# Reconfigurable planar inverted-F antenna for radio frequency identification tag and global positioning system applications

**Assiya Amri, Tomader Mazri**
Department of Electrical Engineering, Networks and Telecommunication Systems, National School of Applied Sciences of Kenitra, Ibn Tofail University, Morocco

**Article Info**

***Article history:***

Received Aug 20, 2021
Revised Apr 05, 2022
Accepted Apr 13, 2022

***Keywords:***

GPS
ISM
PIFA
PIN diode
Reconfigurable antenna
RFID tag

**ABSTRACT**

This paper presents the design of a reconfigurable planar inverted-F antenna (PIFA). The proposed antenna is designed and optimized to operate in two frequency bands. 2.4 GHz allocated to the industrial, scientific and medical (ISM) band for the identification of a set of vehicules within a given area, and 1.575 GHz allocated to the global positioning system (GPS) band to locate them outside. The ISM band is used for microwave frequencies for active radio frequency identification (RFID) tag, which is associated with the object to be identified. This antenna consists of two radiating elements connected by a positive-intrinsic-negative (PIN) diode to obtain the frequency reconfigurability. The first radiating element is connected to the ground plane by a shorting pin and excited by a 50 Ω coaxial feed line. Its total size is 30 mm × 50 mm × 7 mm. The substrate used is FR4 with constant dielectric relativity of 4.4 and a height of 1.6 mm. Computer simulation technology microwave studio (CST MWS) software is used to simulate and optimize the proposed reconfigurable PIFA antenna.



***Corresponding Author:***

Assiya Amri
Department of Electrical Engineering, Networks and Telecommunication Systems
National School of Applied Sciences of Kenitra, Ibn Tofail University
University Campus, B.P 241, Kenitra - 14 000, Morocco
Email: assiyaamri7@gmail.com

## 1. INTRODUCTION

Nowadays, reconfigurable antennas have attracted much attention in the fields of wireless communications, due to the growing need to provide an antenna capable of covering several standards such as global system for mobile communications (GSM), global positioning system (GPS), universal mobile telecommunications system (UMTS), wireless local area network (WLAN), and radio frequency identification (RFID) [1]. Indeed, a reconfigurable antenna is an antenna capable of dynamically modifying at least one of its characteristics according to the needs dictated by the environment of the antenna and the need of the application [2]. Its basic advantage is that starting from a classical antenna with fixed operation, and integrating an internal mechanism able to extend the capabilities and improve the operation and performance of wireless terminals, with minimal impact on the complexity and cost of these systems [3]. There are no standard methods for designing a reconfigurable antenna. The general approach is to start from a given antenna geometry, often chosen according to the intended application which fixes for example the dimensions and the operating frequencies, and the addition of structures and elements to achieve the desired reconfiguration functionalities [4]-[7]. For our application, we have chosen the planar inverted-F antenna (PIFA) for its compactness, ease of design and integration, low manufacturing cost [8], and its suitability for our application. It consists of a radiating element of quarter wavelength generally excited by a coaxial probe, and connected to the ground plane by a shorting pin of type plan, languet or wired [9]. The variation in the dimensions of the PIFA, the position of the power supply, the plane of the shorting pin, the height of the substrate modify its performance [10]-[12]. The PIFA antenna has advantages over a traditional antenna including a simple structure and easy to manufacture [13], [14]. It is considered to be one of the most promising structures for mobile applications because it presents a compromise between design simplicity, small size, low manufacturing cost and ease of deployment. However, in order to respond to the rapid evolution of these systems which cover several standards, the antenna must have multi-band functioning. Indeed, PIFA antennas are suitable for both single-band and multi-band applications or reconfigurable by adding active components. Thus, most new RFID applications use the ultra high frequency (UHF from 860 MHz to 960 MHz) and microwave (MO at 2.4 GHz and 2.45 GHz) bands. These frequency bands provide several advantages compared to low and high frequencies (LF, HF), namely a possibility of reading at great distance and a faster transfer of data. RFID applications are becoming very diverse and the need to use two or more frequency bands in the same system has prompted researchers to develop reconfigurable and multi-band antennas [15], [16]. This paper presents a new frequency reconfigurable PIFA antenna for RFID tag and GPS. This antenna makes it possible to identify a set of cars within an area, and locate them outside [17]. Reconfigurability is achieved by using a single positive-intrinsic-negative (PIN) diode between two patches of different dimensions.

