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A Novel Miniature Edge Fed Planar Inverted-F Antenna (PIFA) for Future 5G Wireless Devices

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Abstract
In this paper a novel miniature Planar Inverted F Antenna (PIFA) for 5G wireless technology has been proposed. The overall size of the proposed antenna including the ground plane is 18mm × 10mm × 3.5mm, which is suitable to be used in a mobile device as well as in small wearable electronics. The antenna covers proposed 5G frequency band and covers a wide frequency range from 9.77GHz-11.58GHz. The top radiating patch of the antenna has two truncated edges, hence making it a novel design. In this paper various performance parameters such as return loss, VSWR, gain and radiation pattern are also discussed. Measured results are in good agreement with simulated results.

Keywords
PIFA, 5G, Miniature, Wearable, Truncated.

I. Introduction

The desire for compact antenna has increased these days due to rapid decrease in dimensions of mobile devices [1]. Therefore conventional antennas are replaced by compact Planar Inverted F Antennas. Due to multiband properties and compact dimensions, Planar Inverted F Antenna is the best alternative to be used in mobile devices. The Planar Inverted F Antenna (PIFA) has been devised from Inverted F Antenna (IFA). The Inverted F Antenna suffered from a narrow bandwidth, due to which the wire radiator was replaced by a shorting plane in Planar Inverted F Antenna. PIFA shows improved performance with a compact size [2] [3].
The wireless communication has developed at a fast rate from the past few years. Recently studies are going to design an antenna covering 5 G wireless standards. Due to tremendous increase in mobile data, technologies are approaching from 4G i.e., fourth generation to 5G, fifth generation. Fifth generation technology is used in various different fields such as Internet of Things (IoT), advance MIMO structure, advance small cell technology etc [4] [6]. Using 5G technology millions of devices can be connected and operated simultaneously. Smart grids, Smart Cities, Smart transportation, Telemedicine, Machine to machine communication are some of the future systems which will become a reality due to 5G. In advanced small cell technology 5G technology can be introduced with existing 4G macro cells.
Various designs for 5G wireless standards have been proposed in the recent past [7]. In one such example authors proposed a miniaturized antenna in which the edge of the antenna was folded along with the loading slots and hence decreasing the length of patch by 44% [8]. In another design, a single-band printed Inverted F Antenna was proposed that operates at 28 GHz band and ideal for 5G wireless communication [9]. Till now various designs have been proposed for 5G wireless standard using different antenna structures such as Microstrip patch antenna or Printed Inverted F Antenna [7] [10]. In this paper a novel design for 5G wireless standard is discussed that is made using Planar Inverted F Antenna structure with edge feeding.
Planar Inverted F Antenna (PIFA) has numerous advantages such as small structure, multiband behavior, low cost, mechanically robust and reduced absorption rate as compared to other conventional antennas [5]. Planar Inverted F Antenna (PIFA) has reduced Specific Absorption Rate (SAR) value; hence fewer radiations are illuminated towards user's head and body [6]. The antenna shows moderate to broad bandwidth. The proposed antenna covers a wide band of approximately 2 GHz by using a shorting stub, edge feeding and truncated radiating patch.
In this paper, an antenna is proposed for mobile handheld devices. The proposed antenna has a novel and compact structure with dimensions 18mm × 10mm × 3.5mm and covers frequency band from 9.77GHz-11.58GHz and can be mainly used for 5G communication. The antenna shows wideband property after introducing a shorting plate and truncated patch. The antenna is well suited for mobile handheld devices or the devices where the space is a major issue. The antenna is simulated and optimized using electromagnetic optimization and simulation tool called High Frequency Structure Simulator (HFSS) software for antenna design & analysis.

II. Antenna Design

The proposed design of Planar Inverted F Antenna (PIFA) is shown in figure 1. The proposed antenna consists of truncated patch and edge feeding. Various parameters such as dielectric constant (ε_r = 2.2), resonant frequency (f_r = 10.61 GHz) and thickness of substrate (h= 0.8mm) are considered. Here Roger Duroid 5880 is used for fabrication of top radiating patch which has truncated edges. In this lumped port is used to excite the antenna. The shorting plate shorts the truncated radiating patch and the ground plane. Lumped port feed is used to excite the proposed antenna with height 3.5mm. Table 1 shows the detailed dimensions of the proposed antenna.
As compared with the conventional PIFA designs, the top radiating patch is truncated shaped while conventional PIFAs use rectangular patch. Moreover the co-axial feed is replaced by a lumped feed, hence making it a different antenna from conventional PIFA design.
The final proposed antenna shows a wideband frequency range of 9-11 GHz covering 5G communication standards. The antenna is designed and simulated using electromagnetic optimization and simulation tool called High Frequency Structure Simulator (HFSS) software.

