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Design of New Multiband Slotted PIFA Antennas

Yamina BELHADEF, Nourediene BOUKLI HACENE

Department of Telecommunication, Faculty of Technology,
University of Abou-Bekr Belkaïd -Tlemcen, Company
BP 230, Pôle Chetouane, 13000 Tlemcen- Algerie

Abstract

In this paper, new configurations of slotted PIFA antennas simulated at different frequencies and which can be integrated in mobile handsets are proposed. The design tool is the HFSS software which uses the finite element method. The insertion of slots with various forms on the radiation element allows the creation of new resonances frequencies. The obtained radioelectric results show that the structures are well adapted to the desired resonances frequencies.

Keywords: *PIFA antenna, multibands antennas, slotted PIFAs, Simulation.*

1. Introduction

The planar inverted-F antenna (PIFA) is evolved from a $\lambda/4$ length monopole antenna. It is now widely widespread in mobile and portable radio applications due to its simple design, its light weight, its low cost and its attractive radiation pattern. It is well known that, for a monopole antenna, the desired length is equal to the quarter wavelength since it is resonant in this case. By using the same analogy, one proposed the following empirical equation for finding the resonant frequency of a PIFA.

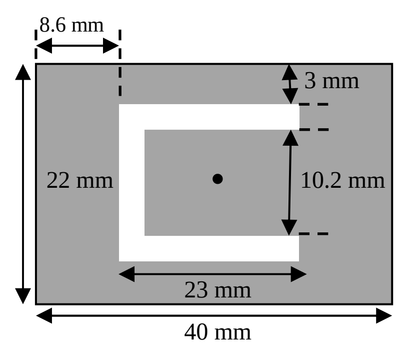
$$f_0 = \frac{c}{4(W+L)} f_0 = \frac{c}{4(W+L)} \qquad (1)$$

Where c is the light speed, *L* and *W* are the length and width of the PIFA top plate, and f_0 is the resonant frequency. This equation means that the sum of the length and width of the top plate should be equal to the quarter wavelength. However, it is really a very rough approximation and does not cover all the parameters which significantly affect the resonant frequency of a PIFA. It can hardly be used to guide the design in practice; thus, a more accurate and comprehensive design equation is required [1].

The compact PIFA antenna use spread in the modern telecommunications various systems, in particular, in the mobile communications field and more recently into the one of the wireless communications. Generally, there is miniaturization techniques used to have compact antennas, like example, the slots insertion in the radiation element [2]. Those are used: to create new resonances [3] [4], to lengthen the electric lengths [5] and to create new resonators [6]. The common point of all these actions is to create capacitive effects distributed all around the slot. These effects are taken into account in the reduction in frequency of the resonators operating modes.

2. The Bi-band PIFA Antenna

The antenna shape proposed result initially from the reference [7], in which the structure is modified. The principal changes carried out are: the elimination of two vertical shorts-circuits and the elimination of the interior slot. Also the radiation element position which becomes in the structure center, the ground plan size (100 X 50 mm), and the slot width which will be equal to 2.9 mm. The antenna global geometry is presented by figure 1.



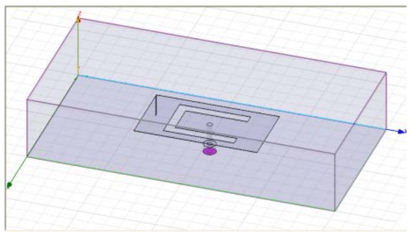
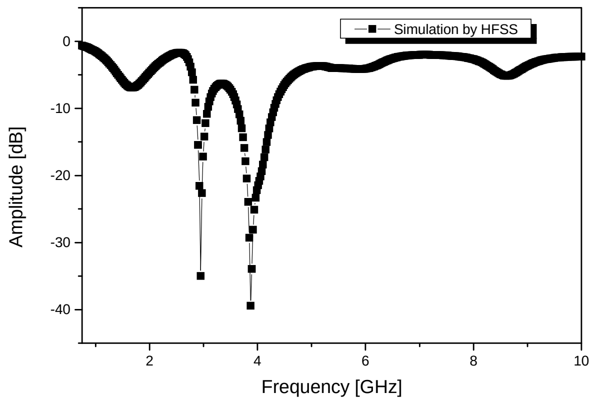
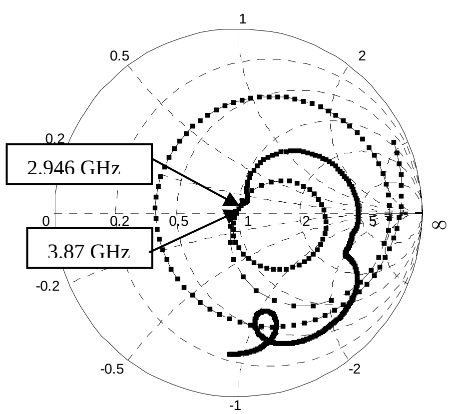


Fig. 1**:** Radiation element form and the PIFA global structure on the HFSS editor.

