The Conception and the Study of a Triple-band Planar Inverted-F Antenna

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Abstract

The development of small integrated antennas plays a significant role in the progress of rapidly expanding mobile communications systems.

Although the resonance frequency, gain and bandwidth performance of an antenna are directly related to its dimensions, the idea is not only to decrease the overall size of the antenna, but also to find the best geometry and structure, for a specific problem. The advantage of planar inverted-F antenna (PIFA) makes them popular in many applications requiring a low profile antenna, PIFA antenna is promising to be a good candidate for the future technology due to the flexibility of the structure as it can be easily incorporated into the communication equipments.

In this paper, a triple-band Planar Inverted-F Antenna (PIFA) with Slots and a parasitic element is introduced. The proposed antenna is compact with a single feed and a single short strip. It operates at the frequency bands of 800 MHz, 1.6 GHz and 2.9 GHZ. So the antenna has been successfully researched and well optimized.

Keywords: *Planar inverted-F antenna, PIFA, Slots, triple-band antennas, parasitic element.*

1. Introduction

Nowadays, several novel multiband antenna designs have been introduced in the literature. The objective is to find the best geometry and structure giving the best performance while maintaining the overall size of the antenna small. The integration of different radio modules into the same piece of equipment has given a need for triple-band antennas. If three separate antennas are used, this will be inefficient in terms of space usage, which is an important factor in small hand-held devices. At present, triple-band planar inverted-F antennas have gained a lot of interest, due to their small size and good applicability for portable device because of its low profile and built-in structure. In recent years; many methods can be used to achieve a compact multiband antenna. In [1], it is shown that a capacitive load between the short and the feeding probe can considerably enhance the impedance bandwidth of a small size PIFA. A capacitive load has also been employed in [2] and [5] to increase the electrical length of the radiating element without increasing the antenna volume. In [2], three coplanar parasitic patches were used to enhance the impedance bandwidth of the dual-resonant driven element. In [3], a meandered multiband planar inverted-F antenna with two coplanar parasitic patches is presented operating in the GSM band with high radiation efficiency. The multiband antennas introduced in [2-6] have rather complicated geometries, which makes them less attractive for mass production. A slot also has been used to decrease the size of antenna, to achieve multi band and alter the polarization characteristic as a means of conventional technique [7-10].

2. Antenna Geometry and Parametric Study

2.1 Planar inverted-F antenna (PIFA)

The inverted-F antenna is evolved from a quarter-wavelength monopole antenna. It is basically a modification of the inverted F antenna IFA which consists of a short vertical monopole wire.

To increase the bandwidth of the IFA, a modification is made by replacing the wires with a horizontal plate and a vertical short circuit plate to obtain a PIFA antenna.

The PIFA antenna has the advantages of having small and multiband resonant properties, a simple design, a light weight, a low cost, a conformal nature, an attractive radiation pattern, and a reliable performance [11]. These

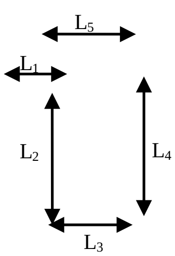
characteristics make the PIFA a suitable antenna candidate for mobile phones.
The conventional PIFA consists of a top patch, a shorting pin and a feeding pin. The top patch is mounted above the ground plane, which is also connected to the shorting pin and feeding pin at proper positions. They have the same length as the distance between the top patch and the ground plane.
The standard design formula for a PIFA antenna is [12]:

$$f= \frac{C}{4(L+W)} \quad (1)$$

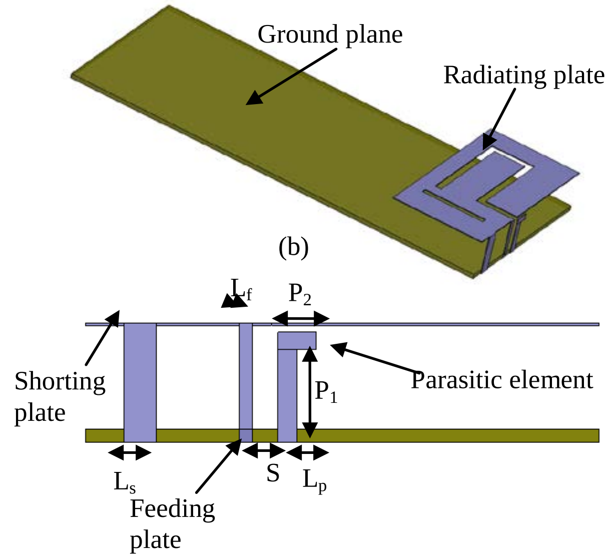
Where f is the resonant frequency of the main mode, C is the speed of light in the free space; W and L are the width and length of the radiation patch respectively.