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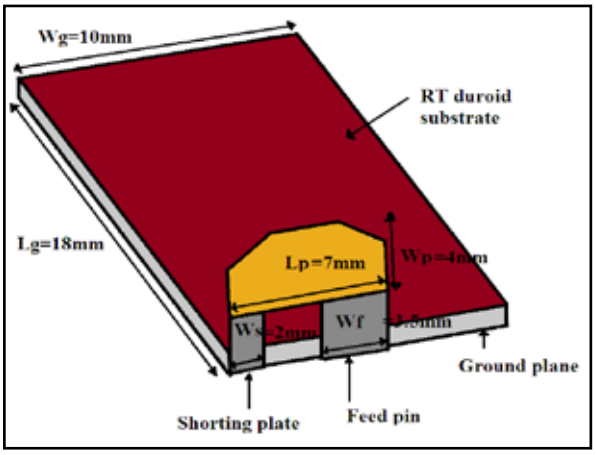

Fig. 1 : Detailed Dimensions of proposed Planar Inverted F Antenna

Table 1 : Detailed Dimensions Of Proposed Antenna

PARAMETER	VALUE (mm)
L_g	18
W_g	10
L_p	7
W_p	4
L_s	18
W_s	2
H	3.5
W_f	3.5

Proposed antenna is fabricated using Rogers Duroid 5880 with thickness 0.8mm. For top radiating patch a copper sheet of thickness 0.2 mm is used. SMA connector is used to excite the antenna. Fabricated antenna is shown in Figure 2.

III. Simulated Results

A. Return Loss Plot

S11 parameters are obtained as antenna return loss using wave port configuration. -10dB is the base value which is considered excellent in case of mobile communication.

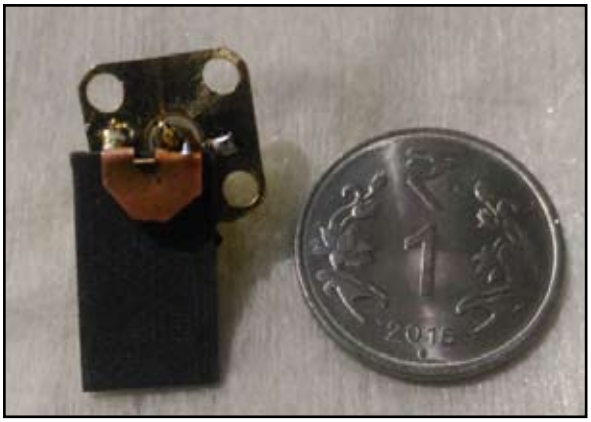

Fig. 2 : Fabricated Proposed PIFA Antenna

The antenna operates at 5G wireless standard. The proposed antenna resonates at 10.61 GHz with a return loss of -17.62 dB and showing a wider bandwidth of 1.81 GHz (9.77 - 11.58 GHz) after the simulation. After testing the design resonant frequency achieved is 10.18 GHz with return loss of -30.80 dB. Total bandwidth Coverage is 1.15 GHz (9.57 - 10.72 GHz).

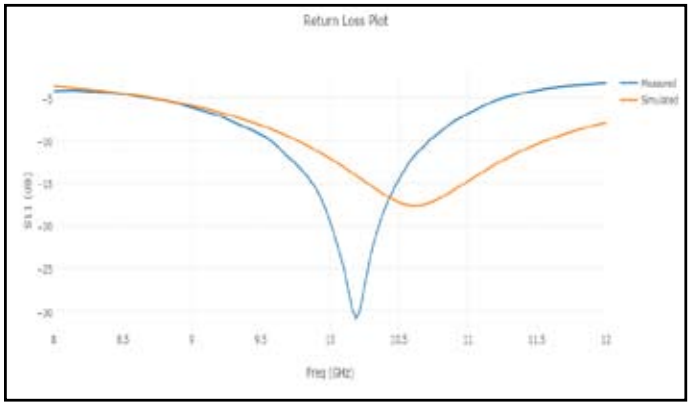

Fig. 3 : Simulated & Measured Return Loss Plot of Proposed PIFA

B. Voltage Standing Wave Ratio Plot

The Voltage Standing Wave Ratio (VSWR) of the proposed antenna is shown in figure 4. The value of VSWR should not exceed 3 and ideally it should be 1. As seen in figure 4, the value of VSWR is less than 3 which is considered good in case of an antenna. VSWR obtained at 10.67 GHz is 2.31 dB. As one can observe in the measured VSWR plot above that the value at resonance 10.18 GHz is 1.30 dB which is near to perfect matching condition i.e. 1 dB.

