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Planar Antenna Covering Sub-6 GHZ for 5g Enabled Mobile Devices Worldwide

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Abstract*: A miniaturized planar inverted F antenna (PIFA) for 4G/ 5G wireless technology is presented in this paper. It operates at frequency range 2.9 GHz to 4.9 GHz covering all the sub- 6 GHz frequency bands all over the world. The structure of PIFA is quite trouble-free and simple but the dimensions are quite minute. The patch is 11.3 mm x 8.3 mm. The antenna displays S_{11} equals to –37.9 dB at 3.9 GHz frequency. It seems really promising where simplicity is the concern for the 5G environment. The antenna is compatible with 4G environment and useful for 5G wireless technology.

***Keywords:* 4G, 5G, PIFA, wireless communication**

I. INTRODUCTION

Since last century, plethora of technologies has paved their way in our daily lives resulting in more and more advanced circuitry and complicated coding techniques. With the availability of internet, smartphones, tablets and laptops to one and all universally, antenna and related circuitry are becoming indispensible. Therefore with data communication requirements soaring in this era, advanced antennas with better characteristics are in big demand. In nutshell, antennas form the backbone of the communication world or more specifically the wireless domain.

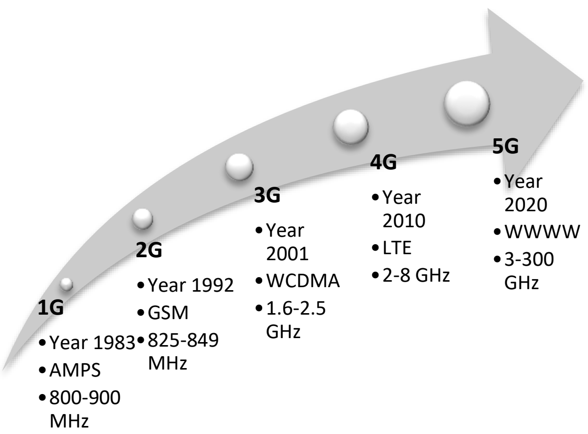

Fig. 1 Various Wireless Technologies

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Recently, a lot of advancements are taking place in the area of wireless mobile technology. From 1st generation (1G), finally we are in the 5th generation (5G) of wireless systems, which seems quite promising in many fields. Compact antennas along with advanced digital circuitry made it possible to live in a 5G environment. Fig. 1 shows various wireless technologies faced since last century[1].

The 5G frequency domain is categorized into three frequency regions: Sub 1GHz, 1 – 6GHz and above 6GHz [2]. It is expected to be launched by year 2020 in India, though in certain parts of the world 5G has already been launched. It is supposed that 5G cellular networks will deal with some challenges that are not addressed by 4G.

The overall objective is to provide a system that supports[3] :

a) Increased user data rate
b) Extended battery life for communication devices
c) Increased number of connected devices
d) Reduced End-to-End (E2E) latency

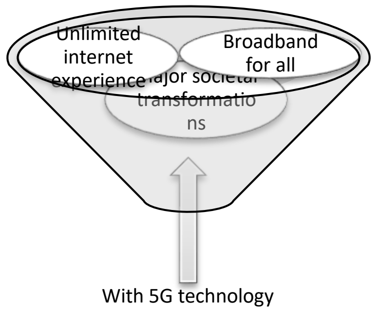

Fig. 2 Outcomes of 5G technology on common man

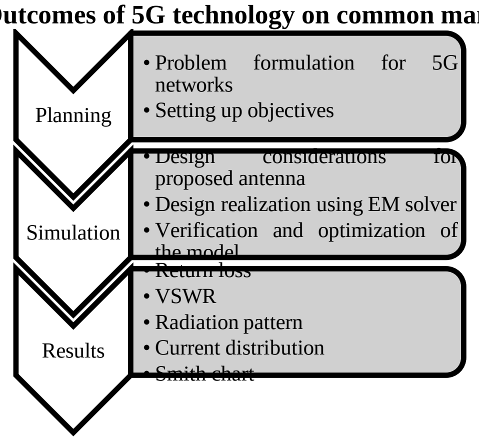

Fig. 3 Methodological frame of the proposed work

As shown in Fig. 2, with the advent of 5G, ordinary people can have broadband facility at negligible price, really good internet speeds and this can create reforms in rural and economical weaker segments of the society.

