 mm apart from the top edge, side edge and bottom edge of the patch, respectively.The positions and dimensions of the slots are determined using trial and error method to get good antenna characteristics such as S-parameter, radiation pattern, bandwidth, directivity etc. All the optimized structural parameters of the proposed MPA are given in Table1.

2 Simulation

To observe the effects of slots and ground modification, we have designed two types of MPAs using CST simulation software. A conventional MPA has also been designed to compare the improvement of characteristics of the proposed MPA. The substrate is taken FR4 with a copper cladding thickness of 35 µm and the final dimension of the MPAs is 40.1X35.5 mm. patterns of three types of MPAs are shown in Figs. 2 and 3, respectively.

3 Results

4 III.

We have shown the return loss (?? 11) of the conventional MPA (without slot and with full ground plane) in Fig. 2 (a). We have seen that there are two resonant peaks at 3.008 GHz and 4.48 GHz with the magnitudes of ?41.35 dB and ?22.04 dB, respectively. The corresponding bandwidths of these two frequencies are 100 MHz and 120 MHz, respectively. Introducing slots in the patch with the full ground as conventional one, the magnitude of ?? 11 is found to be ?35.32 dB at 3.00 GHz which is very close to the designed resonant frequency of 3 GHz (see Fig. 2 (b)). We have eliminated the second resonant peak of the conventional antenna by incorporating six slots on the patch. We have gradually decreased the size of the slots from middle to the patch-edge. The bandwidth of the resonant peak at 3.00 GHz is found 100 MHz which is similar to the conventional one.

To increase the bandwidth, the ground plane is modified to form a helipad-like structure keeping slots in the patch. The obtained ?? 11 is shown in Fig. 2(c). The bandwidth and minimum return loss of the final proposed MPA are 1.77 GHz and ?46.5 dB at 3.028 GHz, respectively. Thus the bandwidth has been increased remarkably, and our proposed MPA is appropriate for wideband applications.

5 Measured Results

The conventional and the proposed MPAs are fabricated in our laboratory by liquid etching technique. First of all, Copper substrate has been cut into rectangular pieces with the dimensions according to the optimized values shown in Table-1. Then the patch and ground sides of the MPA are masked using photo resist. Ferric Chloride solution is used to chemically etch out the unwanted copper to get the desired portions of the patch and ground plane. After cleaning up the mask with Ethanol, SMA connectors are fixed on the mount at the antenna port. In Fig. 4, the photograph of the patch side (left) and the ground plane (right) of the proposed MPA are shown. shows the characteristics of measured radiation pattern for the proposed MPAwith modified ground plane. This result also agrees very well with the simulated one. Since bandwidth of our proposed MPA has increased remarkably, the gain has reduced. The measured radiation pattern of our proposed MPA is also found bidirectional pattern which is similar to that of simulated one.

6 IV.

the conventional and the proposed MPA in Fig. **??**(a

7 Conclusion

The simulation part of this experiment has been done at Fabrication laboratory (Fab lab) and the fabrication and measurement have been carried out at Microwave and Fibre Optical Communication laboratory,

