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Design and Parametric Analysis of Compact Internal Antenna for 4G LTE Application

Ashish Kumar Verma [1]*, Dr. Sanjeev Maheshwari [2] and Nikita Goel [2]

*1 Department of Electronics and Communication Engineering, Meerut Institute of Technology, Meerut
2 Department of Electronics and Communication Engineering, Meerut Institute of Technology, Meerut
2 Department of Electronics and Communication Engineering, Meerut Institute of Technology, Meerut

Abstract- This paper presents the design of a Planar Inverted-F antenna with very small rectangular shape radiating patch(22mm X 25.5mm) lifted up at a height from the ground plane and excited by co-axial feed. The effect of various vital physical design parameters have been studied. Simulations are done using FEM based electromagnetic solver. The proposed antenna is optimized for LTE2300 band.
Keywords: PIFA, LTE, FEM, HFSS

1. Introduction

World is demanding the real time communication i.e. the information interchange any time anywhere with seamless connectivity. For making this possible the wireless enabled devices for short range as well as long distance communication are being designed and developed at a very rapid rate. For a wireless enabled transceiver an antenna is the most important and crucial organic part that should be designed and fabricated with extreme precision. The choices for the antennas for such devices are wire monopoles and normal mode helical antennas. Planar printed antennas like micro strip antennas are also used.[1],[2]. For a hand-held cellular phone and any portable device like Laptops or PDAs, the antenna should be miniaturized to reduce the size, light weight, low cost and conformal to the surface. Besides the compact size these antennas should have omni-directional radiation pattern, high gain and wide impedance band width.The PIFA are proving themselves as the most suitable candidates for mobile and portable terminals as they can be easily integrated with the RF circuits and can be installed inside the device internally[3].Planar Inverted-F Antenna is derived from Inverted F Antenna (IFA) in which a linear wire is replaced by shorting plate.[3],[4].Planar Inverted F Antenna (PIFA) has a low profile structure and hence can be easily integrated in mobile devices.[4].Several PIFAs have been reported for the mobile phone applications for multi band operations like for the GSM900 (890–960 MHz), GPSL1 (1565-1585 MHz), DCS1800 (1710–1880 MHz), DCS1900 (1850–1990 MHz) DECT (1880–1990 MHz), and UMTS2100 (1920–2170 MHz) cellular mobile phone applications[5],on body communications[6] and also for ultra wide band,GSM and WiMAX applications[7]. One major advantage of PIFA over other alternatives like wired monopole and Planar Inverted F Antenna structures have many advantages such as reduced Specific Absorption Rate (SAR) i.e., less radiations are absorbed by user's head, provides moderate gain and Omni-directional patterns and shows improved performance than other conventional antennas [8].The compactness of these antennas also suggests to use them for RFID applications also.[9][10].

Currently in INDIA, 4G LTE band-40 having 2300 to 2400 MHz (TD-LTE) frequency range is active (online) and offered by the operators in Indian Territory. The other LTE band in 1800 MHz (FDD-LTE) frequency is also auctioned by the INDIA government. But this LTE band is not offered for LTE by any telecom operators. [11]

This 100MHz bandwidth of Band-40 from 2300MHz to 2400MHz is divided into downlink and uplink. Downlink refers to transmissions from eNB (i.e. base station) to UE (i.e. mobile user) and uplink refers to transmission from UE to eNB. This paper presents a simple PIFA design for mobile phone application. The PIFA resonates at 2300MHz which is suitable for 4G-LTE. The specifications of key elements for the design of the rectangular planar inverted-F antenna are listed in Table 1.

Table 1. Design specifications of antenna

Shape	Rectangula
Operation Frequency	2300MHz
Dielectric Constant of Substrate	2.2
Thickness of Substrate	1.6mm
Gain	0dB-5dB

This paper is divided into four sections as follows: Section I discuss the introduction and basic theory of PIFA. Section II presents the antenna design and structure, section III presents about the simulation results and section IV will summarize the conclusion of this paper.

2. Antenna design

The geometry of proposed planner antenna is shown in fig.1.It consist of the top radiating rectangular patch and the shorting plate which connects the rectangular patch and the ground plane. The dimension of the ground plane and the substrate are same that are 37mm×35mm. The height of the substrate is the 1.6mm. The material used for the substrate and ground fabrication is the Roger RT/ duroid 5880(tm) whose dielectric constant is 2.2. The dimension of the top radiating patch is the 25.5mm×22mm which is lifted up 5mm from the substrate. Air is used as a dielectric to fill the gap between the patch and the substrate. Coaxial feed is used for the excitation of the antenna.The resonant frequency of the proposed PIFA can be determined based on theequation (1). The resonant frequency, f is inversely proportional to the total dimension of patch (Lp x Wp). The operating antenna frequency can be calculated from the length of the antenna patch as shown in equation (2) and (3) below

$$f = \frac{c}{4(L_p + W_p)} \quad (1)$$

$$L_p \approx \frac{1}{4}\frac{c}{f\sqrt{\varepsilon r}} \quad (2)$$

$$W_p = \frac{c}{4(f)}\sqrt{\frac{2}{\varepsilon r + 1}} \quad (3)$$

Where Lp and Wp are the length and width of the radiating patch, c is the speed of light and εr is the dielectric constant of the substrate material.[8].