2.2 PIFA antenna Configuration

The configuration of the studied PIFA antenna consists of a radiating top plate with the dimensions 40 × 22 mm^2, and the thickness of the copper used is 0.8 mm. The ground plane dimensions are 40 × 100 mm^2. The dielectric material used above the rectangular ground plane is FR-4 having a thickness t=1 mm, a loss tangent of 0.02 and a relative permittivity of 4.4, this is meant for the application when the antenna is integrated with the printed circuit board (PCB). The antenna height is h=8 mm, and the space between the top plate and the substrate is filled with air (free space).
Figure 1 shows the structure of the proposed antenna in top view, a tri-dimensional view and a side view. The detailed dimensions are given in Table I.



(a)



(c)

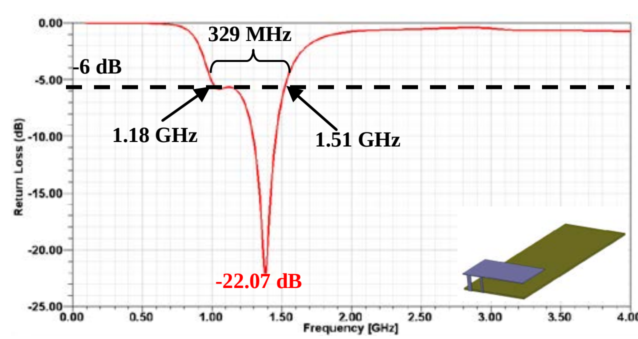
Fig. 1 Geometry of the proposed PIFA antenna, (a).Top view, (b).3D view and (c).Side view.

Table 1: The overall dimensions

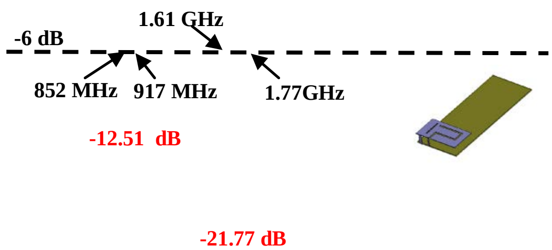
L1	**L_2**	**L_3**	**L_4**	**L_5**	**P_1**
8 mm	20 mm	10.5 mm	23.5 mm	15 mm	7.2 mm
P_2	**L_f**	**L_s**	**L_p**	**S**	
6 mm	1 mm	2.5 mm	1.5 mm	2 mm	

3. Results and discussions

3.1 The return loss



(a)



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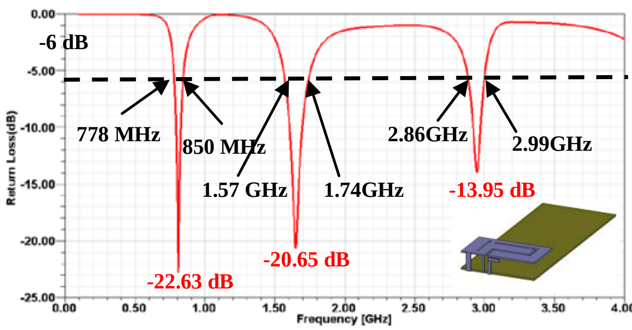

(c)

Fig .2 The simulated return loss for the proposed antenna (a) without slots and without parasitic element, (b) with slots and without parasitic element (c) with slots and with parasitic element.

As shown in Figure 2(a), we notice that the maximum return loss is -22.07 dB at 1.38GHz, The upper and lower band frequencies are 1.18 GHz and 1.51 GHz respectively and the absolute impedance bandwidth is 329 MHz and the bandwidth obtained for the proposed PIFA is 13.24%. It can be seen in Figure 2(b) that a new resonance frequency is added due to the slots. These slots force the surface currents to meander, thus artificially increasing the antenna's electrical length without modifying its global dimensions, which results in a new resonant frequency. The figure 2 (c), demonstrates that by adding a parasitic element, we obtain an odder resonance frequency. We conclude that by adding slots and a parasitic element to a PIFA antenna we have obtained a triple-band antenna.