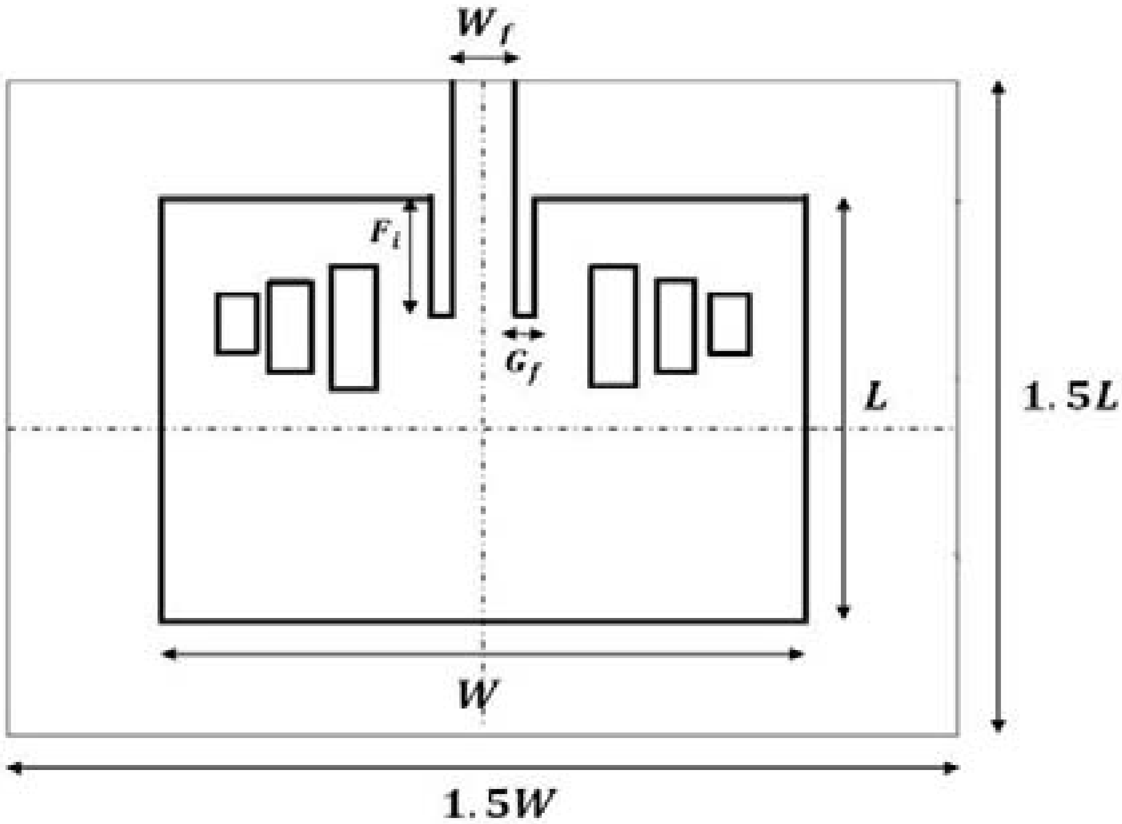
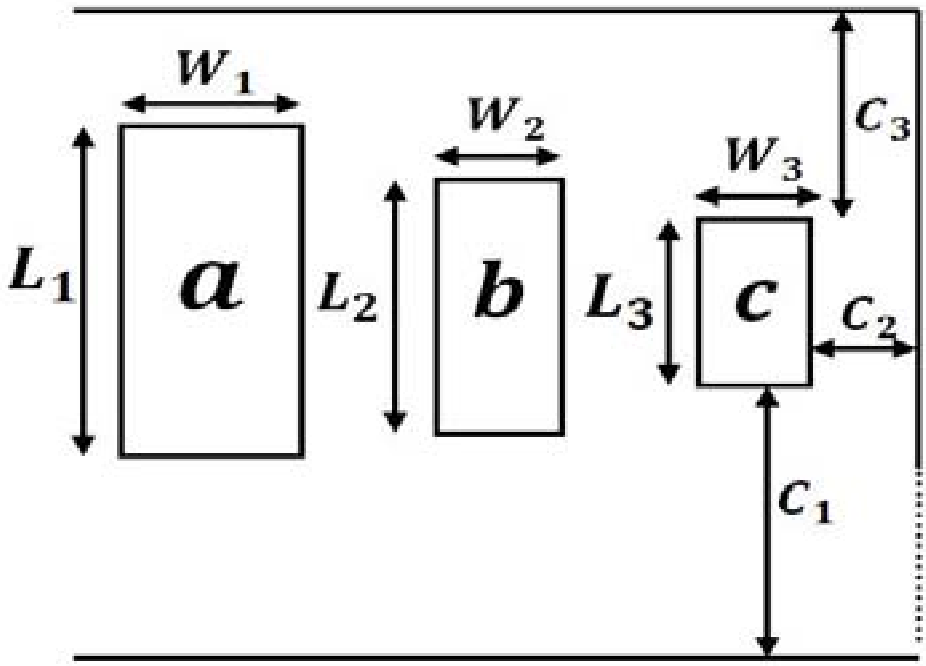