This paper depicts a planar antenna for sub-6 GHz band for 4G/5G technology.

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The methodological frame of the proposed work is as shown in Fig. 3. It has been analyzed that though very high frequencies are targeted nowadays for 5G applications on portable devices, researchers are still evolving around the lower frequency ranges also due to health hazards at very extreme frequency bands. A brief literature survey is tabulated in Table I since year 2017 in the field of PIFA for 4G/5G wireless systems.

Table I: Literature review since year 2017

Author, Year	**Frequency bands covered (GHz)**	**Return loss (dB)**	**Objective of the work**
[4]	6GHz (5–7GHz), 10GHz (9–10.8GHz), and 15GHz (14-15GHz)	Lies betwee n -25 to -30 dB	Proposed a multiband split-ring resonator based PIFA antenna for 5G applications .
[5]	2.4 GHz as Wi-Fi, 7.8 GHz as WiMAX and 33.5 GHz as 5G communication purposes	-22.37 dB, -26.02 dB and -29.01 dB	Designed antenna suitable for multiband purpose for Wi-Fi, WiMAX and 5G applications .
[6]	13.84–15.73 GHz, 14.14–16.26 GHz, 14.05–15.79 GHz and 14.60–15.15 GHz	Lies betwee n -12dB to -19 dB	Designed graphene array antenna for different substrates.
[7]	10 GHz, 28 GHz, and 38 GHz	-25.5 dB, −26.3 dB and −15 dB	Proposed antenna is for future 5 G wireless applications to reduce interference between systems in that band.
[8]	2.5-2.7 GHz and 3.4-3.8 GHz	less than -6dB	Presented a miniature MIMO dual- band antenna array for 5G devices Handsets.
[9]	2.6 GHz and 3.6 GHz	-20dB and -35 dB	Studied the model of a 4G/LTE and 5G antenna systems committed to mobile terminals.
Proposed PIFA	3.99 GHz	-37.9 dB	Useful for 4G/ 5G worldwide. Simple structure.

The various sections of the paper are organized as: Section I presents a brief introduction to wireless technologies, objective of using planar antenna and literature review of latest work done in this domain, Section II describes the configuration of the proposed PIFA antenna, Section III represents the simulated results and related discussions and finally Section IV provides conclusions and future scope of the presented work.

II. PROPOSED ANTENNA CONFIGURATION

The Planar Inverted F Antenna (PIFA) is progressed from a quarter-wavelength monopole antenna. The PIFA can be also thought as evolved from the conventional half-wavelength microstrip or patch antenna [14]. The PIFA evolution as a $\lambda/4$ monopole antenna, started with the basic quarter-wavelength wire monopole antenna with 37.5 Ω input impedance fed at the bottom as shown in Fig. 4(a).

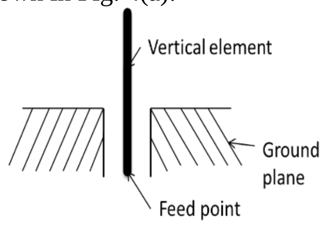

Fig. 4(a) Structure of a Monopole Antenna

Further, for reducing the size, the $\lambda/4$ monopole wire antenna was bent to form an inverted-L shape which is known as inverted-L antenna (ILA) as shown in Fig. 4(b).

