Design of Antenna to support 4GLTE Communication and Performance Evaluation of various PIFA AntennaCharacteristics

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Abstract:
During the past decade the wirelesstechnology has evolved from zero generation to 4 generation and the main emphasis of this enhancement is to provide high Quality of Service (QoS), performance and efficiency. This technology gives higher data rates for VOIP and online gaming requirements in the handsets and mobile internet devices. To achieve these applications, a low-profile communication systemwith dual band as well as single band behaviour with good gain is needed. In this paper, we have designed, simulate and tested PIFA structure for LTE high band. Also, examined various characteristics such as isolation, Diversity Gain, ECC etc.

Keywords:Antenna, Bandwidth, Gain, LTE, PIFA.

I. Introduction

The technology of wireless communication has shown a rapid development from the era of cordless phones to the latest mobile phones in last few decades. Initially, the cordless phones have external antenna but with the development of smaller size antenna, its size has been reduced drastically and finally, converted into the internal antenna. Since the signal performance of mobile phone is depends upon the sensitivity of its antenna, the performance of antenna in terms of gain and bandwidth has been degraded due to its reduced size [1-3].Gain, radiation efficiency and operating bandwidth are the fundamental limitations of small antennas. Also, antenna has self-resonant and self-immune structure. Therefore, a compact antenna with wideband and multiband characteristics is desired which has low cost, light weight, compact size, robustness, flexibility and ease of mass production [4]. Since the wireless devices are getting compact and slimmer due to the advancement of technology, the height of the antenna should be very small so that the same can be integrated in the housing of mobile phones. Hence the Planar Inverted-F Antenna (PIFA) is used as an internal antenna in which the bandwidth achieved and radiation efficiency is proportional to its height [5-6].

There are various challenges in designing a handset antenna such as small size, thin dimensions, light weight and user-friendly mobile handsets and above all that they should be able to cover multiple frequency bands and provide wide coverage.

Antenna design challenges are briefly explained as follows:

- To make an antenna a compact and miniaturized various design parameter are altered. Conventionally, a small antenna is defined as the one which occupies a fraction of wavelength [4-5]. Impedance matching is the main concern in the design of such antennas. Various losses occur due to finite conductivity of the antenna structure [7]. The currents are induced on nearby structures including ground plane that constitutes the antenna input resistance also causes different losses [8]. To get proper impedance matching it is desirable to operate the antenna around its resonance.
- The ground plane of an antenna is made up of metallic layer of the PCB and other metallic parts of the chassis. Planar Inverted F Antenna used in handheld devices shows different characteristics when it is placed on an infinite ground plane to that when it has particular dimensions and location of chassis [9-11]. Radiating surface of the ground plane induces currents due to presence of antenna structure [12]. Hence, the overall performance of the antenna is highly affected by the dimensions of the ground plane. In other words, compromise has to be made among volume, impedance bandwidth, gain and radiation characteristics of an antenna while making miniaturized antenna for a handheld application.

II. Various Antenna Structures for Wireless Devices

In the past few years a multiband antenna that supports multiple frequencies with maximum coverage and compact size is required. The demand has increased due to advancements in wireless communication technologies and tremendous growth of cellular service users. Hence there is an upsurge for the requirement of an antenna that not only supports multiple frequency standards but also provides wide bandwidth characteristics. Therefore, mobile handsets and other wireless devices should be low profile and aesthetically good [13]. This paper is focused on the design and development of an antenna for USB devices. Thus, in this section a brief account of various antenna structures and designs that supports multiband frequencies is outlined. Various designs discussed in this section have the potential to be used in future wireless devices.

Several antenna structures have been developed and implemented for various wireless handheld devices. The antennas so designed are used to meet the demand of the rapidly increasing cellular phone market. The presented antennas are mainly focused on supporting various communication standards worldwide such as GSM, DCS, PCS, UMTS (3G), WiMAX and 4G LTE etc while on the other hand, some of the antenna designs are also used for non-cellular frequency bands such as Bluetooth, Wireless LAN, GPS & GLONASS [14].

a. Microstrip Patch Antenna (MSA)

Microstrip Patch Antenna can be engraved easily on a circuit board such as PCB having copper layer on one side and hence are also known as patch antenna. Microstrip structures consist of a ground plane made up of copper on one side of the low loss dielectric substrate while a partly metal patch on the other side of the substrate [15]. These antennas have compact structures, robust and support circular and linear polarization. Narrow bandwidth, low gain, low power handling capacity is some of the cons of MSA Antennas [16-18]. These antennas find its applications in communication systems, satellite systems, handheld devices etc.

b. Inverted-F Antenna (IFA)

