Design of PIFA Antenna for 4G Wireless Communications

Amin H. Al Ka'bi
Australian College of Kuwait, Kuwait
Email: a.kabi@ack.edu.kw

ABSTRACT

With the introduction of the fourth generation (4G) of cellular mobile communications, there has been an increase in the frequency bands that a generic mobile phone should be able to operate. This requirement poses some challenges in the design of the transceiver modules of the device as well as the RF front-end and the antenna.

In this paper we discuss the effect of Planar Inverted F-Antenna (PIFA) dimensions on its resonance frequency, and we come up an empirical equation for this relationship.

KEYWORDS

PIFA, Antennas, 4G, Resonance frequency.

I. INTRODUCTION

The current trend in mobile communications devices is to provide faster access, higher processing capabilities, extra memory space, higher resolution displays, and more reliable connectivity with Wi-Fi, GPS, and fourth generation (4G) mobile cellular networks, altogether with longer battery life and more compact packages.

Combining all these goals with the need for additional band allocations, and what results in critical industrial design requirements, where manufacturers are struggling for physical space within the boundaries of the mobile device to accommodate all the required components, and in particular the antenna.

In this paper we focus on an antenna design for fourth generation (4G) of cellular mobile communications, where there has been an increase in the frequency bands that a generic mobile phone should be able to operate. This requirement poses more challenges in the design of the mobile device including its transceiver modules, RF circuitry and the antenna.

In last three decades PIFA antenna structure has emerged as one of the most promising candidate in the category of low profile antennas used in handheld devices. Wide range of applications uses PIFA as their basic antenna. For a system to perform optimally, the antennas must have simple construction, high radiation efficiency, small volume, low-loss impedance matching. In IEEE literature Planar Inverted-F Antenna (PIFA) was first introduced in 1987[1]. Nowadays, many mobile applications employ PIFA as their primary antenna in order to cover wide frequency bands, including GSM 850, GSM 900, DCS 1800, PCS 1900, WLAN, Wi-Bro, Bluetooth, UMTS, and 4G LTE.

There are many advantages of using PIFA antennas in handheld mobile devices. Some of these advantages are easy fabrication, simple structure, small volume, low manufacturing cost, easy to hide in the casing of the mobile handset as compared to other types of antennas. Moreover, PIFA has less backward radiation towards user's head and body which results in improved performance [1]. PIFA antennas can resonate at much smaller antenna size and resonance can be adjusted by cutting slots in radiating patch. Multiband operation can be achieved by proper shape of the patch and positions of feed plate and shorting pin [2].

Moreover, PIFA antennas introduce a solution to the effect of mutual coupling on the performance of the system through the use of a single-structure antenna that optimally produces different radiation modes as shown in Fig. 1 [3]. PIFA design reduces mutual coupling between the antenna's two feed points, which results in more rotational capability of antenna patterns, lower antenna pattern envelope correlation coefficient (APECC), and consequently, leads to better system efficiency.

The design of multiband PIFA antennas for 4G has been discussed in various research works, e.g. [4] and [5]. The main issue here is that antennas support some unauthorized frequency bands by spectrum regulators, while other authorized bands are not supported. For example, the 2.3, 3.65, 5.8 GHz bands supported by PIFA, and allocated for 4G by FCC are not authorized in Europe. Therefore, antenna designs for 4G should take into consideration the authorized bands e.g. 710 MHz, 1900 MHz, 2.3 GHz, and 3.65 GHz.

The PIFA consists in general of a ground plane, a top plate element, a feed wire attached between the ground plane and the top plate, and a shorting wire or strip that is connected between the ground plane and the top plate.

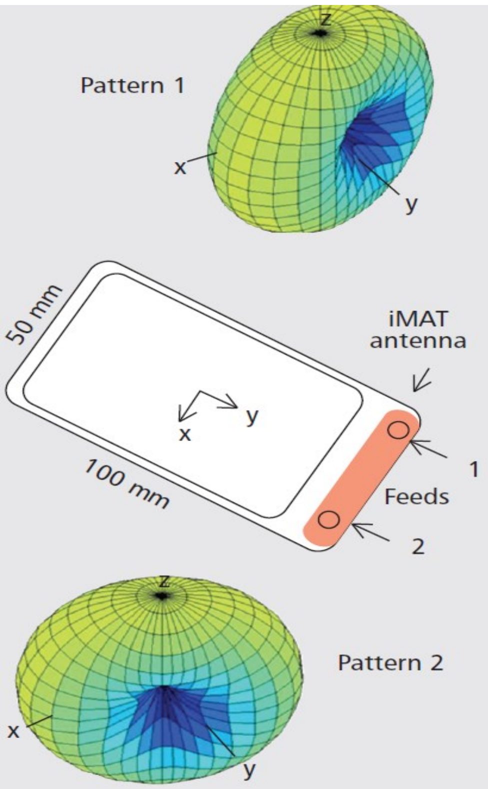

Fig. 1. Coupling and radiation patterns resulting for antennas at one end of the phone chassis using isolated mode antenna technology (iMAT)[3].