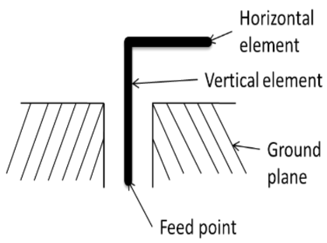

Fig. 4(b) Structure of Inverted- L Antenna (ILA)

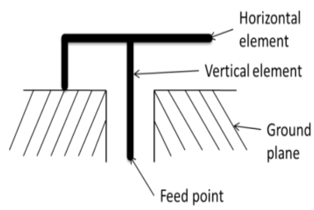

Fig. 4(c) Structure of Inverted- F Antenna (IFA)

By combining Fig. 4(a) and Fig. 4(b) configurations, a new configuration was obtained which is known as inverted-F antenna (IFA) as shown in Fig. 4(c).

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However, this configuration had a drawback of lower bandwidth which was then improved by replacing the top wire element with a planar structure, which is known as Planar Inverted F Antenna represented in Fig. 4(d). The following flowchart (Fig. 5) illustrates the process of selecting dimensions of PIFA antenna. While configuring it some parameters have to be optimized to get the desired results.

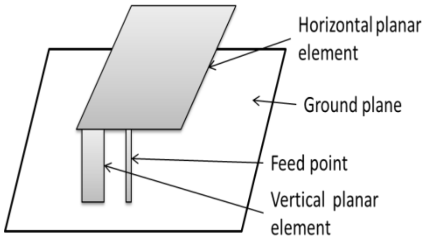

Fig. 4(d) Structure of Planar Inverted- F Antenna (PIFA)

This is how a PIFA evolved from a basic λ/4 wire monopole antenna.

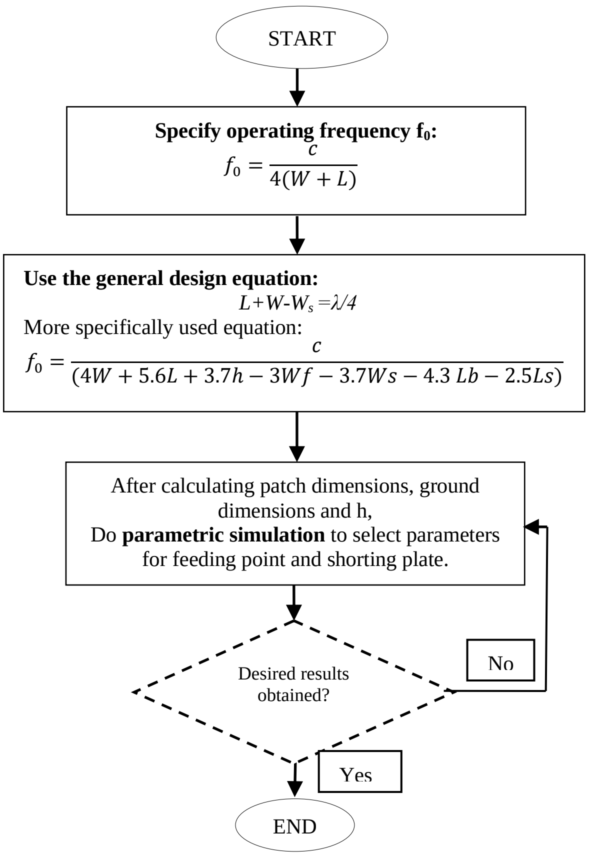

Fig. 5: Flowchart explaining design considerations for a PIFA

where, L and W is length and width of the top radiating element, W_s is the width of shorting plate, λ is wavelength, f_0 is the operating frequency of PIFA antenna and c is the speed of light, respectively[10].

Fig. 6(a) shows the 3D view of proposed planar antenna for 4G/5G wireless applications. The proposed antenna consists of a radiating patch, shorting plate, ground plane and coaxial feed with SMA connector. Fig. 6(b) and (c) provides the side and top view of the antenna.