## 2. PIFA ANTENNA THEORY

The addition of a shorting pin is still a good solution to reduce the size of an antenna. The quarter-wave antenna has a reduced dimensions compared to the half-wave antenna. The size reduction is achieved by a shorting pin placed along the line where the electric field between the radiating pad and the ground plane is zero for the fundamental mode of the printed antenna [3], [18]. This method is used in particular in PIFA antenna. It consists of a radiating metal plate which is connected to the ground plane by a shorting pin. The width of the shorting pin can be more or less important depending on the desired properties. The radiating plate is excited by a vertical feed at a point where the matching is best [19]. These antennas are compact and have low production costs. The first resonant frequency of the non-slotted PIFA can be calculated using this basic formula:

$$f0 = \frac{\text{C}}{4(\text{Wp}+\text{Lp})} \quad (1)$$

Where $C$ is the speed of light, $Wp$ and $Lp$ are the width and length of the top plate of the PIFA, and $f_0$ is the resonant frequency [20]-[22]. The configuration of a PIFA antenna is very simple and easy to design, and the addition of a slots such as $U$ slot or $L$ slot in the radiating element bring back other resonances [4]. Figure 1 shows the basic structure of the PIFA antenna with its different composant.

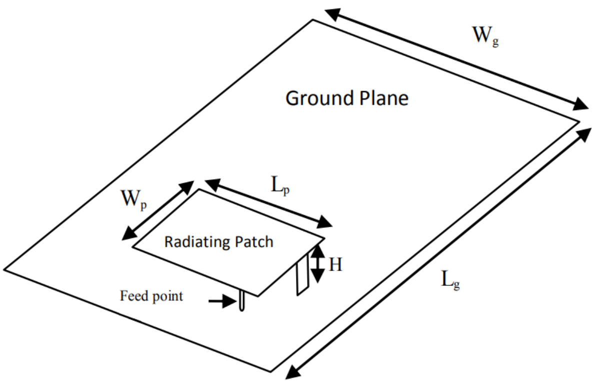



Figure 1. The basic structure of the PIFA antenna [9], [23]