Figure 1:



1

Figure 2: Fig. 1 :

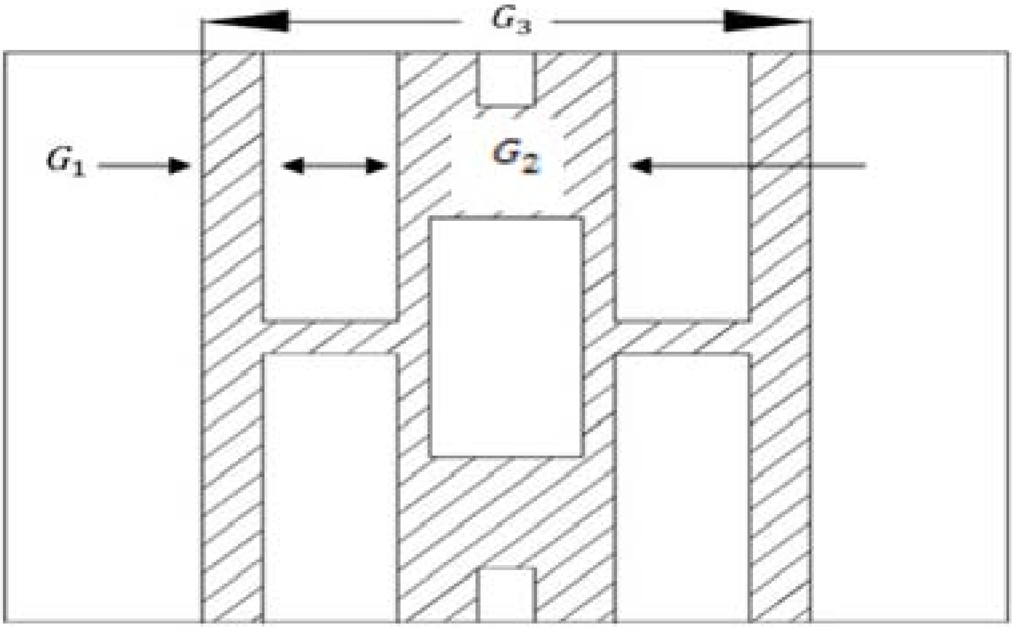


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Figure 3: Fig. 2 :