On figures 2 - ((a) - (b)), one respectively represents the return loss and the input impedance locus.



(a)

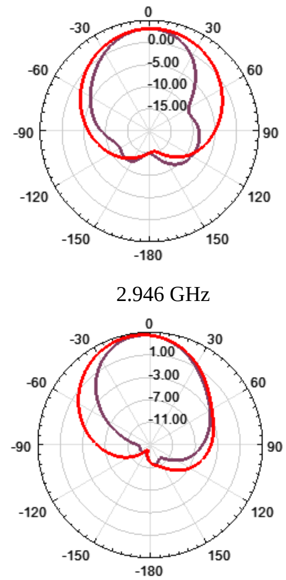


(b)

Fig. 2. (a) : The return loss.
(b) : The input impedance locus.

The simulated antenna by HFSS software is well adapted at two resonant frequencies of 2.946 and 3.87 GHz. The reflected power reaches the values of -35 dB and -39 dB with band-widths of 7.84% and 17.91% at these resonant frequencies respectively. The input impedance locus's are in the Smith chart medium for the two desired frequencies. The adaptation is then perfect and the antenna can be integrated in wireless systems like the networks MBWA and UWB.

The polar radiations patterns in 2D are presented in figure 2.(c). They are globally almost omnidirectional in the two resonant frequencies.



2.946 GHz

3.871 GHz

(c)

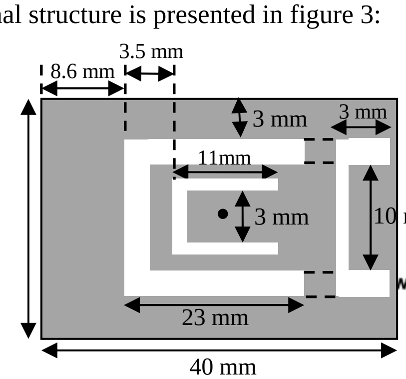
Fig. 2.(c) : *The radiation pattern in 2D.*

plane E (φ=0°)
plane H (φ=90°)

3. The tri-band PIFA antenna

The slots cutting in certain parts of a radiation element can allow new resonators emergence. We can for example note the use of a not emerging U-shaped slot [8] or the use of emerging slot with unspecified form [6] [9]. Thanks to this process and to the created capacitive effects, miniature broadband and multibands antennas at the same time can be designed.

The proposed antenna is obtained starting from the previous structure for which we applied miniaturizations techniques on the radiation element. Among these techniques the two U form slots insertion in the radiation element and the use of a capacitive loading inserted in the end of the radiation element. Its height is equal to 1.8 mm. The final structure is presented in figure 3:



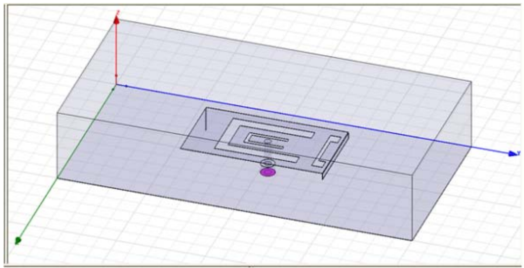
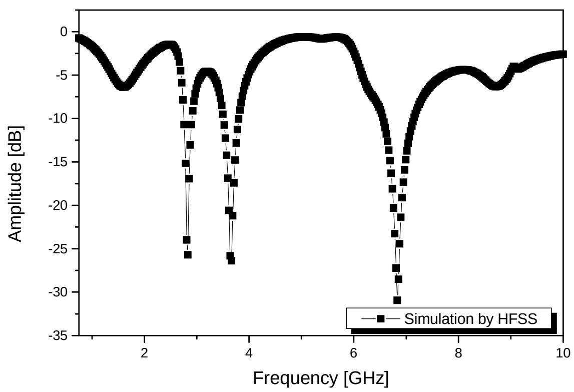
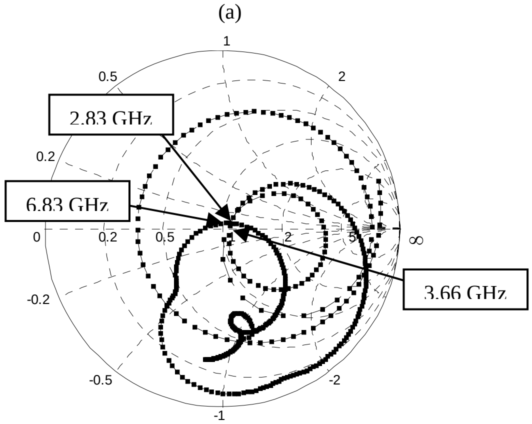


Fig. 3 : The tri-band PIFA antenna radiation element form and its structure on the HFSS editor.