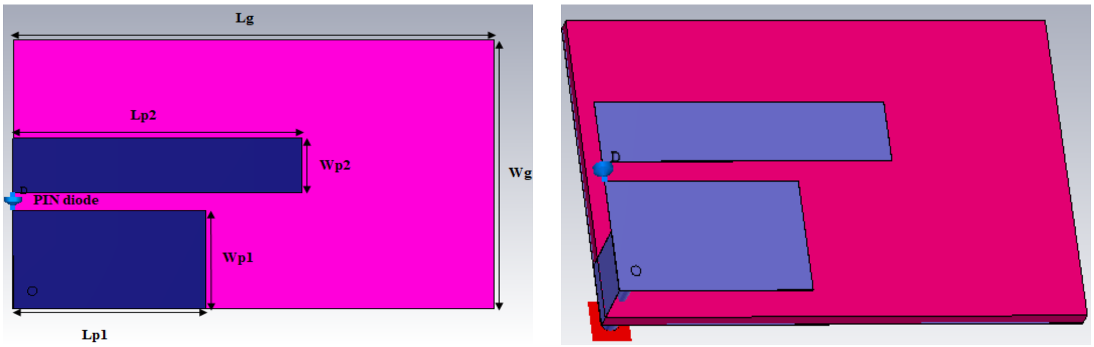
## 3. RESEARCH METHOD

### 3.1. Proposed PIFA antenna design

The geometry of the proposed PIFA antenna is shown in Figure 2(a) and Figure 2(b). The size of the proposed antenna is chosen after a parametric study [11], [12], which includes all parameters that affect its characteristics. The proposed PIFA antenna consists of two patches (radiating elements) printed on an FR4 substrate with a relative dielectric constant of 4.4, loss tangent of 0.025, and a height of 1.6 mm. $Tt$ is loaded by a 50 Ω coaxial feed line. The primary radiating element is a rectangular antenna of length $Lp1$ and width $Wp1$. It is connected to the ground plane of dimensions $(Lg \times Wg)$ through a languet of length $H$ and width $Wc$. The dimensions of the antenna make it possible to obtain the first resonant frequency of 2.4 GHz, and the second patch (radiating element) of length $Lp2$ and width $Wp2$ provides the second frequency of 1.575 GHz. The first patch is connected to the second patch by a PIN diode to have frequency reconfigurability according to the state of the PIN diode (on and off). The PIN diode is placed in an optimized position to achieve the desired operation. Table 1 shows the dimensions of the proposed PIFA antenna after optimization.

Table 1. The optimum parameters of reconfigurable PIFA antenna

| Parameters | Values in mm |
|---|---|
| $Wg$ | 30 |
| $Lg$ | 50 |
| $Wp1$ | 11 |
| $Lp1$ | 20 |
| $Wp2$ | 6 |
| $Lp2$ | 30 |
| $Wc$ | 6 |
| $H$ | 7 |



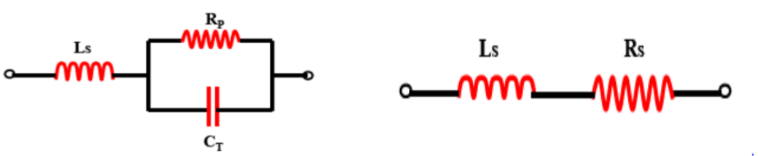

(a) (b)

Figure 2. The geometry of the proposed reconfigurable PIFA antenna (a) front view (b) perspective view

In order to realize the reconfigurability, i.e. to switch the antenna between two bands industrial, scientific and medical and global positioning system (ISM and GPS), a PIN diode is placed between the two patches (radiating elements). The on state of the PIN diode corresponds to the antenna operating in the GPS Band (1.575GHz), and the off state of the PIN diode corresponds to the antenna operating in the ISM Band (2.4GHz).

### 3.2. PIN diode modeling

The PIN diode is used in many applications ranging from UHF to microwave frequencies. The switches based on PIN diode have a very short switching time (some tens of nanoseconds) between two states on and off. In reverse bias, the electrical equivalent circuit of the diode is then a parallel circuit composed of a capacitance $Ct$ and a resistance of losses $Rp$ in series with parasitic self $Ls$. And in forward bias, the electrical equivalent circuit of the diode is a resistor $Rs$ in series with a low inductance $Ls$ [24]. Figure 3 shows the electrical equivalent circuit of a PIN diode polarized Figure 3(a) in reverse and Figure 3(b) in direct. The diode chosen for this application is PIN HPND-4028 [25].




(a) (b)

Figure 3. The electrical equivalent circuit of a PIN diode polarized (a) in reverse and (b) in direct (b) [24]

## 4. RESULTS AND DISCUSSION
### 4.1. Reflection coefficient and VSWR

Computer simulation technology (CST) microwave studio software is used to simulate the proposed reconfigurable PIFA antenna. Figure 4 shows the reflection coefficient (S11) of the initial design of PIFA antenna with a single radiating element, and Figure 5 shows the reflection coefficient (S11) of the PIFA antenna with two radiating elements, it corresponds to the off state of the PIN diode. During this state the antenna operates in ISM band (2.4 GHz). It can be noted that the antenna achieved an excellent reflection coefficient of -56.490 dB and an ultra wideband. We note that there is a slight variation in the peak of the S11 after the addition of the second radiating elements in Figure 5. This variation is due to the influence exerted between the two patches. Figure 6 shows the reflection coefficient of the reconfigurable PIFA antenna with the on state of the PIN diode. The antenna has an excellent frequency response in GPS band. We can see that the antenna operates at 1.575 GHz with peak of -62.58 dB and also with an ultra wideband.