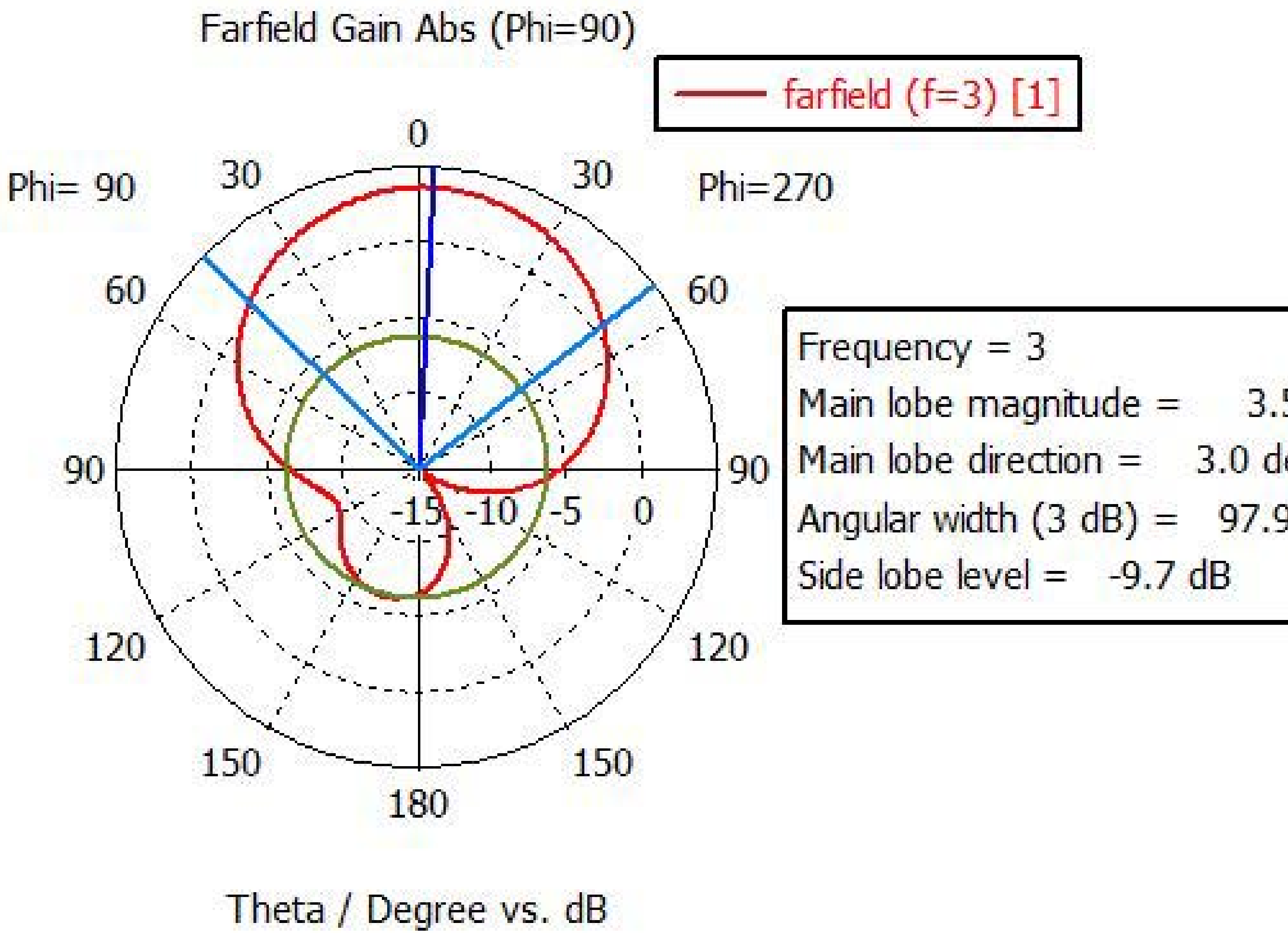

Figure 4: F

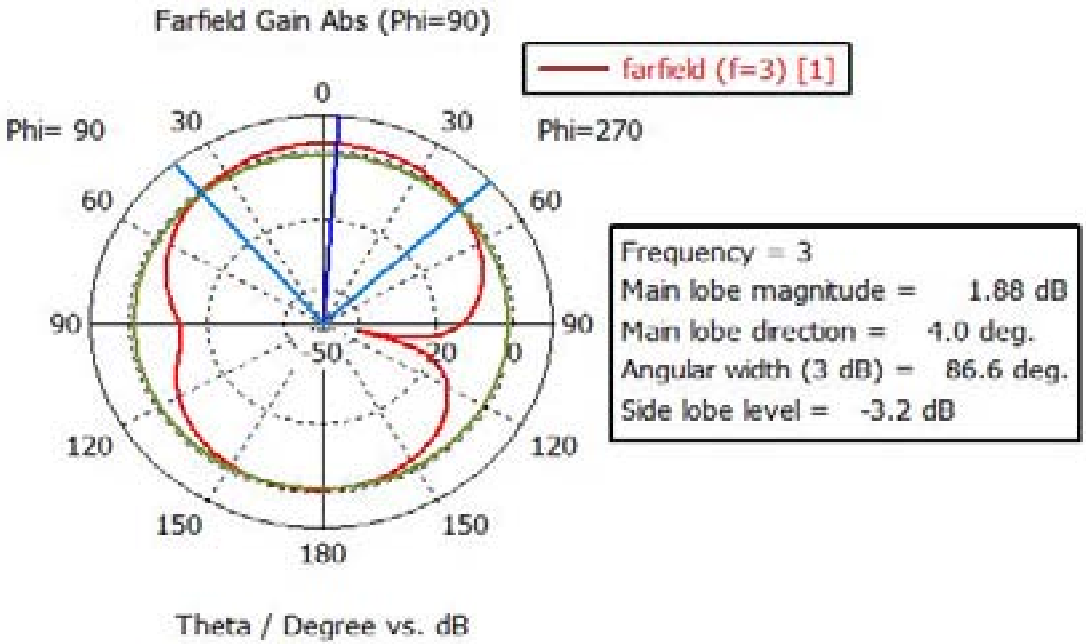

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Figure 5: Fig. 3 :