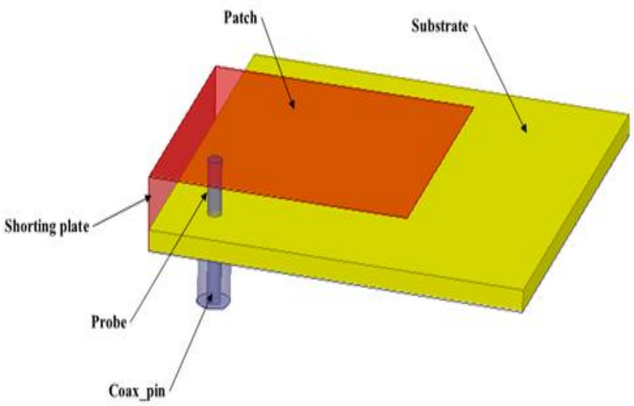

Fig.1 Geometry of proposed Rectangular PIFA Antenna

This proposed antenna structure comprises of: a main radiator, shorting plate and coaxial feed. The front and the side view of the geometry has been depicted in fig. 2 and fig. 3 respectively.

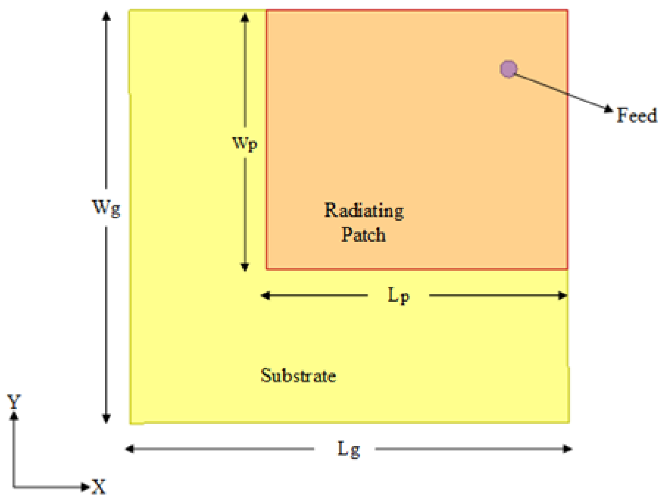

Fig.2 Front view of the PIFA

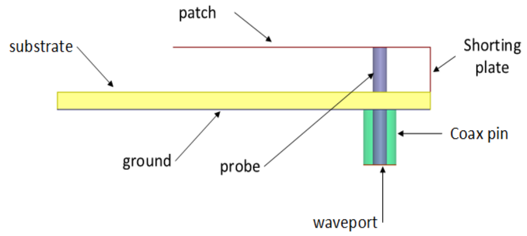

Fig.3 Side view of the PIFA

The geometrical shape specification of the proposed PIFA has been enlisted in Table 2.

Table 2. Geometrical Specifications of antenna

S.No	Parameters	Optimized Values(mm)
1.	Length of ground plane (Lg)	37
2.	Width of ground plane (Wg)	35
3.	Length of substrate (Ls)	37
4.	Width of substrate (Ws)	35
5.	Height of substrate (Hs)	1.6
6.	Length of the patch (L_p)	25.5
7.	Width of the patch (W_p)	22
8.	Height of the patch (H)	5
9.	Width of the short plate	22
10.	Feed Location(x,y)	(32,30)

3. Simulation and Results

The optimization and simulation of proposed rectangular PIFA (Planer Inverted-F Antenna) is carried out using High Frequency Simulating Structure (HFSS), an FEM based em solver. The parametric analysis of Length and Width of the patch and the location of feed is performed. The reflection coefficient curve and the 3D radiation pattern of optimized antenna are also shown.

3.1 Effects of design parameters

The major design parameters are the dimension of patch and the location of feed. The effect of these parameters have been investigated and presented.

3.1.1 Effect of length of patch

Length of patch may be considered a crucial parameter that decides its resonant frequency of PIFA. As the length of patch is decreased, the resonating frequency increases. The S_{11} vs. Frequency curve for different values of patch length is depicted in fig.4. The length of patch (L_p) is optimized to 25.5mm for LTE2300 Band.