On figures 4 - ((a) - (b)), one respectively represents the return loss and the input impedance locus.



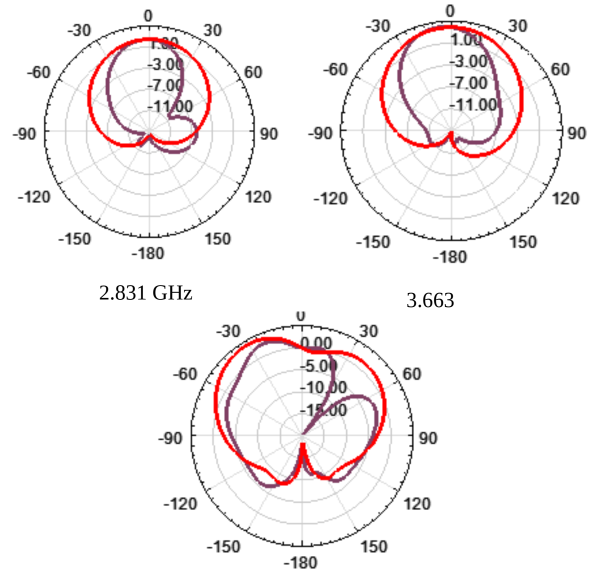
(a)



(b)

Fig. 4. (a) : *The return loss.*
(b) : *The input impedance locus.*

The antenna operate at 2.83, 3.66 and 6.83 GHz; which corresponds to the standards MBWA, UWB and MiMAX. The bandwidths for the 3 frequencies are respectively 5.71 %, 8.2 % and 9.14 %. The return loss is equal to -31dB at 6.83 GHz. The input impedance locus for the three resonant frequencies are at the Smith chart medium (Fig 4.(b)). The polar radiations patterns in 2D (Fig.4.(c)) are almost globally omnidirectional for the plans E and H.



2.831 GHz 3.663

6.831 GHz

(c)

Fig. 4.(c) : The radiation pattern in 2D.

plane E (φ=0°)
plane H (φ=90°)

4. Multibands PIFA antenna

We want to create new resonators on the same use band. For that we modified the radiation element shape by adding two emerging rectangular slots (8.6 x 2.4 mm) and (3 x 2 mm) at the radiation element ends according to figure 5.

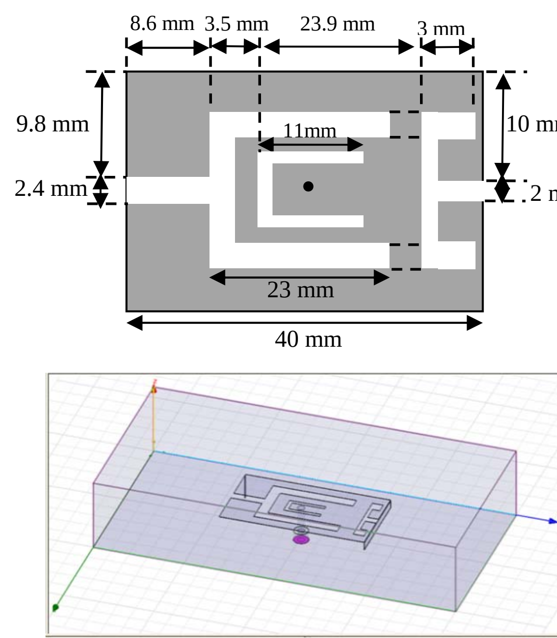
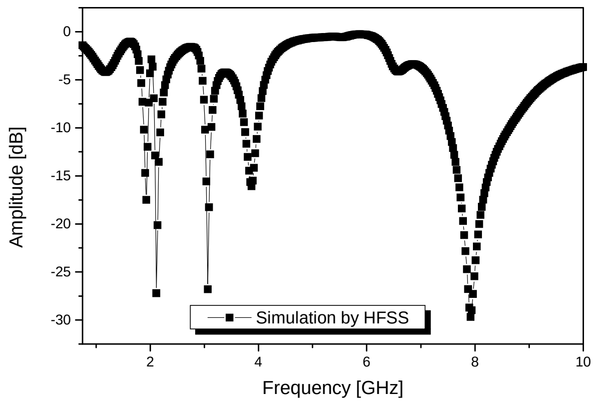
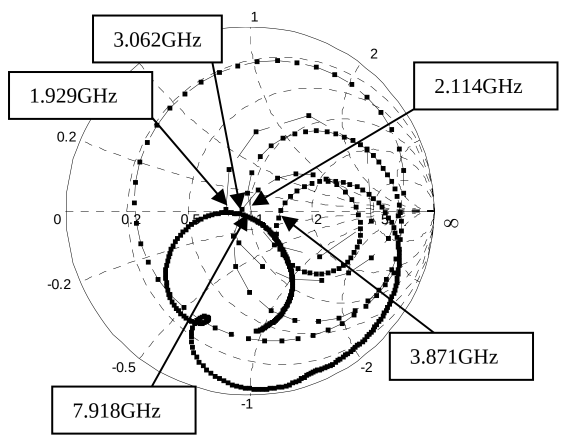