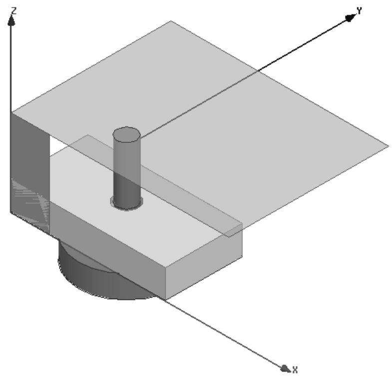

Fig. 6(a) 3D view of the proposed PIFA antenna

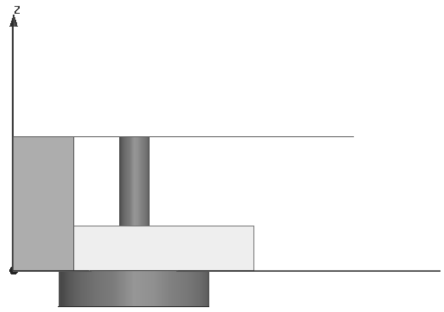

Fig. 6(b) Side view of the antenna

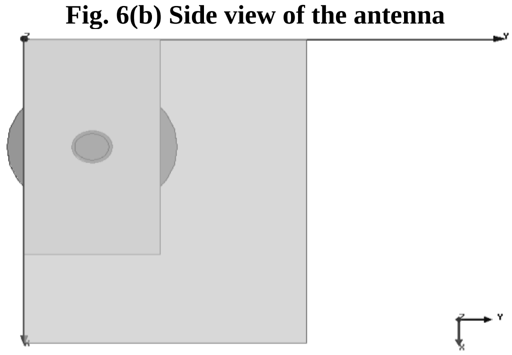

Fig. 6(c) Top view of the proposed antenna

The antenna dimensions are as displayed in Table II. The antenna design is based on FR4 dielectric substrate with height of h = 4.5 mm, relative permittivity of 4.4 and dielectric tangent loss, δ = 0.02.

Table II: Overall antenna dimensions (in mm)

Antenna Components	Dimensions in mm
Patch	11.3 x 8.3
Shorting pin	2 x 4.5
Ground plane	8 x 4
Substrate material - FR4 epoxy	

The proposed antenna can be acceptable worldwide for sub-6 GHz band. Moreover, the dimensions are also minute and hence can be useful for most of portable devices.

III. Simulated Results and Discussions

A. *Return Loss or S_{11} Parameter*

It is one of the imperative parameter for evaluating the performance of an antenna, which specifies how much power is reflected to the input terminal when the input power is given to an antenna [11].

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The return loss is generally measured in decibels (dB) and can be represented by equation (1) as follows:

$$\text{Return Loss, (RL)} = \left|20 \log10 \left|\frac{V_{reflected}}{V_{incident}}\right|\right| \quad (1)$$

where, $V_{reflected}$ is the amplitude of reflected wave from the antenna input terminal and $V_{incident}$ is the amplitude of incident wave coming towards the antenna input terminal.

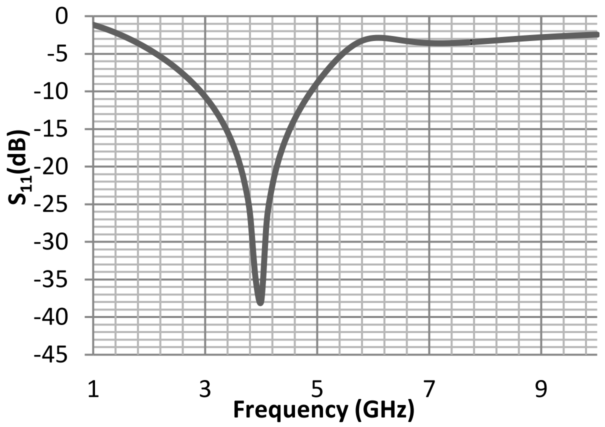

Fig. 7 S_{11} (dB) simulated of the proposed design

The proposed PIFA antenna is simulated using FEM (Finite Element Method) technique. The values of obtained S_{11} are less than -10 dB. Fig. 7 shows a plot for simulated S_{11} values in dB against frequency in GHz. The simulated S_{11} value obtained at resonant frequency of 3.99 GHz is -37.9 dB, which is really good. It can cover frequency bands of IEEE 802.16e mobile WiMAX and useful for 5G globally.