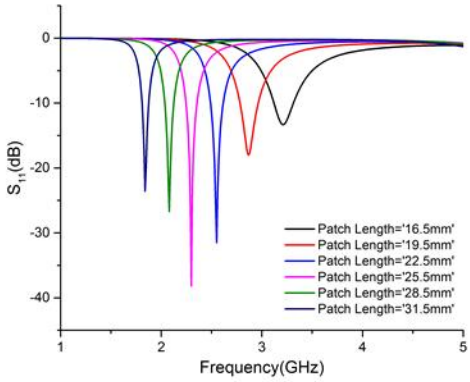

Fig.4 Simulated Return Loss for different Patch Length

3.1.2 Effect of width of the patch

This parameter of rectangular PIFA antenna governs the impedence matching of the antenna. If the width of patch decreases the impedence matching shows poor result as in fig5.

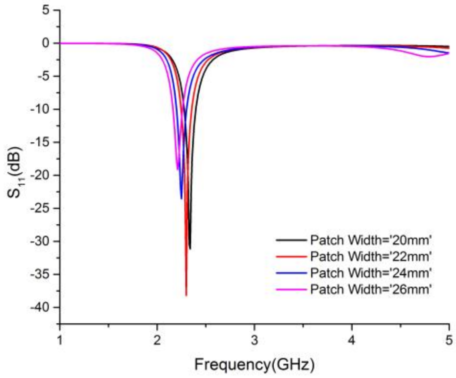

Fig.5 Simulated Return Loss for different patch Width

3.1.3 Effect of probe feed location

The effect of the probe feed location on the antenna performance is that as the feed is moved away from the shorting plate the antenna impedence shows poor result. Both longitudenal and lateral movements of feed are done and the effect is investigated. The movement of feed along X-axis results i.e. parallel to the shorting plate results better impedance matching and the shift of resonant frequency towards lower values if feed shifts towards right in fig2.

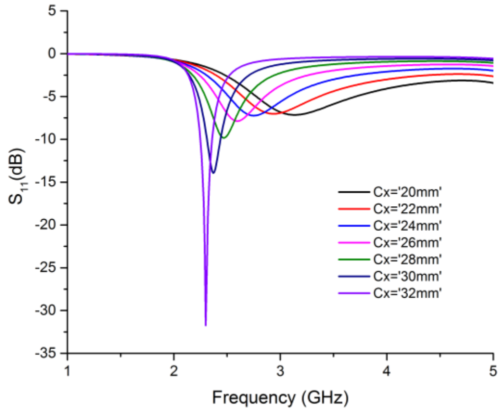

Fig.6 Probe feed movement along x- axis

And if the same feed is moved along Y-axis, the better impedance matching results as feed is shifted towards the shorting plate while the resonating frequency remains unchanged. The effect of feed location is revealed in fig6 and fig7.

***3.2** Results of optimized antenna*

The simulated results of optimized parameters exhibit that the proposed antenna resonates on 2300MHz. The optimized values of parameters are listed in table 2. The reflection coefficient vs. Frequency curve shows the good agreement of the result with specified spectrum of LTE2300 Band. The maximum gain which is observed from this simulation is 4.1079dB at 2.3GHz resonating frequency. Both reflection coefficient curve and Gain of antenna are plotted in fig 8 and fig 9 respectively.

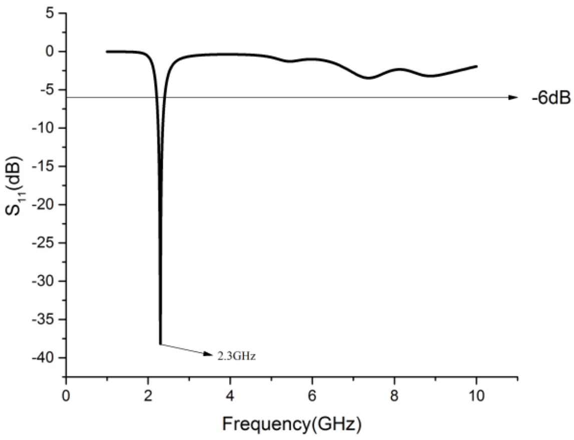

Fig.8 Return Loss Curve for the optimized Antenna

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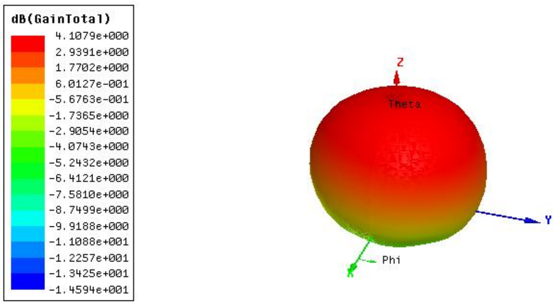

Fig.9 Gain of the proposed rectangular PIFA

4 Conclusion

In this paper a simple PIFA with rectangular shaped radiating patch has been optimized and designed to operate at 2300MHz with an omni-directional radiation pattern which is suitable for 4G-LTE portable devices. The antenna has a very small size and volume so as to fit inside the device. The physical parameters and their effect has also been investigated.

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