Figure 7 illustrates the simulated voltage standing wave ration (VSWR) of the proposed reconfigurable PIFA antenna in ISM band, and Figure 8 illustrates the simulated VSWR of the proposed reconfigurable PIFA antenna in GPS band. Where the VSWR is a measure for how the line is matching with the load. We have a VSWR of 1.003 for ISM band and a VSWR of 1.001 for GPS band. The proposed antenna could meet the practical requirements of (VSWR ≤ 2) [26], so the antenna can be described as having a good match.

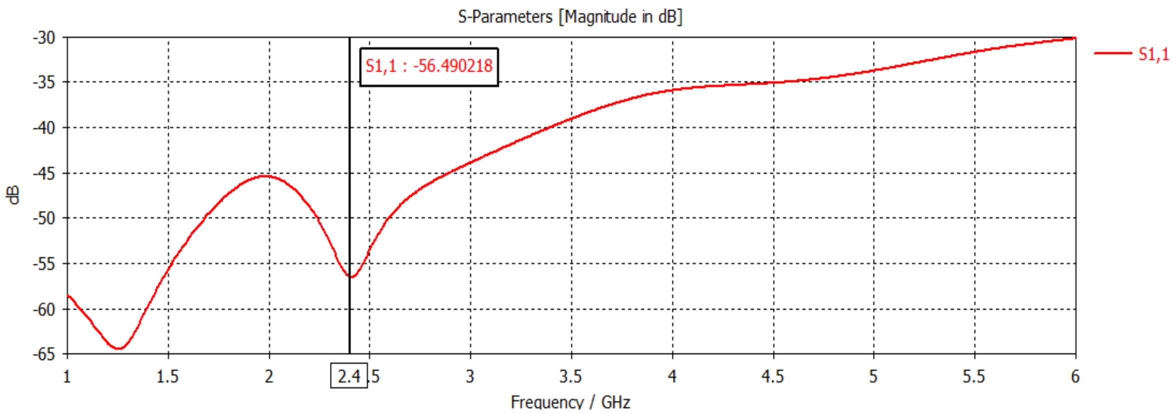



Figure 4. Reflection coefficient of the initial design of the PIFA antenna with a single radiating element in ISM band

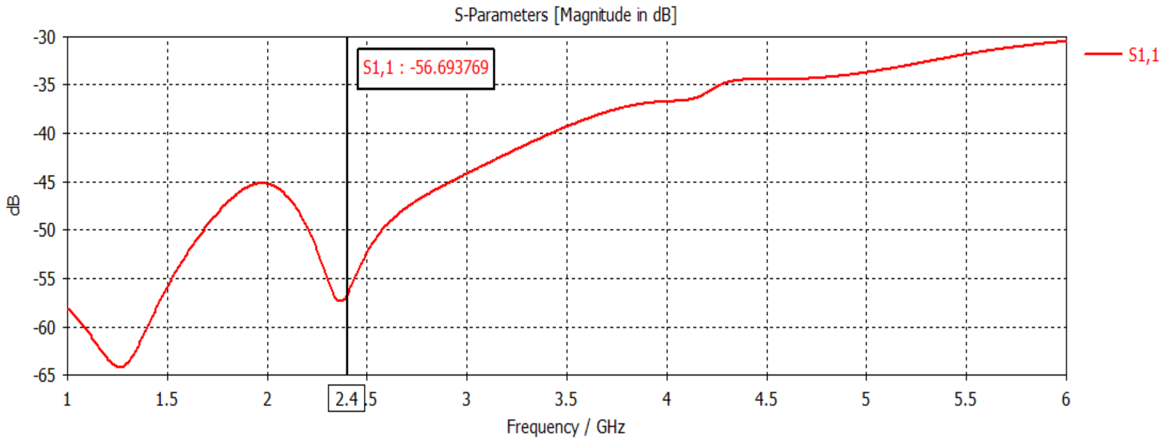



Figure 5. Reflection coefficient of the reconfigurable PIFA antenna with the two radiating elements in ISM band (off state)