B. *VSWR*

VSWR is another important parameter for evaluation of antenna. VSWR can be given by equation (2) as follows

$$VSWR = \frac{1+\left|\frac{V_{reflected}}{V_{incident}}\right|}{1-\left|\frac{V_{reflected}}{V_{incident}}\right|} \quad (2)$$

The simulated and measured results for VSWR of proposed antenna are shown in Fig. 8. The VSWR at resonant frequency is less than 2, which is vital for most of the wireless applications[7].

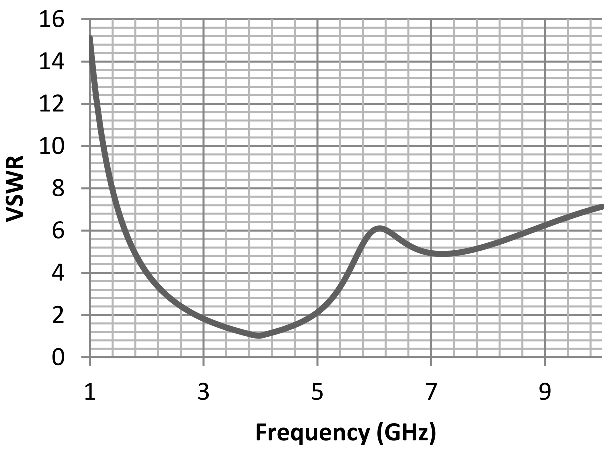

Fig. 8 VSWR versus frequency plot for the antenna design

C. *Radiation Pattern*

Radiation pattern is the graphical illustration of radiation properties of antenna as a function of space coordinates and displays the relative field strength of power radiated by the antenna [12].

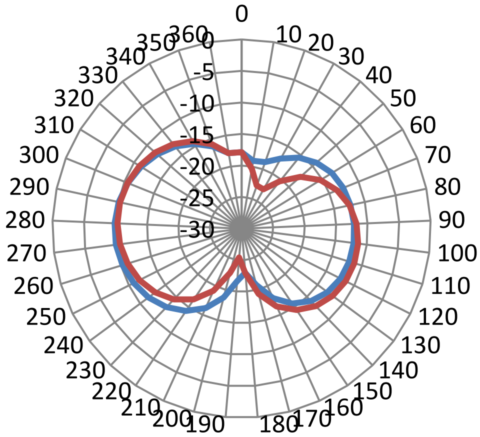

Fig. 9 Simulated radiation pattern at 3.9 GHz frequency

Fig. 9 shows the two-dimensional radiation patterns for the resonant frequencies 3.9 GHz for $\phi = 0^{\circ}$ (xz-plane) and $\phi = 90^{\circ}$ (yz-plane) with total gain in dB.

D. *Current distribution*

Current distribution is another essential parameter of antenna which contributes in explaining the working principle of an antenna. The surface current distribution in the top patch of proposed PIFA for each resonant frequency or mode is presented in Fig. 10.

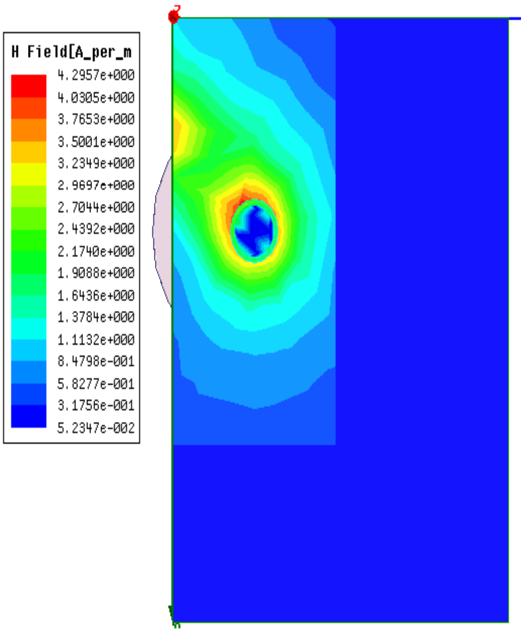

Fig. 10 Surface current distribution for 3.9 GHz

As observed from the Fig. 8, current density is more at the feed point and reduces as it moves away from feed.

