Indonesian Journal of Electrical Engineering and Computer Science
Vol. 8, No. 1, October 2017, pp. 69 ~ 76
DOI: 10.11591/ijeecs.v8.i1.pp69-76

A New Compact CPW-Fed Dual-Band Monopole Antenna for RFID Applications

Ahmed El Hamraoui*[1], El Hassan Abdelmounim[2], Jamal Zbitou[3], Ahmed Errkik[4], Hamid Bennis[5], Mohamed Latrach[6]
[1,2]ASTI Laboratory, FSTS, Hassan 1st University, Settat, Morocco
[3,4]LMEET, FSTS, Hassan 1st University, Settat, Morocco
[5]TIM Research Team, EST, Moulay Ismail University, Meknes, Morocco
[6]Microwave Group, ESEO, Angers, France
*Corresponding author, e-mail: a.elhamraoui@uhp.ac.ma

Abstract

This paper presents a study of a new dual-band monopole antenna fed by a Coplanar Waveguide (CPW) line suitable for Radio Frequency Identification (RFID) applications especially designed for RFID readers and covering free ISM bands of 2.45GHz and 5.8GHz. The proposed antenna benefits from the advantages of the CPW line to simplify the structure of the antenna into a single metallic level, by consequent making it easier for integration with microwave integrated circuits. The simulation of the antenna was carried out using ADS from Agilent technologies and CST Microwave Studio electromagnetic solvers. A good impedance bandwidth of 500MHz is achieved in measurement (from 2.1GHz to 2.6GHz for the lower band), while the upper band covers 800MHz (from 5.2GHz to 6GHz). Details of the proposed antenna design and both simulated and experimental results are described and discussed.

***Keywords**: antenna; RFID (Radio Frequency Identification); Coplanar waveguide (CPW) fed; Dual-frequency operation; monopole antenna*

1. Introduction

RFID (radio frequency identification) is a technology that incorporates the use of electromagnetic or electrostatic coupling in the radio frequency (RF) portion of the electromagnetic spectrum to uniquely identify an object, animal, or person [1-2]. RFID is coming into increasing use in industry for traceability as an alternative to the bar code [3]. The advantage of RFID is that it does not require direct contact or line-of-sight scanning.

An RFID system comprises two components, a RFID transponder (tag) and an interrogator or reader. The RFID interrogator transmits a radio frequency interrogation signal through the reader antenna and receives the backscattered signal from the antenna of the in-field transponder which contains the stored contents in the internal memory of the tag. The block diagram of RFID system is shown in Figure 1.

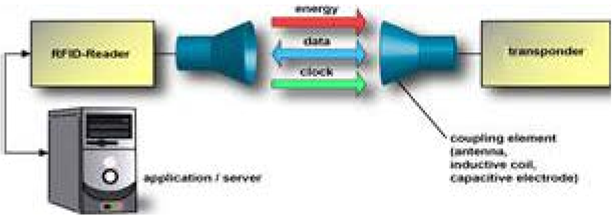


Figure 1. Block diagram of RFID system

The RFID technology operates in different standardized unlicensed frequency bands. The Low-frequency (LF, 125–134 kHz) and high-frequency (HF, 13.56 MHz) applications are most matured and worldwide accepted. These applications are based on magnetic field

Received May 10, 2017; Revised August 1, 2017; Accepted August 17, 2017

coupling between the reader's and tag's coils. RFID systems at Ultra-high frequency (UHF, 860–960 MHz) and microwave (2.4 GHz and 5.2 GHz) involve electromagnetic coupling between antennas and establishing a communication link at longer distance [4].

Analogous to wireless communication and personal area network technology, the multi-standard capability, high data performance, security protocols and compact profile are becoming obvious expectations of the users of RFID devices [5]. In order to reduce the overall size of the handheld RFID readers, the need to reduce the size of the antenna is highly essential [6-9]. But reducing the size of antenna limits its performances.