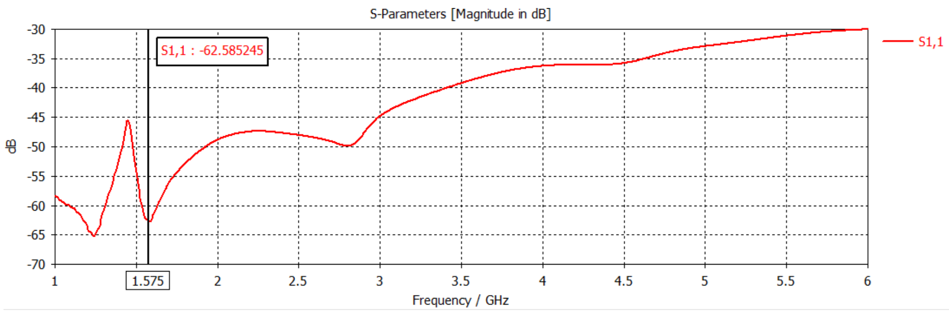



Figure 6. Reflection coefficient of the reconfigurable PIFA antenna in GPS band (on state)

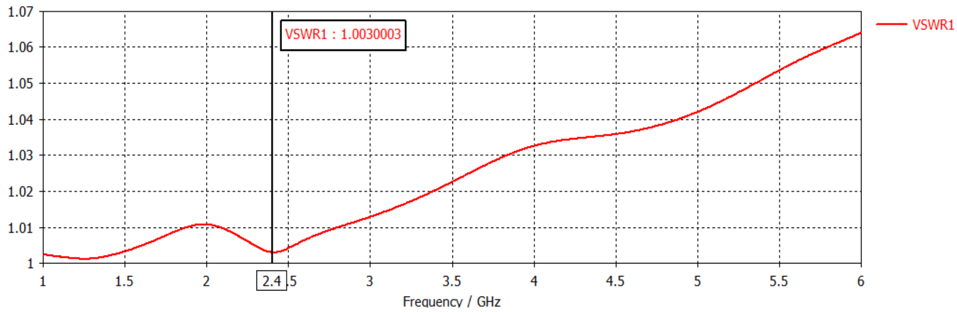



Figure 7. VSWR of the proposed reconfigurable PIFA antenna in ISM band (off state)

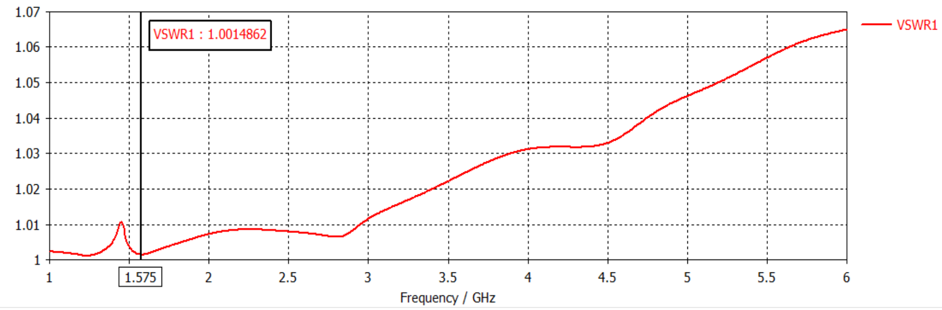



Figure 8. VSWR of the proposed reconfigurable PIFA antenna in GPS band (on state)

### 4.2. Radiation pattern

Figure 9 shows the 3D radiation pattern of the reconfigurable PIFA antenna in GPS band (on state) with a directivity of 3.48 dBi and a high gain of 17.3 dB, and Figure 10 shows the 3D radiation pattern of the reconfigurable PIFA antenna in ISM band (off state) with a directivity of 2.75 dBi and a high gain of 17.6 dB. We can see that the antenna directivity at the on state is better than that at the off state as the losses in the dielectric substrate increase with the frequency. The results of the radiation patterns at both frequencies (1.575 GHz and 2.4 GHz) of the reconfigurable PIFA antenna show that the antenna has a good performance for establishing power efficient communication.