Fig.5: The multibands PIFA antenna radiation element form and its structure on the HFSS editor.

On figures 6- ((a) - (b)), one respectively represents the return loss, the input impedance locus and the polar radiation patterns in 2D.



(a)

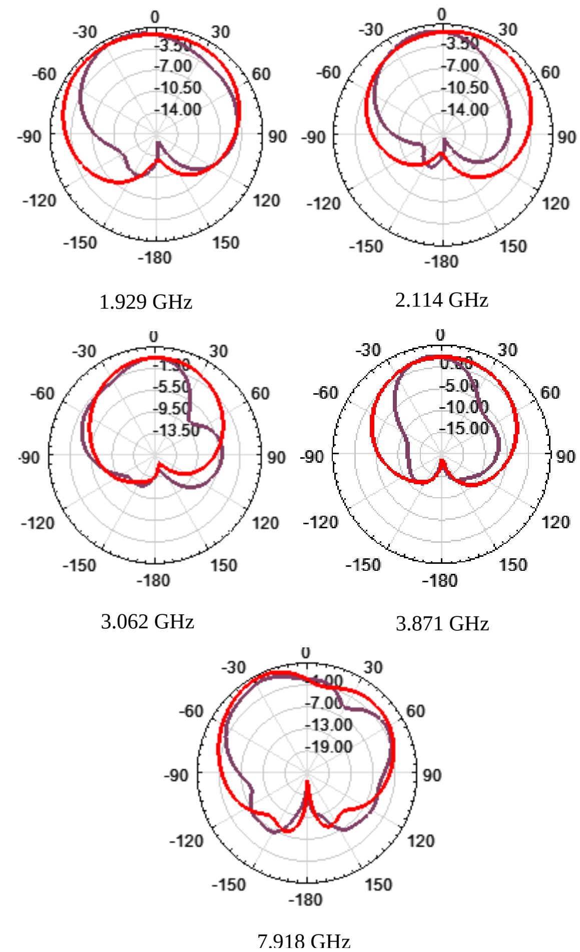


(b)

Fig. 6. (a) : The return loss.
(b) : The input impedance locus.

One can observe that the new antenna combines five return loss corresponding to the following standards: PCS (1.850-1.990 GHz), UMTS (1.920-2.170 GHz), MBWA (< 3.5 GHz), UWB (3.1-10.6 GHz) et WiMAX (2-11 GHz) (fig. 6.(a)) with peaks equal to -17.5 dB, -27 dB, -26.5 dB, -16 dB and -29.5 dB respectively. It is significant to note that the bandwidth to 7.918 GHz was improved to 14.89 %. The first and the second resonant mode around 1.929 GHz and 2.114 GHz have a bandwidth equal to 4.7 % and 5 % respectively. The others resonant frequencies (3.062 GHz and 3.871 GHz) have a bandwidth equal to 3.8 % and 6.6 % respectively.

On the Smith chart the input impedance locus are located around the chart center for the five resonances frequencies. This shows that the imaginary input impedance part for each frequency is almost null and the real part is close to 50 ohms.



(c)

Fig. 6.(c) : Diagramme de rayonnement en 2D.

plane E (φ=0°)

plane H (φ=90°)

The radiations patterns for all the resonances frequencies (plan E and plan H) are quasi-omnidirectional.