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E. *Gain Polar plot*

Fig. 11 displays the total gain polar plot for different values of theta and phi. The gain is reduces as we move away from the center point.

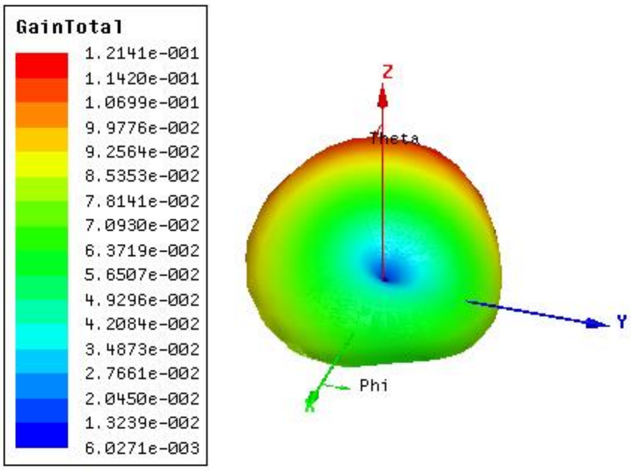

Fig. 11 3-D polar plot

F. *Smith chart*

Smith chart is a tool used by engineers to evaluate the transmission line and matching problems[13]. Fig. 12 illustrates the smith chart of the proposed antenna.

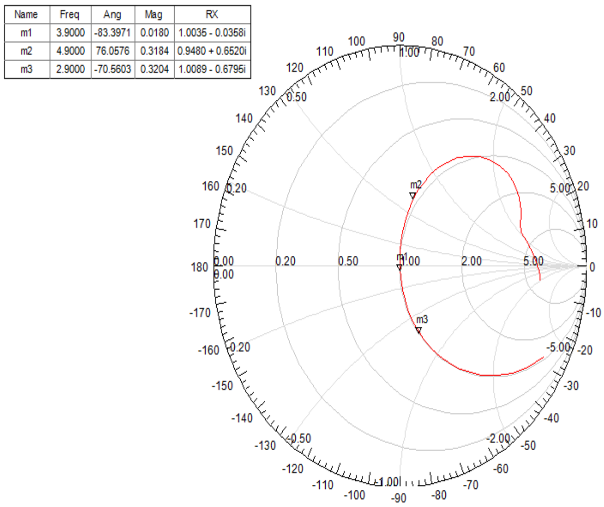

Fig. 12 Simulated Smith chart

The summary of the specifications of the proposed antenna structure is as in Table III.

Table III: Specifications of PIFA antenna

Antenna Characteristic	Specifications
Patch	11.3 x 8.3 mm^2
Resonant Frequency	3.99 GHz
Bandwidth	Wide
Reflection Coefficient (S_{11})	-37.7 dB
VSWR	< 2
Feeding Method	Coaxial feed

CONCLUSION

In this paper, a compact wide band PIFA antenna is proposed for 4G/ 5G wireless applications. The outcomes of 5G technology on common man, literature survey and evolution of PIFA are briefed. The proposed antenna is compatible for frequency range 2.9 GHz to 4.9 GHz of sub – 6 bands of frequencies all over the world. The results of various parameters are investigated and respective plots displayed. A superior value of -37.9 dB for S_{11} parameter is observed. The finest part of the design is that it is a simple planar inverted F antenna with modified dimensions. The results can be improved further with the aid of special material such as metamaterials and techniques for instance inserting slots in future modified structure.

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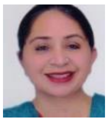

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