Table 2 provides a summary of the proposed reconfigurable PIFA antenna performance in the two bands (ISM and GPS). Our proposed antenna is highly resistant to environmental changes thanks to its strong connection to the ground plane. Moreover, our proposed antenna performance is characterized by an ultra wideband and a high gain at 2.4 GHz (ISM band) and 1.575 GHz (GPS band).

Table 2. Summary of the reconfigurable PIFA antenna performance in the two bands

| Characteristics | GPS band | ISM band |
|---|---|---|
| Resonance frequency (GHz) | 1.575 | 2.4 |
| Reflection coefficient (dB) | -62.56 | -56.71 |
| Directivity (dBi) | 3.48 | 2.75 |
| VSWR | 1.001 | 1.003 |
| Gain (dB) | 17.3 | 17.6 |

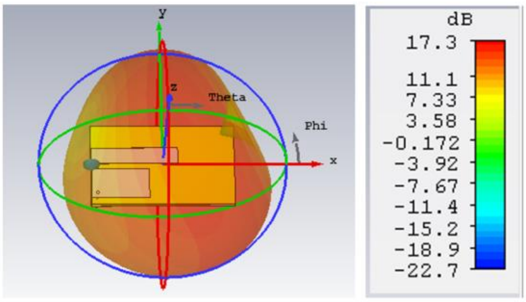



Figure 9. 3D radiation pattern of the reconfigurable PIFA antenna in GPS band (1.575 GHz)

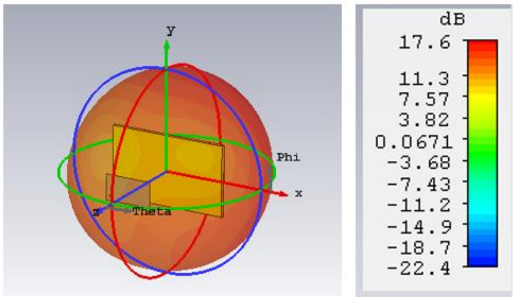



Figure 10. 3D radiation pattern of the reconfigurable PIFA antenna in ISM band (2.4 GHz)

## 5. CONCLUSION

A novel compact reconfigurable PIFA antenna is presented in this work. The antenna is printed on a FR4 substrate with a dielectric constant of 4.4 and a height of 1.6 mm. Its total size is only 30 mm × 50 mm × 7 mm. A PIN diode is used to switch the antenna between two frequencies 2.4 GHz corresponds to the ISM band and 1.575 GHz corresponds to the GPS band. The proposed structure has a good performances due to its compact size, planar structure and good characteristics in terms of reflection coefficient, VSWR, gain, and directivity. The simulation is performed using CST Microwave Studio.

## ACKNOWLEDGEMENTS

The work is carried out with the support of the CNRST within the framework of the Research Excellence Scholarship Programme.

## REFERENCES

[1] T. D. Nguyen, "Reconfigurable Smart Antenna Design for Cognitive Radio," M.S. thesis, University of Grenoble Alpes, 2012. [Online]. Available: https://tel.archives-ouvertes.fr/file/index/docid/859818/filename/32189_NGUYEN_2012_archivage.pdf

[2] S. E. Kadri, "Contribution to the study of Miniature Antennas Reconfigurable in Frequency by Association of active elements," M.S. thesis, University of Grenoble, 2011. [Online]. Available: https://tel.archives-ouvertes.fr/tel-00767173/document

[3] C. Requin, "Quasi-auto-complementary antennas for multi-standard mobile terminals," M.S. thesis, University of Nice Sophia Antipolis, 2013. [Online]. Available: https://tel.archives-ouvertes.fr/tel-00954410/document

[4] Y. Belhadef and N. B. Hacene, "Design of New Multiband Slotted PIFA Antennas," *IJCSI International Journal of Computer Science Issues*, vol. 8, no. 1, pp. 1694-0814, July 2011. [Online]. Available: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.402.6491&rep=rep1&type=pdf

[5] A. Romputtal, B. Luadang, and C. Phongcharoenpanich, "Characteristics of a multi-slotted PIFA for UHF RFID tag," *TENCON 2014 - 2014 IEEE Region 10 Conference*, 2014, pp. 1-4, doi: 10.1109/TENCON.2014.7022497.

