International Journal of Computer Science and Business Informatics

IJCSBI.ORG

Enhanced-bandwidth Compact Printed Inverted F Antenna Suitable for LTE/GSM Mobile Phone

S. Jesse Jackson
PG Student, ECE Department
QIS College of Engineering and Technology, Ongole, India
sikha.jessejackson@gmail.com

T. Thomas
Assistant Professor, ECE Department
QIS College of Engineering and Technology, Ongole, India
thomas.thatapudi.t@ieee.org

ABSTRACT

In this paper design of multi band Printed Inverted F Antenna for LTE/GSM mobile application is manifested. The proposed design is suitable for embedding in the mobile handset and has advantages in aspects like low profile, small radiation effect, and good tuning properties. A matching circuit is employed in addition with the proposed aerial constructed by a rectangular plate placed on top of the FR-4 dielectric substrate of 65x80 mm^2 size to provide wide operating frequency band. This makes the design more suitable for better tuning to a required frequency bands. The ground plate is coated on substrate of its bottom side. Overall size of PIFA is small enough to be embedded in a smart phone, and it has been optimized to cover the LTE and GSM bands at 2600, 1500, and 800 MHz frequencies respectively. It has a gain ranging from 1.469 dBi to 5.428 dBi at the resonating frequency bands. The study of antenna's performance in term of impedance bandwidth, S-parameters, radiation pattern and gain is presented with CST Microwave studio simulation results.

Keywords

Chip inductor, chip capacitor, Impedance matching circuit, Mobile phone, Multi band, PIFA, Tuning.

1. INTRODUCTION

Nowadays mobile phones are everywhere and users are depending on phones for multiple services. The hard-hitting issues for handheld cellular user equipment are the antennas with broad impedance bandwidth, low profile, less weight and it should be cost effective, and Omni-directional radiation pattern is desirable. To provide continuous interactive voice, data and even video services many improvements are being made in communication systems to make these services available anytime and anyplace. Next-generation cellular communication systems higher bandwidths are mandatory, LTE bands are only alternative for future needs. LTE generally offer high reception date rates [1–3]. In general based on specification either internal or external antennas are used in mobile handsets. The close proximity of external antenna causes higher radiation absorption rate, it is the major disadvantages of such type of mobile antennas. Contrary to this, to avoid human interference internal antennas are printed on substrate system board, and care will be taken to make sure that the major radiation from antenna is radiated away from head. The printed aerial are designed depending on the mobile phone type and amendments have to be made to meet the specifications. The design of low profile antenna is expected in the mobile handsets and all performance parameters should be up to the mark so that it can be used for commercial services. To achieve wide bandwidths for LTE/ WWAN operation the inverted-F antenna (IFA) is usually used as internal antenna in mobile phones, but 6-10mm of extra profile is a added size to the basic design, leading to more sophisticated design called PIFA printed inverted F-shape antenna [4-9].

Mono pole antenna is improved in many aspects to be used in mobile phones, which is now called as PIFA. The advantages of PIFAs made them very suitable for small devices so they are widely used in mobile user equipment. A wide planar radiator is used in place of a slim conductive radiating element of an Inverted F antenna, this new design is named as Planer IFA. In the basic PIFA construction one element as top plate, another as ground plane, for feeding the resonating upper element a strip is used. For DC-shorting between ground and upper element a plane is used for connection at one edge of the radiating plane. For better impedance matching, the following are optimized in PIFA design, they are the signal feed position, and the shorting pin position in the slot. The separation between signal feed and DC-shorting pins is another design issues for the better impedance matching of the PIFA. Design of both E-plane and H-plane polarizations with desired directional properties is possible with PIFA. PIFAs are the best antennas when the antenna point of reference is not predictable and reflections are present [10-12]. Control of the resonance frequencies independently by changing lengths of strips or slots is a widely known method in the micro strip patch antenna design.

The antenna space in a mobile handset environment is extremely limited. Therefore, designing an internal antenna for a mobile handset is difficult, especially when multi-band operation is required. This paper presents an antenna for mobile phone with attractive characteristics as shown in figures 1 and 2, the proposed antenna [13] with multiband operation design to support GSM/LTE bands is presented. Embedded matching circuit provides tuning property for the system to different resonant frequencies.