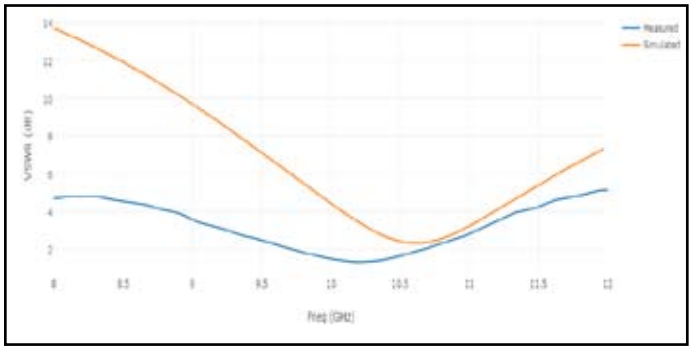

Fig. 4 : Simulated & Measured VSWR of Planar Inverted F Antenna

C. Gain Pattern

The efficiency of the antenna is determined by the gain of the antenna. The proposed antenna shows a gain of 4.27 dB which is considered excellent in terms of Planar Inverted F Antenna (PIFA). Figure 5 shows the gain pattern of the proposed antenna.

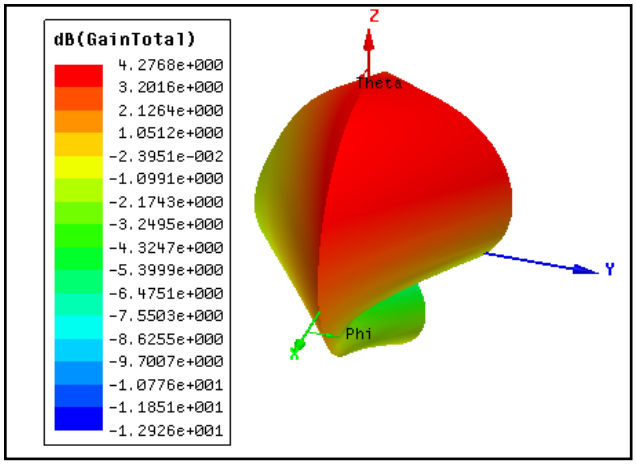

Fig. 5 : Gain Pattern of Planar Inverted F Antenna

D. Radiation Pattern

The radiation pattern of the antenna is shown in figure 6. From the figure it is clear that the antenna shows an omni directional pattern.

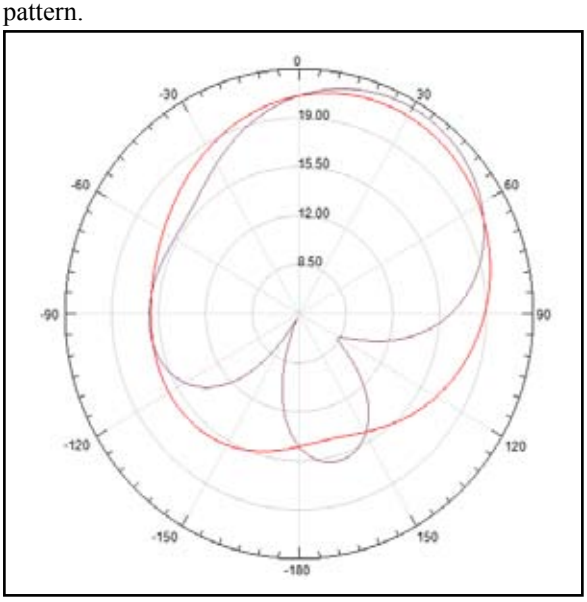

Fig. 6 : Radiation Pattern of Planar Inverted F Antenna

Results have shown that the antenna shows a good radiation pattern with good gain. The antenna covers a wide bandwidth of nearly 2 GHz and can be used for 5G wireless communication. 5G wireless standard is a new and novel standard for high speed transmission links. In the near future various more uses will be seen for 5G technology.

IV. Conclusion

In this work, a novel edge fed Planar Inverted F Antenna has been proposed. The antenna resonates at 10.61 GHz with a return loss of -17.62 dB while measured value of resonance is 10.18 GHz with return loss of -30.80 dB and can be used in future 5G wireless devices. The designed antenna shows good radiation pattern and good gain of 4.27dB. The structure of the antenna is very compact i.e., 18mm × 10mm × 3.5mm and can be easily placed in the housing of the wireless devices.

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