[6] P. Panaia, R. Staraj, C. Luxey, G. Kossiavas, and G. Jacquemod, "*Slot Switchable PIFA Antenna," 13th National Microwave Days*, 2003. [Online]. Available: https://www.researchgate.net/publication/266451024_Antenne_pifa_commutable_a_fente.

[7] W. Ahmad and W. T. Khan, "Small form factor dual band (28/38 GHz) PIFA antenna for 5G applications," *2017 IEEE MTT-S International Conference on Microwaves for Intelligent Mobility (ICMIM)*, 2017, pp. 21-24, doi: 10.1109/ICMIM.2017.7918846.

[8] B. Wang, S. H. Yang, D. Feng, T. L. Wang, Z. W. Su, and Y. C. Chen, "Design and Simulation of the Inverted F Antenna for RFID Tags," *Applied Mechanics and Materials*, vol. 303-306, pp. 1822-1825, Feb. 2013, doi: 10.4028/www.scientific.net/amm.303-306.1822.

[9] Namita and D. Khosla, "Planar Inverted-F Antenna (PIFA) for Mobile Communication: A Review," *Journal of Mobile Computing, Communications & Mobile Networks*, vol. 6, no. 2, pp. 10-14, 2019. [Online]. Available: https://www.researchgate.net/publication/339472122_Planar_Inverted-F_Antenna_PIFA_for_Mobile_Communication_A_Review

[10] A. H. A. Ka'bi, "PIFA antenna design for 4G wireless communications," *2017 2nd International conferences on Information Technology, Information Systems and Electrical Engineering (ICITISEE)*, 2017, pp. 188-191, doi: 10.1109/ICITISEE.2017.8285492.