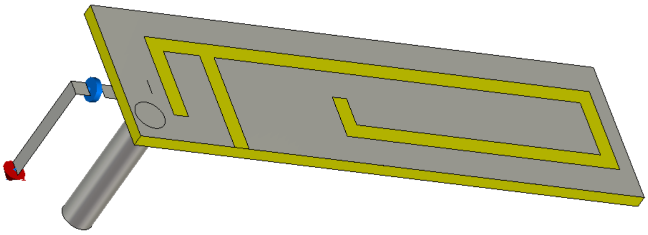


Figure 1. Proposed antennas' radiating section with slots and matching circuit

2. PROPOSED ANTENNA

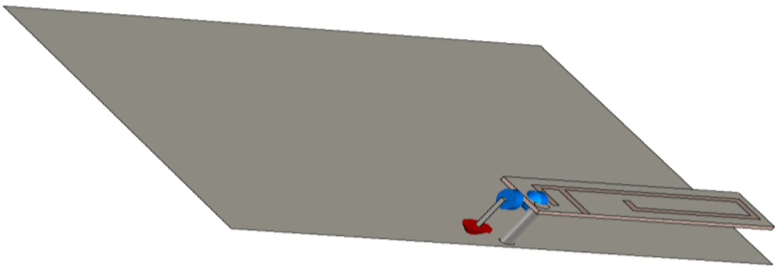
Tuning of antenna for different resonance frequencies is easy with alteration of element values of a matching circuit connected to the antenna of a mobile phone. To avail this advantage in the proposed design matching circuit with three elements is employed. A capacitor (1 pF) is connected in series with a parallel combination of capacitor (3.1 pF) and inductor (8.8 nH). For the given set of values of matching elements the proposed antenna resonates at three different frequencies. And other lower and upper resonance frequencies can be obtained with different combination of values for the matching circuit elements.

The substrate is a made up of FR4 having ε_r = 4.4 and thickness 0.8 mm, on top of this the radiator plane of 35 x 10mm^2 surface area is realized. At a height of 8.2 mm the separate PCB structure is hovered above a ground plate of 65 x 80 mm^2 with the support of DC-shorting rod with 1.2mm radius and 9mm height. Slots in the structure are crafted to make it resonate at different frequencies, moreover the spacing between feed and shorting strips has considerable impact on resonance frequencies.

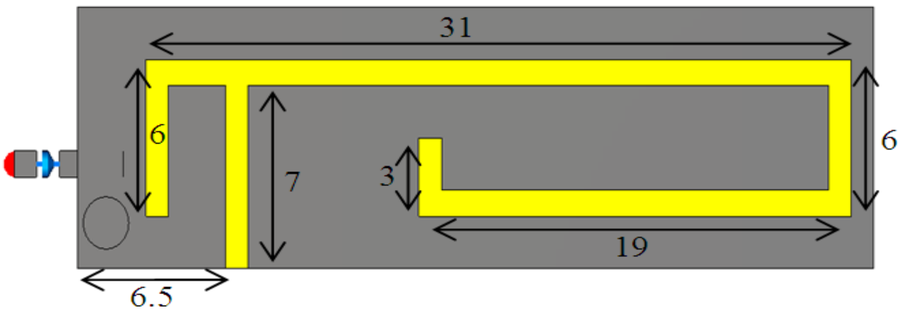
For resonance at different frequencies patch slots are introduced. In figure 2. (b) the measurements of the slots of width 1mm in the radiator patch are shown. For the feed line the length and the width are 15.5mm and 1mm. Where as in case of rectangular patch antenna dimensions are calculated based upon operating frequency. Dimensions of radiator are calculated from the following equations [13], in which F_r resonant frequency, c light velocity, ε permittivity of substrate. To make available higher data rates for various services the antennas are planned to support foremost cellular system bands namely GSM/UMTS/LTE. In this proposal both rectangular strip and its slots are designed to support multiple bands.

$$L = \frac{C}{2F_r\sqrt{\varepsilon_{eff}}} \quad (1)$$

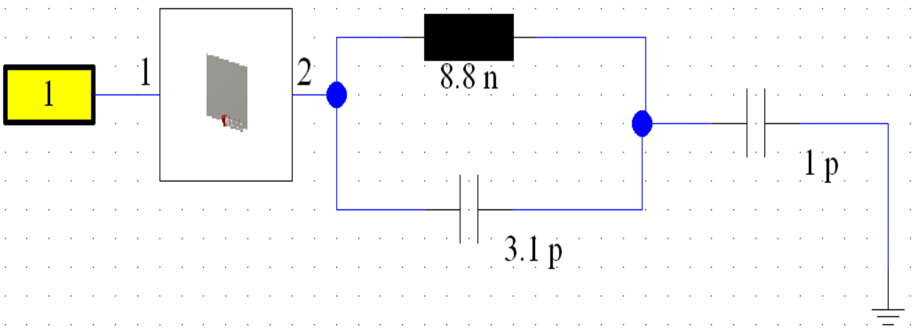
$$W = \frac{1}{2F_r\sqrt{\varepsilon_o\mu_o}}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad (2)$$