Many compact printed monopole antennas were manufactured for dual band applications and reported in the literature. For example the symmetrical L-strips and square-slot techniques were proposed to achieve multiband behavior [10]. A triple-band antenna with three simple circular-arc-shaped strips was created for WiMAX and WLAN applications [11]. The whole dimensions of antennas are large three-dimensional size in [12], which possibly limit the integration size of the wireless communication devices and impact the portable characteristics. A printed dipole [13] with etched rectangle apertures on surface has reported to have dual-band characteristics; but it suffers mostly in the consistency of the radiation patterns Again, these are mostly double sided planar antennas.

In this paper, we propose a new design of a compact dual-band monopole antenna fed by a CPW line (see Figure 2). The proposed antenna is particularly simple in manufacturing owing to its single dielectric and single metal layer. In this study, several designs are investigated by simulation, and the characteristics of the return loss and radiation patterns are analyzed and discussed.

2. Antenna Design

Figure 2 shows the geometry of the proposed antenna.

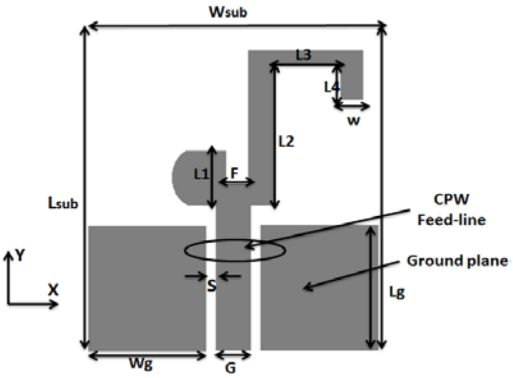


Figure 2. Geometry of the proposed antenna

The dual-band monopole antenna consists of two monopoles with different lengths. The longer one (i.e., Monopole 1) is for a lower frequency band while the shorter one (i.e., Monopole 2) is dominant at the higher frequency. The two monopoles are combined at their lower ends and fed by a CPW fed line. By folding the longer monopole, resonance is achieved at much lower frequency than in the case of a straight monopole of the same height. By widening the width of the shorter monopole with a circular shape we make improving the bandwidth performance of the second frequency band.

A 50-CPW transmission line, having a strip conductor of width G and a gap of distance S, is used to feed the antenna [14-15]. In the design, two finite ground planes with the same dimensions of length Lg and width Wg are symmetrically on each side of the CPW feed line. By selecting a proper length of the ground plane, it is found that the first two resonant modes of the proposed antenna can be excited with good input impedance matching.

The first resonance frequency f1 of the printed monopole antenna depends on the total length (L2+L3+L4) and it is chosen to have a frequency band centered at 2.45 GHz. The second resonant frequency f2 depends on the total length L1 and it is chosen to be centered at 5.8 GHz. Without the element of length (L2+L3+L4), the antenna is found to be resonate only at one resonant frequency close to f2=5.8 GHz, whereas by including this element in the radiating monopole, the first resonant frequency is obtained. By properly tuning the dimensions of the antenna, we can fix the antenna resonance at 2.45 GHz and 5.8 GHz respectively.

The length of each element is proportional to the guided wavelength as follows:

$$\mathrm{L_i} = k.\lambda_{\mathrm{g}} = k.\frac{\lambda_0}{\sqrt{\varepsilon_{re}}}$$

Where is the wavelength of f1 or f2 in free space, is the effective dielectric permittivity and i=1, 2.

From the obtained results it demonstrated that the first resonant path has a length of about 27 mm (L_2+L_3+L_4) or about 0.36 wavelength relative to the frequency of 2.45 GHz, and the length of the second resonant path is 4.2 mm, which is 0.13 wavelength at the resonant frequency of 5.8 GHz.