[11] H. T. Chattha, Y. Huang, M. K. Ishfaq, and S. J. Boyes, "A Comprehensive Parametric Study of Planar Inverted-F Antenna," *Wireless Engineering and Technology*, vol. 3, no. 1, pp. 1-11, Jan 2012, doi: 10.4236/wet.2012.31001.
[12] H. M. Chen, Y. F. Lin, P. S. Cheng, H. H. Lin, C. T. P. Song, and P. S. Hall, "Parametric study on the characteristics of planar inverted-F antenna," *IEE Proceedings - Microwaves, Antennas and Propagation*, 2005, vol. 152, no. 6, pp. 534-538, doi: 10.1049/ip-map:20045158.
[13] S. Surwase, R. Yadahalli, and S. Nawale, "PIFA RFID Tag Antenna Design and Simulation using CST Microwave Studio," *International Journal of Science and Research (IJSR)*, vol. 7, Issue 10, pp. 1018-1021, Oct. 2018. [Online]. Available: https://www.ijsr.net/archive/v7i10/ART20192021.pdf
[14] S. Yan, V. Volskiy, and G. A. E. Vandenbosch, "Compact Dual-Band Textile PIFA for 433-MHz/2.4-GHz ISM Bands," in *IEEE Antennas and Wireless Propagation Letters*, vol. 16, pp. 2436-2439, 2017, doi: 10.1109/LAWP.2017.2723419.
[15] B. Leyla, "Design of a Reconfigurable RFID System," M.S. thesis, University of Sciences and Technology Houari Boumediene, 2019. [Online]. Available: http://repository.usthb.dz//xmlui/handle/123456789/8187.
[16] M. S. R. Bashri, M. I. Ibrahimy, and S. M. A. Motakabber, "A Compact Wideband Patch Antenna for Ultra High Frequency RFID Tag," A*utomatika Journal for Control, Measurement, Electronics, Computing and Communications*, vol. 56, no. 1, pp. 76-83, Jan. 2017, doi: 10.7305/automatika.2015.04.598.
[17] A. Amri and T. Mazri, "Frequency Reconfigurable Antenna Design for RFID Tag: A Study," *Proceedings of the 4th International Conference on Networking, Information Systems & Security*, 2021, no. 63, pp. 1-5, doi: 10.1145/3454127.3458772.
[18] A. Elouadih, A. O. -Said, and M. M. Hassani, "Design and Simulation of a PIFA Antenna for the Use in 4G Mobile Telecommunications Networks," *International Journal of Communications, Network and System Sciences*, vol. 6, no. 7, pp. 325-332, 2013, doi: 10.4236/ijcns.2013.67035.
[19] V. Preethi and S. A. Devi, "PIFA Antenna for Wireless Communications," *International Journal of Engineering and Techniques*, vol. 4, no. 3, pp. 646-648, 2018.[Online]. Available: https://oaji.net/articles/2017/1992-1530787484.pdf
[20] A. E. Ouadih, A. O. -Said, and M. M. Hassani, "Design of a triband PIFA antenna with slot for integration on mobile stations of telecommunications networks," *TELECOM'2013 & 8th JFMMA*, pp. 1-4, 2013. [Online]. Available: https://www.researchgate.net/publication/261994323_Conception_d'une_antenne_PIFA_tribande_avec_fente_pour_integration_sur_les_stations_mobiles_de_reseaux_de_telecommunications
[21] L. Berrich, and L. Zenkouar, "Study of the PIFA Antenna for RFID Applications", in *RF Systems, Circuits and Components*. London, United Kingdom: IntechOpen, 2018, doi: 10.5772/intechopen.76564.
[22] Y. Belhadef and N. Boukli Hacene, "PIFAS antennas design for mobile communications," *International Workshop on Systems, Signal Processing and their Applications, WOSSPA*, 2011, pp. 119-122, doi: 10.1109/WOSSPA.2011.5931429.
[23] N. Kumar and G. Saini, "A Novel Low profile Planar Inverted-F Antenna (PIFA) for Mobile Handsets," *International Journal of Scientific and Research Publications*, vol. 3, no. 3, pp. 1-4, 2013. [Online]. Available: http://www.ijsrp.org/research-paper-0313/ijsrp-p1562.pdf
[24] T. Mazri, F. Riouch, and N. E. A. E. Idrissi, "Design and Simulation of a SP4T Switch Based on The PIN Diode Suitable For UMTS Use," *IJCSNS International Journal of Computer Science and Network Security*, vol. 11, no. 9, 2011. [Online]. Available: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1070.9024&rep=rep1&type=pdf
[25] *Data Sheet HPND-4028, HPND-4038 : Beam Lead PIN Diodes for Phased Arrays and Switches*, Avago Technologies, 2006. [Online]. Available: http://www.hp.woodshot.com/hprfhelp/4_downld/products/diodes/hpnd4018.pdf
[26] A. A. Jabber, A. K. Jassim, and R. H. Thaher, "Compact reconfigurable PIFA antenna for wireless applications," *TELKOMNIKA Telecommunication, Computing, Electronics and Control*, vol. 18, no. 2, April 2020, pp. 595-602, doi: 10.12928/TELKOMNIKA.v18i2.13427.


## BIOGRAPHIES OF AUTHORS

**Assiya Amri** Received the B.Eng. degree in Networks & Telecom Systems engineering from National School of Applied Sciences (ENSA) of Kenitra in 2018. She is currently working toward the PhD degree at ENSA of Kenitra /Ibn Tofail University, Morroco. Department of Electrical Engineering, Networks and Telecommunication Systems. Her major research interests microwave system and antennas. She can be contacted at email: assiyaamri7@gmail.com.

**Tomader Mazri** Received the P.h.D degree in Microelectronics and Telecommunication Systems from Sidi Mohammed Ben Abdellah University and the National Institute of Posts and Telecommunications of Rabat, Morocco. She is a Professor at ENSA of Kenitra, holder of a Habilitation to direct research in Networks and Telecommunication Systems from Ibn Tofail University. Her major research interests microwave system and antennas. She can be contacted at email: tomader20@gmail.com.