(a)



(b)



(c)

Figure 2. (a) Proposed antenna with elevated radiator shorted to ground. (b) Dimensions of radiating element (all dimensions are in mm). (c) Matching circuit for the proposed antenna, the rating of the capacitor is pF while that of the inductor is in nH.

3. SIMULATION RESULTS

When matching circuit with given combination of elements is connected resonance can obtained at three different frequencies that is 0.8 GHz, 1.5 GHz and 2.7 GHz as shown in Fig. 3. On the other hand the antennas' return loss value with coaxial feed without matching circuit is -15.5dB at 0.93GHz and -31dB at 1.8 GHz. The impedance bandwidth is wide enough to cover GSM800, 1500 and LTE2600 bands. The proposed Z-shaped feed extension helps to adjust the return loss value to a desired lower level and shows considerable affect on bandwidth characteristics of the proposed antenna.

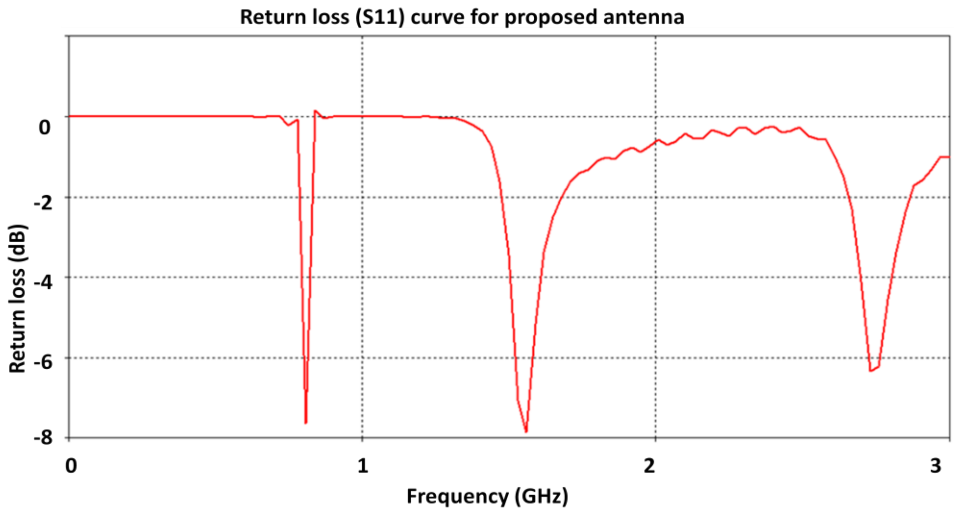
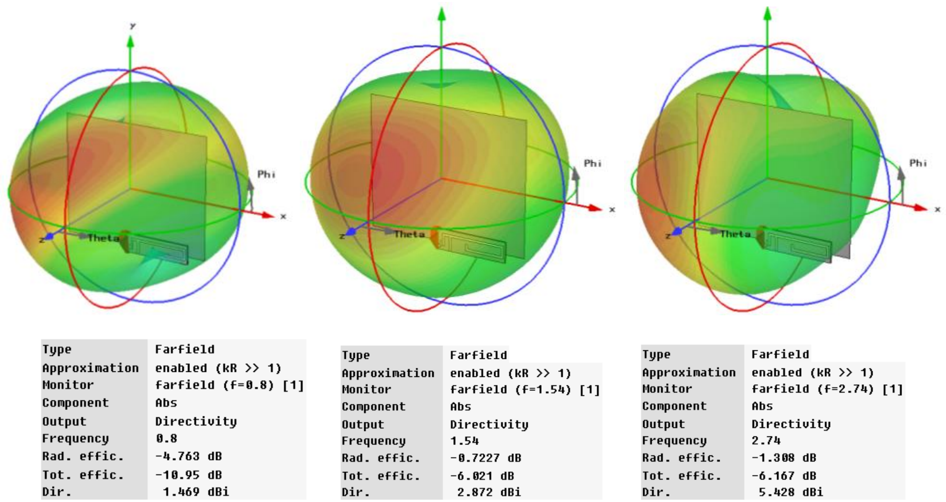