II. PLANAR INVERTED F-ANTENNA

The basic structure of the Planar Inverted F-antenna is depicted in Figure 2. Changing the antenna dimensions shown in Fig. 2, results in reshaping the radiation pattern of the antenna. In this paper the effect of changing the antenna dimensions is investigated and the corresponding simulation results are presented.

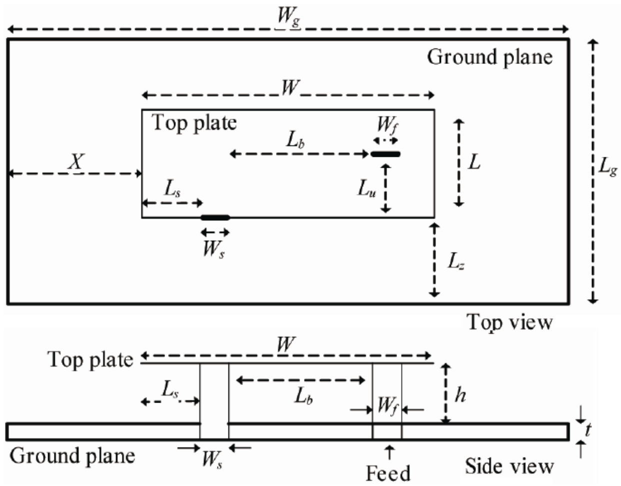

Fig. 2. Typical PIFA structure.

The antenna is fed through feed plate which connects to the ground plane through the dielectric substrate. The short pin and short plate allow good impedance matching achieved with the patch above ground plane of size less than λ/4. This design provides more compact size in comparison with conventional λ/2 patch antennas.

The resonance frequency of the PIFA antenna is given by

$$f_0 = \frac{c}{4(L+W)} \quad (1)$$

where c is the speed of light, L_1 and L_2 are the width and length of the top plate of PIFA as shown in Fig. 2. This equation is just a rough estimate for the resonance frequency, as it does not take the other antenna dimensions into consideration. Better estimation of the resonance frequency is presented in [6], where other parameters are incorporated the estimation of resonance frequency. Specifically, the width of the shorting plate (Ws) was incorporated with two degrees of freedom. Providing that $Ws \geq 20$ mm, the resonance frequency is given by:-

$$f_c = \frac{c}{4(L+\Delta L+k_1(W-W_S)^2+k_2(W-W_S))} \quad (2)$$

where $\Delta L = 2.741$, $k_1 = 0.0188$ and $k_2 = 0.0767$. It should be noted that Equation (2) is incomprehensive due to the restriction on the dimension Ws, besides ignoring the effect of other important parameters on resonance frequency of the antenna.

In order to study the effect of PIFA dimensions on the resonance frequency, we change one dimension at a time and hold the other dimensions constant. The operational frequency is changed from 0.5 GHz up to 3 GHz in order to cover the available mobile phone frequency bands. As a reference model, the following dimensions of PIFA structure are selected, W=37.5 mm, L=18 mm, h=12 mm, W_f=10 mm W_s=5 mm, L_b=15 mm, L_z= 0 mm, X=0 mm, L_s=0 mm, L_g=75 mm, W_g=65 mm, L_u= 0 mm and t = 1.5 mm.

II.1 Effect of Top Plate Dimensions

Fig.3 illustrates the effect of changing the length and width of PIFA top plate. It can be seen that the resonance frequency decreases by increasing the length (L) and width (W) of PIFA top plate.

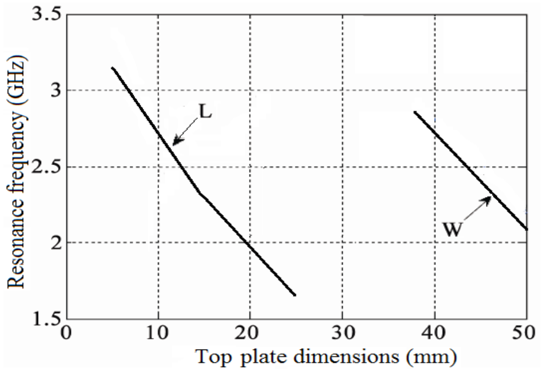

Fig. 3. Effect of PIFA top plate dimensions on the resonance frequency.