The Inverted-F Antenna (IFA) mainly consists of a rectangular planar element called radiator or patch located at a height above the ground plane, a short-circuiting wire or pin, and a co-axial feed for the planar element. In order to reduce the height of the antenna Inverted F antenna is used which is a variation of the monopole antenna where the top section has been folded down so that it becomes parallel with the ground plane and the resonant trace length is maintained [19]. Capacitance to the input impedance of the antenna is introduced by the parallel section of the antenna. The ground is connected to the stub's end. In IFA the ground plane of the antenna plays an important role in its operation as the excited current in printed IFA causes excitation of currents in the ground plane. When the ground plane is infinite in its dimensions than the monopole, it behaves as a perfect energy reflector [20]. In general, the dimensions of the PCB ground plane length should be one fourth of the operating wavelength otherwise it may lead to multiple lobes or degraded performance. The bandwidth of IFA was very narrow and in order to expand the bandwidth of the antenna the wire radiator was replaced by a plate, hence PIFA was invented.

c. Planar Inverted-F Antenna (PIFA)

PIFA is also referred as short-circuited microstrip antenna, as the plate is used to short circuit the radiator and the ground plane [21]. The size of the ground plane plays an important role in designing Planar Inverted F Antenna and can be used to optimize the antenna for wide-band and multi-band frequencies.PIFA's find their advantages in a variety of communication systems applications especially in mobile phone handsets due to compact size, low profile, light weight and easy integration. Different shape of slots etched on ground plane and radiator are used to obtain different configurations in order to achieve single and multiple frequencies.The bandwidth of the antenna can be improved by transforming the horizontal element from a wire to a plate which also results in PIFA structures. These designs have self-resonating structure. However, the electrical performance of the antenna structures can further be improved by varying the length, distance and location of the feed &shorting point, and height of the radiator [22]. PIFA structures have various advantages when compared to other conventional antennas such as that it can be placed inside the mobile housing just above the battery when comparable to whip/rod/helix antennas. PIFA structures produce reduced electromagnetic radiations in the backward direction toward the user's body and hence minimizing Specific Absorption Rate (SAR). PIFA structures also shows moderate to high gain in horizontal and vertical states ofpolarization [23]. Apart from various advantages, the efficiency of PIFA is reduced by various losses such as ohmic losses, mismatch losses, edge power losses, external parasitic resonances, feed line transmission losses, etc. [24]. The comparison between handheld device antennas used for various applicationsin terms of antenna parameters, applications, merits and problems is presented in table 1 whereas effect of PIFA parameters on its characteristics is presented in table 2.

Table 1: Comparison of Microstrip Patch and PIFA structures

Parameters	**Antenna Type**	
	Microstrip Patch	PIFA
Radiation Pattern	Directional	Omnidirectional
Gain	High	Moderate to high
Modelling & Fabrication	Easier to fabricate and model	Easier fabrication using PCB
Applications	Satellite Communication, Aircrafts	Internal antennas of Mobile phones
Merits	Low cost, Low weight, Easy in integration	Small size, Low cost, reduced backward radiation for minimizing SAR
Problems	No band pass filtering effect, surface-area requirement	Narrow bandwidth characteristic

Table 2: Effect of PIFA parameters on its characteristics

Parameters	**Effects**
Length	Increase inductance of the antenna
Width	Control impedance matching
Height	Control Bandwidth
Width of shorting plate	Effect on the anti-resonance and increase bandwidth
Feed position from shorting plate	Effect on resonance frequency and bandwidth

III. Design of PIFA Antenna

The structure of the proposed PIFA antenna with square top patch is shown in figure 1. It consists of main radiating patch, ground plane, shorting plate, and a coaxial feed. The height of PIFA can be reduced to a great extent by using the ground plane as a radiator in addition to its main patch situated above ground plane for overall reduction in the thickness of antenna.

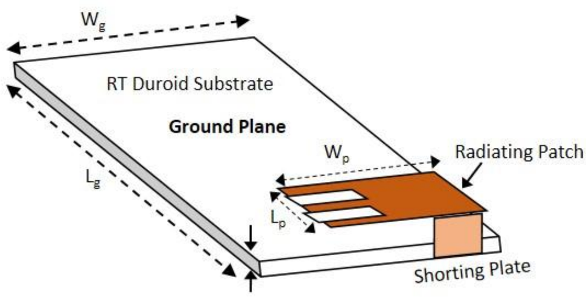

Figure 1: 3-D view of Proposed PIFA Structure

In the proposed structure, the size of radiating patch is 17x14mm^2 and size of ground plane is 90x50mm^2. The height of shorting plate is 4mm. Since the radiating patch coversaround 5% of the total size of the antenna, the space available can be used by other electronic components. The antenna is intended for the LTE applications. The top &side view of the antenna is shown in figure 2, and dimensions of PIFA are presented in table 3.