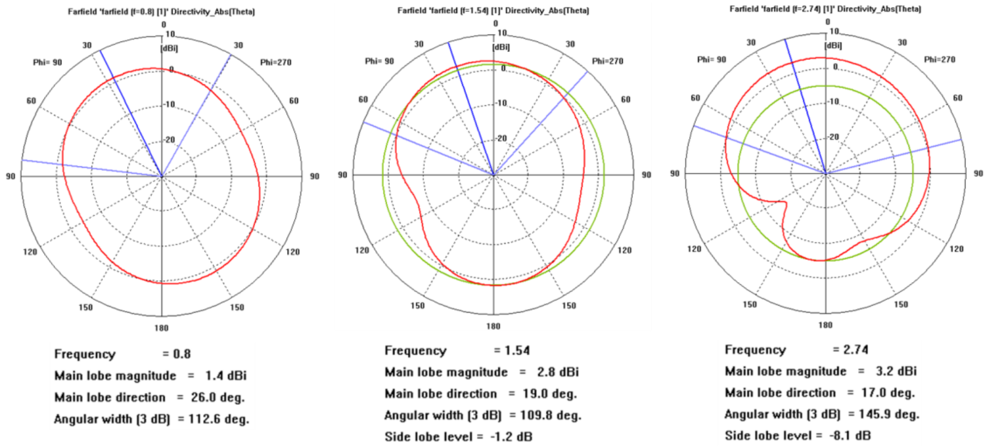
Figure 3. S11 return loss value over 0- 3GHz frequency band.



(a) (b) (c)

Figure 4. 3D Radiation pattern of the proposed antenna at

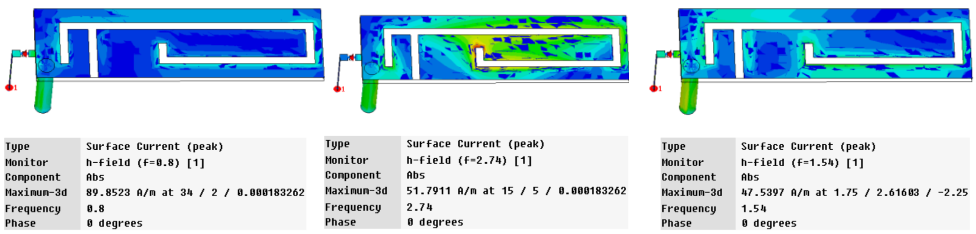
(a). 0.8GHz, (b). 1.5GHz, (c). 2.7GHz



(a) (b) (c)

Figure 5. 2-D Radiation pattern at (a). 0.8GHz, (b). 1.5GHz, (c). 2.7GHz

The radiation pattern can be defined as the angular distribution of the strength of the radiator. The 2D and 3D radiation patterns are shown in figure 5 at the 0.8GHz, 1.5GHz and 2.7 GHz. From given figures it is obvious that the proposed antenna exhibits omni-directional radiation characteristics at lower resonant frequency, where as its radiation characteristics are different from omni-directional at higher frequencies. For the given set of frequencies the proposed antenna offers directive gain ranging from 1.469 dBi to 5.428 dBi, the substrate height, thickness of the substrate, and relative permittivity of the substrate can affect the gain characteristics of the proposed antenna.



(a) (b) (c)

Figure 6. Current density at (a). 0.8GHz, (b). 1.5GHz, (c). 2.7GHz

The surface current distribution at different resonance frequencies is presented in figure 6. In the standard PIFA the surface current has a maximum distribution near the DC-shorting strip. In the proposed antenna similar behavior can be observed. The high concentrated surface current path lengths represent the resonating strip lengths responsible for resonance at various frequencies. Table 1 shows the gain value of the proposed antenna at various resonating frequencies.

Table 1. Gain of proposed antenna at resonant frequencies

parameter	Frequency (GHz)		
	0.8	**1.5**	**2.7**
Gain (dBi)	1.469	2.872	5.428

4. CONCLUSION

The presented compact PIFA design has enough frequency bandwidth to support GSM, LTE, and DCS bands having directivity ranging from 1.4dBi to 5.4dBi. The proposed antenna has an appreciable return loss at different resonant frequencies 0.8GHz, 1.5GHz and 2.7GHz. The low profile flat design of presented multiband PIFA for cellular user equipment is simple and easy to fabricate. Matching circuit used in the modal has given fine tuning possibility making it to resonate at different frequencies. The proposed antenna is recommended for smart phones with multiband functionality.