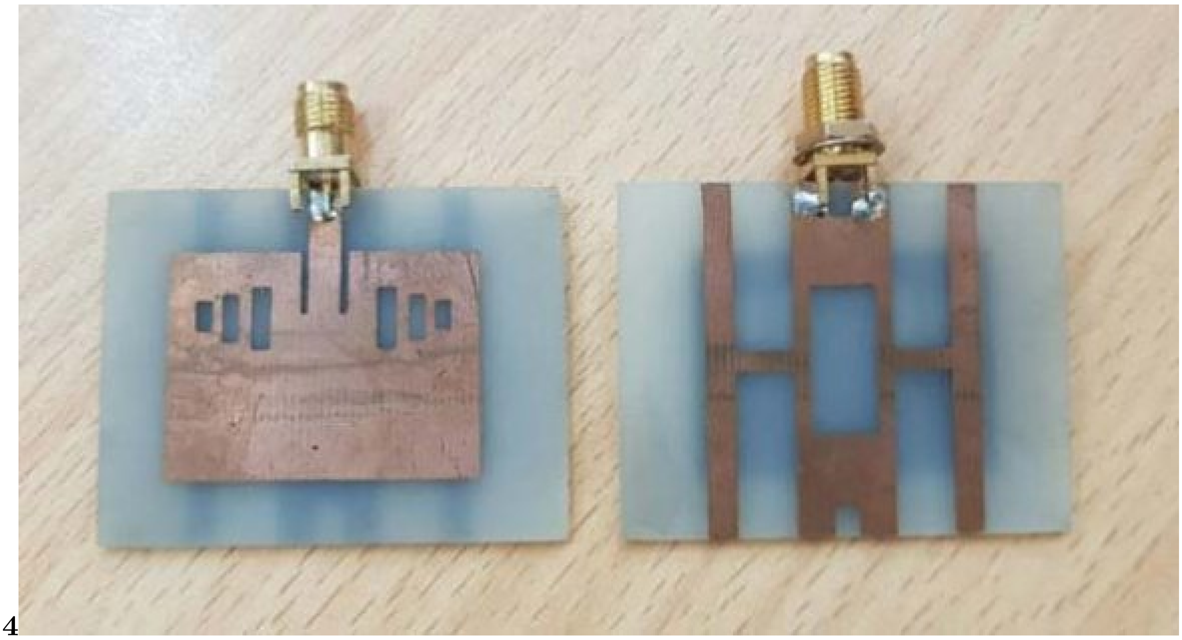

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Figure 6: Fig. 4 :

[Note: ? = 1.6 mm. The effective dielectric constant ?? ????ð ??"ð ??"ð ??"ð ??" is expressed as [8] Year 2019 F Novel Microstrip Patch Antenna with Modified Ground Plane for 5G Wideband Applications © 2019 Global Journals]

Figure 7:

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.1 V.

A new slot-loaded patch antenna with ground modification has been designed to enhance the resonance characteristics with improved bandwidth. The antenna works at the resonance frequency in S-band i.e. at 3 GHz. The return loss magnitude of the proposed MPA is found quite satisfactory than the conventional structure. The simulated return loss bandwidth of the proposed MPA has been increased from 100 MHz to 1.77 GHz compared to the convention MPA. The measured return loss characteristics and radiation pattern of the proposed antenna match well with the simulated results. The bandwidth of the measured MPA is found 380 MHz, a reduced bandwidth value due to the inaccuracy of fabrication and measurement in our laboratory without anechoic chamber. The far field gai n and directivity of the fabricated antenna are quite satisfactory. The radiation pattern of the proposed MPA is bi-directional and is suitable for WLAN, intra-satellite communication and beam forming applications.

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