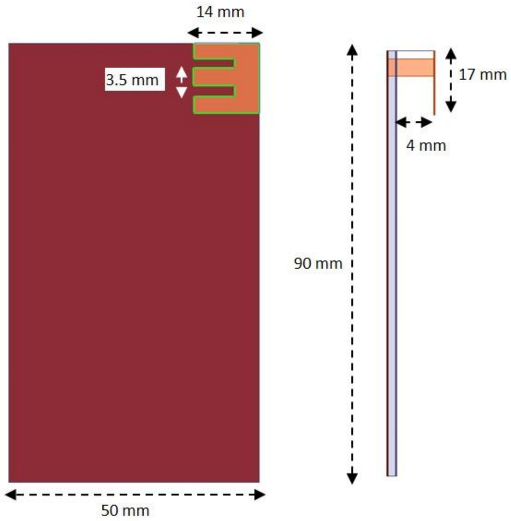

Figure 2: Top and side view of the PIFA

Table 3: Dimensions of PIFA for LTE applications

Parameter	Size (mm)
L_g	90
W_g	50
L_p	17
W_p	14
L_s	4
W_s	9
t	1

As the main objective of this work is to propose a small antenna having thin structure, therefore, the height of the PIFA selected is 3 mm from the FR4 substrate and 4 mm from the ground plane. The structure is simulated through electromagnetic simulation software HFSS, and has been observed that with these dimensions, the antenna resonates at 3.4 GHz which can be used for 4G LTE and 5G applications. The accomplished results such as return loss (S_{11}), 3-D Gain plots, VSWR plots and radiation patterns are discussed.

IV. Results

After designing and analysing a simple single band antenna then the next step was to design and simulate a Planar Inverted-F Antenna (PIFA). Proposed antenna covers proposed 4G/5G band at 3.5 GHz and this is achieved by using a modified top patch and edge feeding mechanism. From the simulated return loss plot for the proposed PIFA antenna design as shown in figure 3, the return loss parameters are obtained using wave port configuration. The antenna operates at proposed 4G LTE/ 5G frequency band. The proposed antenna resonates at 3.4 GHz with a return loss of -18.15 dB and showing a wider bandwidth of 410 MHz.

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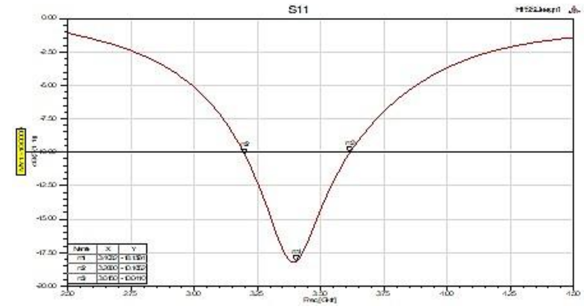

Figure 3: Simulated return loss plot for the proposed PIFA

The simulated 3D radiation pattern resonance obtained from the simulation results is shown in figure 4. From the plot, it has been observed that the antenna is a good radiator with almost omnidirectional radiation pattern which can be useful for mobile handsets and other portable devices.

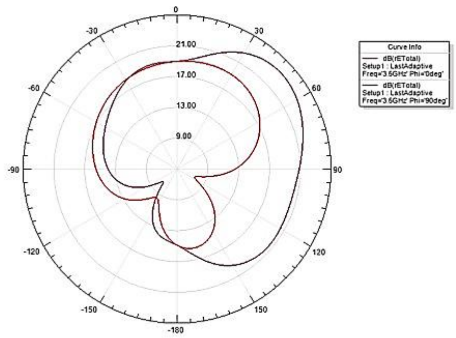

Figure 4: Simulated 3D radiation pattern of proposed PIFA

The gain and efficiency are two important figure of merit of the antenna. It has been found that the overall gain of the antenna is 5.66 dB at resonance of 3.4GHz. The value of VSWR should be less than 3 dB at resonant frequency and the same can be computed from the plot. The value of VSWR is found 2.15 dB at 3.40 GHz. The simulated 3-D gain plot is presented in figure 5 and the VSWR plot is shown in figure 6.

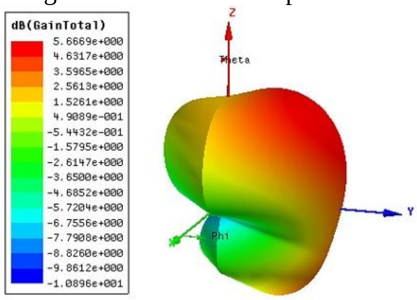

Figure 5: Simulated 3-D Gain Plot of Proposed PIFA

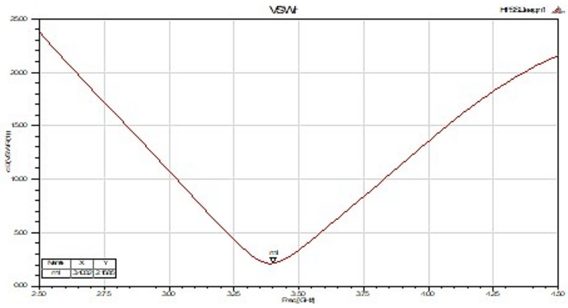

Figure 6: Simulated VSWR plot of Proposed PIFA

V. Conclusion

The main objective of this work is to achieve a new antenna design that supports 4G LTE frequency band which is candidate band for future 5G communication also. The designed antenna can be integrated with any wireless device because of its low profile and reduced size. The work also deals with the aspects of design and simulation of different PIFA structure that can be used in wireless applications. It has also been observed that the simulation results obtained relates well with the basic theory PIFA structures.

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