5. ACKNOWLEDGMENTS

The authors are pleased to acknowledge the support of management of the organizations for providing all required facilities to carry out the work, and sincere thanks to principal for suggestions.

6. FUTURE SCOPE

This modal can be further improved to have more frequency bands like LTE700, LTE2300 etc., and matching circuit can be optimized for better profile advantage.

REFERENCES

[1] F-H Chu and Kin-Lu W, “Planar printed strip monopole with a closely-coupled parasitic shorted strip for eight-band LTE/GSM/UMTS mobile phone,” *IEEE Transactions. on Antennas and Prop.*, V. 58, No. 10, Oct. 2010, pp. 3426–3431.

[2] Keng-Chih Lin, Chih-Hao Lin and Yi-Cheng Lin, “Simple printed multiband antenna with novel parasitic-element design for multi standard mobile phone applications,” *IEEE Trans. on Antennas and Propag.*, Vol. 61, No. 1, Jan. 2013, pp. 488–491.

[3] Yong-Ling Ban, Jin-Hua Chen, Joshua Le-Wei Li and Yujiang Wu, “Small-size printed coupled-fed antenna for eight-band LTE/GSM/UMTS wireless wide area network operation in an internal mobile handset,” *IET Microw. Antennas Propag.*, Vol. 7, Iss. 6, Jun. 2013, pp. 399–407.

[4] Y. K. Park and Y. Sung, “A reconfigurable antenna for quad-band mobile handset applications,” *IEEE Trans. on Antennas and Propag.*, Vol. 60, No. 6, Jun. 2012, pp. 3003–3006.

[5] Yun-Wen Chi, Kin-Lu Wong, “Quarter-wavelength printed loop antenna with an internal printed matching circuit for GSM/DCS/PCS/UMTS operation in the mobile phone,” *IEEE Trans. on Antennas and Propag.*, Vol. 57, No. 9, Sept. 2009, pp. 2541–2547.

[6] Jae Hee Kim, Won Woo Cho and Wee Sang Park, "A small dual-band inverted-F antenna with a twisted line," *IEEE Antennas and Wirel. Propag. Lett.*, Vol. 8, 2009, pp. 307–310.

[7] Chien-Wen Chiu and Yu-Jen Chi, "Planar hexa-band inverted-F antenna for portable device applications," *IEEE Antennas Wirel. Propag. Lett.*, Vol. 8, 2009, pp. 1099–1102.

[8] Sung. Y, "Compact quad-band reconfigurable antenna for mobile phone applications," *Electron. Lett.*, Vol. 48, No. 16, 2012, pp. 977–979.

[9] N. Misran, M. M. Yunus and M. T. Islam, "Small Dual-Band Planar Antenna with Folded Patch Feed," *Journal of Applied Sciences Research*, Vol. 6, No. 12, pp. 1975-1980, 2010.

[10] Mikko Komulainen, Markus Berg, Heli Jantunen, Eekki T. Salonen and Charles Free, "A Frequency Tuning Method for a Planar Inverted-F Antenna," *IEEE Trans. on Antennas and Propagat.*, Vol. 56, No. 4, Apr. 2008, pp. 944-950.

[11] Z. D. Liu, P. S. Hall and D. Wake, "Dual-Frequency Planar Inverted-F Antenna," *IEEE Trans. Antennas Propagat.*, Vol. 45, No. 10, Oct. 1997, pp. 1451-1458.

[12] F. R. Hsiao, H. T. Chen, T. W. Chiou, G. Y. Lee and K. L. Wong, "A Dual-Band Planar Inverted-F Patch Antenna with a Branch-Slit," *Microwave and Optical Technology Letters*, Vol. 32, No. 4, Feb. 2002, pp. 310-312.

[13] Sandeep Kumar Veeravalli, K Shambavi, Zachariah C Alex, " Design of tri band antenna for mobile applications" *International conference on Communication and Signal Processing*, April 3-5, 2013, pp. 947-950.

This paper may be cited as:

Jackson, S. J. and Thomas, T., 2016. Enhanced-bandwidth Compact Printed Inverted F Antenna Suitable for LTE/GSM Mobile Phone. *International Journal of Computer Science and Business Informatics, Vol. 16, No. 1, pp. 24-31*.