II.2 Effect of PIFA Height

The effect of PIFA height (h) is depicted in Fig. 4.

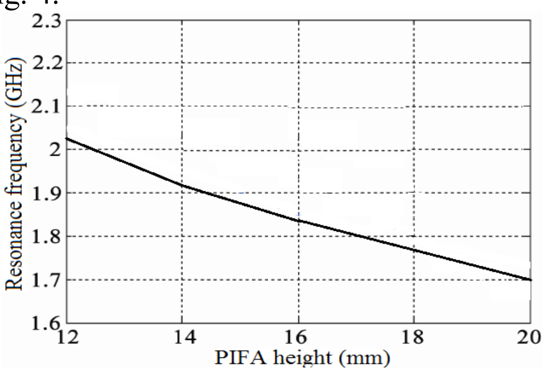

Fig. 4. Effect of PIFA height on the resonance frequency.

It can be noticed that increasing the height results in decreasing the resonance frequency.

II.3 Effect of Position of Feed Plate

On the other hand, the effect of the position of the feed plate determined by L_u and L_b on the resonance frequency is illustrated in Fig. 5. It can be observed that the resonance frequency is proportional to these dimensions.

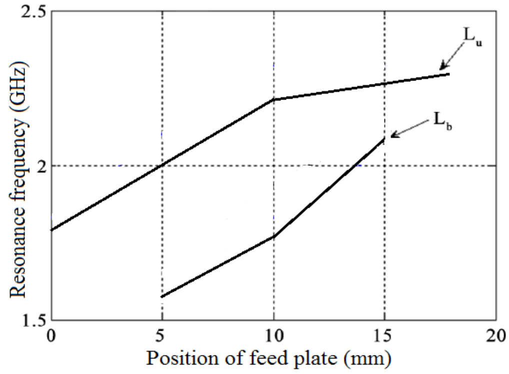

Fig. 5. Effect of feed plate position on the resonance frequency.

II.4 Effect of Top Plate position

Finally, the effect of top plate position with respect to ground plate (determined by X and L_z) on the resonance frequency is illustrated in Fig.6.

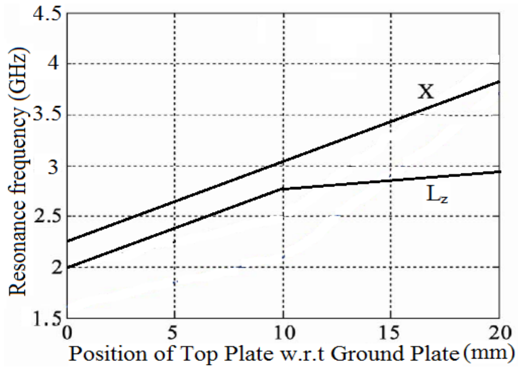

Fig. 6. Effect of top plate position w.r.t ground plate on the resonance frequency.

III. CONCLUSIONS

In this paper we studied the effect of PIFA dimensions on its resonance frequency.

Based on the observations discussed in section II, a rough empirical equation that relates the values of PIFA dimensions to its resonance frequency is concluded, and can be given by:-

$$f_c = \frac{c}{3W+5.5L+3.5h-2.5L_u-4L_b-4X-2.5L_z} \quad (3)$$

This equation gives an indication of the expected resonance frequency for given PIFA dimensions.

REFERENCES

[1] Tokio Taga,“ Performance analysis of a built-in planar inverted F antenna”, IEEE Journal on Selected Areas in Communications, Vol. 5, No. 5, pp. 921-929, June 1987.

[2] Naveen Kumar, “Study of Planar Inverted-F Antenna (PIFA) for Mobile Devices,” IJECT Vol. 4, Issue l, April - June 2013.

[3] Frank M. Caimi, “Antenna Design Challenges for 4G” DBLp, January 2011.

[4] Y. S Tseng. “Wideband Internal Antenna For Tablet Laptop Applications,” AsiaPacefic Microwave Conference Proceeding. Kaoh, 2012, pp.310-312.

[5] C. Rowell and E. Y. Lam, “Mobile Phone Antenna Design,” IEEE Antenna and Propagation Magazine, Vol 54, No. 4, 2012, pp14-34.

[6] P. S. Hall, C. T. P. Song, “Parametric Study on the Character-istics of Planar Inverted-F Antenna,” IEE Proceeding of Microwave Antennas and Propagation, Vol. 152, No. 6, 2005.

[7] Hassan Chattha,“A Comprehensive Parametric Study of Planar Inverted-F Antenna,” Wireless Engineering and Technology, 2012, 3, 1-11