Other changes are made on the radiation element to obtain another multibands antenna operating at seven resonant frequencies. The change includes a U form slot of size 20 X 21 mm inserted at the right end of the radiation element and the modification of the slot located at the left end of the radiation element (figure 7):

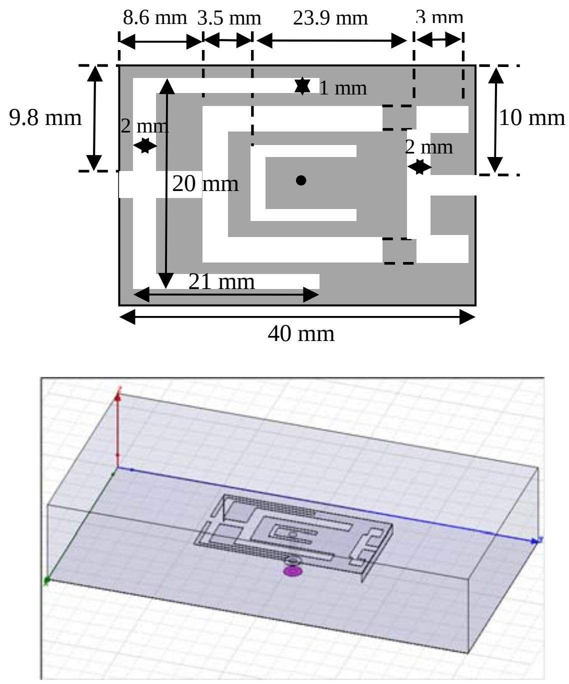
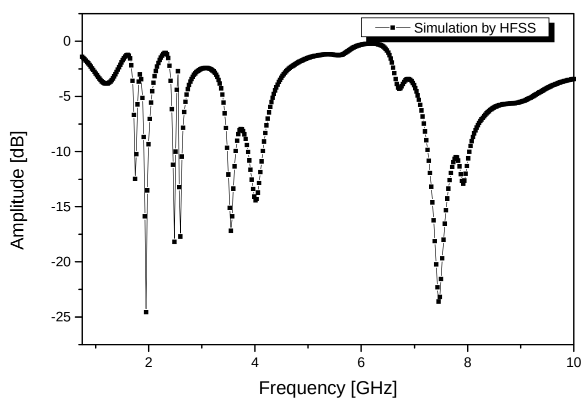


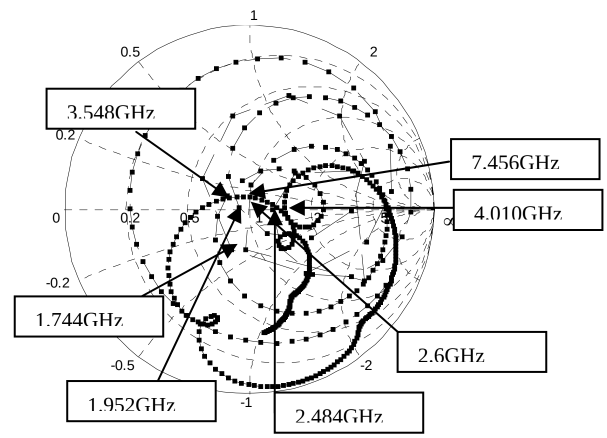
Fig.7: Another multibands PIFA antenna radiation element form.



(a)

Fig. 8. (a) : The return loss.

The design results show that the reflected power contains seven resonant frequencies (1.744, 1.952, 2.484, 2.600, 3.548, 4.010, 7.456 GHz) with levels equal to -12.5 dB, -24.6 dB, -18 dB, -17.7 dB, -17 dB, -14.4 dB and -23.6 dB respectively. For the first four resonators, the bandwidths are narrow around of 1.7% to 4% and meet standards DCS, GCV, Bluetooth, MBWA respectively. For the last three resonators, the operation bandwidths are 4.56%, 7.49 % and 10.85 % respectively.



(b)

Fig. 8. (b) : The input impedance locus.

The input impedance locus for the seven resonant frequencies are all around the Smith chart center. Also the radiation patterns are quasi omnidirectional for the plane E and H.

5. Conclusions

An appropriate PIFA antennas to the mobile and wireless communication systems are presented. The U form slot insertion on the radiation element allows the creation of new resonators on the use band. These multibands antennas are able to cover the popular frequency bands to support multiple standards such as DCS, PCS, UMTS, Bluetooth, MBWA, UWB and WiMAX band. The antenna return loss (S11) is within the acceptable limit at all the frequency bands with a good adaptation and radiation performance. The impedance bandwidth for each antenna was calculated at the desired resonant frequency. The bandwidths are between 1.7 % and 17.91 %. These proposed antennas are in a good agreement with multibands applications.

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