3.2 The radiation pattern

In this section, we have computed the far field radiation patterns at the three operating frequencies for which the proposed antenna have been analyzed.
Simulated cuts of the studied antenna are shown in the Figure 3 before adding the slots and a parasitic element, then after adding slots (Fig. 4) and after adding the slots and a parasitic element (Fig. 5).

H-plane
E-plane

Fig .3 *2D and 3D* radiation patterns for the PIFA antenna before adding slots and parasitic element for f_r=1400MHz

H-plane
E-plane

(a)

H-plane
E-plane

(b)

Fig .4 2D and 3D radiation patterns for the PIFA antenna with slots and without parasitic element for (a) fr=880MHz and (b) fr=1700MHz.

H-plane
E-plane

(a)

H-plane (b)
E-plane

(c)

Fig .5 2D and 3D Radiation patterns for the proposed PIFA antenna with slots and with parasitic element for (a) f r=809 MHz , (b) f r=1.6 GHz abd (c) f r=2.9 GHz

From these results, we can see the gain variation of the antenna in the xz plane (the E-plane of the antenna) and the xy plane (the H-plane of the antenna) before and after adding slots and a parasitic element at the different resonance frequencies. The patterns of our proposed PIFA antenna are omni-directional in the three resonance frequencies with a maximum gain of about 5.11 dB for 809 MHz, 6.94 dB for 1.6 GHz and 6.72 dB for 2.9 GHz (Fig.6).

4.conclusion

This paper has focused on the development of triple-band planar inverted-F antennas, operating in the 809 MHz, 1.6 GHz and 2.9 GHz. The obtained results demonstrate that by adding slots on the top plate of the planar inverted-F antenna and a parasitic element we obtain a triple-band antenna.

Moreover, good radiation characteristics for frequencies within the operating bands have been obtained.

References

[1]S. Villeger, P. Le Thuc, R. Staraj and G. Kossiavas, “Dual-band planar inverted-F antenna”, Microw. Opt. Technol. Lett., vol. 38, no. 1, pp.40–42, 2003.

[2]P. Ciais, R. Staraj, G. Kossiavas and C. Luxey, “Design of an internal quad-band antenna for mobile phones”, IEEE Microw.Wireless Compon. Lett., vol. 14, no. 4, pp. 148–150, Apr. 2004.

[3]Y.-X. Guo, I. Ang and M. Y. W. Chia, “Compact internal multiband antennas for mobile handsets”, IEEE Antennas Wireless Propag. Lett., vol. 2, pp. 143–146, 2003.

[4]Y.-X. Guo and H. S. Tan, “New compact six-band antenna”, IEEE Antennas Wireless Propag. Lett., vol. 3, pp. 295–297, 2004.

[5]J. Ollikainen, O. Kivekäs, A. Toropainen, and P. Vainikainen, “Internal dual-band patch antenna for mobile phones”, in Proc. AP2000 Millennium Conf. Antennas Propagation, Davos, Switzerland, Apr. 9–14, 2000, p. 1111.

[6]P.Salonen.; M. Keskilammi; M.Kivikoski.;“Dual-band and wide-bandPIFA with U- and meanderline-shaped slots” ,Antennas and Propagation Society International Symposium, 2001. IEEE Vol. 2, 8-13 July 2001, pp.116 – 119.

[7]M.Jung, M.; Yunghee Kim; Lee, B.; “Dual frequency meandered PIFA for Bluetooth and WLAN applications” Antennas and Propagation Society International Symposium, 2003. IEEE Vol. 2, 22-27 June 2003, pp.958 – 961.

[8]S. Ibnyaich, A. Ghammaz, and M. M. Hassani, "Development of Wideband Planar Inverted-F Antennas for Wireless Application", Journal of Computer Science, vol. 7, pp. 1172-1177, 2011.

[9]S. Ibnyaich, A. Ghammaz, and M. M. Hassani, " Triple-band Planar Inverted-F antenna PIFA for mobile phone ", 11th mediterranean microwave symposium", MMS’2011, Tunisia-Hammamet .pp 67 September 08-10, 2011,.

[10]Y. Belhadef, N. Boukli-Hacene, "Design of New Multiband Slotted PIFA Antennas, "IJCSI International Journal of Computer Science Issues, Vol. 8, Issue 4, No 1, July 2011 ISSN (Online): 1694-0814.

[11]C. A. Balanis, (1997) Antenna Theory: Analysis and Design, Second, edit. John Wiley & Sons.

[12]Y. Huang and K. Boyle, Antennas: From Theory to Practice. Hoboken, NJ: Wiley, 2008.

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