The final optimized dimensions of the antenna through EM simulations are as follow: ground plane length Lg=13.8 mm, ground plane width Wg=12.9 mm, feed-line width G=3.8 mm, spacing between ground plane and feed length S=0.5 mm. Total volume of the proposed antenna is 34x30.6x1.6 mm3, and dimensions of the proposed antenna according to the Figure 2 are shown in Table 1.

Table 1. Dimension of the Proposed Antenna (unit in mm)

Parameter	Value (mm)
Lsub	34
Wsub	30.6
Lg	13.8
Wg	12.9
L1	4.2
L2	14
L3	7
L4	3
F	1.8
W	3
G	3.8
S	0.5

3. Simulation Results and Discussion

The aim of this study is to design a new compact antenna structure for dual-band RFID applications. The design evolution of the proposed antenna is presented in Figure.3 the conception of the planar antenna with dual frequency operation capabilities is due to the multiple resonances introduced by the combination optimization of the geometry antenna, length of the two monopoles and CPW-feed line dimensions.

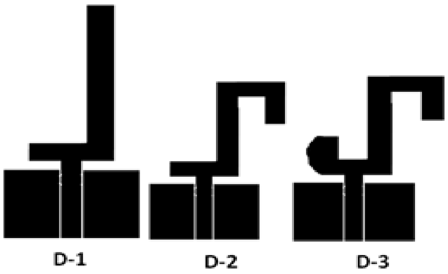


Figure 3. Design evolution of the proposed antenna

The aim of this study is to design a new compact antenna structure for dual-band RFID applications. The design evolution of the proposed antenna is presented in Figure 3 the conception of the planar antenna with dual frequency operation capabilities is due to the multiple resonances introduced by the combination optimization of the geometry antenna, length of the two monopoles and CPW-feed line dimensions.

Figure 4 shows the simulated return losses for successive cases of the conception of the final dual-band antenna. From Figure 3, we can clearly see that the proposed antenna is designed through three steps. Firstly, we start with a straight rectangular monopole (Figure 3.D-1). Secondly by folding the monopole the dimension of the antenna was reduced (Figure 3.D-2). At the end, the final dual-band antenna is achieved by inserting a second monopole (Figure 3.D-3). Thus, the matching input impedance of the final antenna structure is achieved respectively in frequency bands -2.45GHz and 5.8GHz with a return loss less than -10 dB. Figure 4 shows the simulated return loss for each design.

To study the influence of different parameters of the proposed antenna which affect the dual-band performances, CST simulation software has been applied to guide this design [16].

Figure 5 shows the simulated reflection coefficient of the antenna as a function of frequency for the different values of the length of the first monopole L_2 while other parameters are fixed. The center frequency of the first band decreases with the increase of L_2, whereas the second band remains constant.

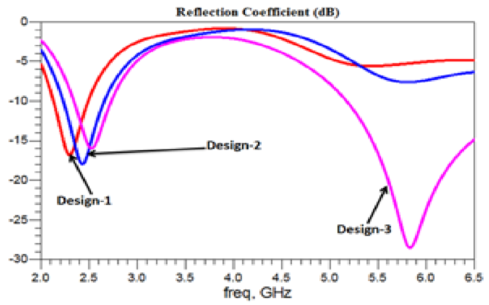


Figure 4. The return loss vs frequency of the proposed antenna for different cases on CST

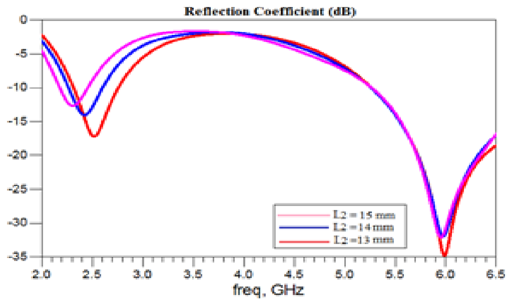


Figure 5. Simulated reflection coefficient of the proposed dual band antenna with varied (L_2) while other parameters fixed

Figure 6, illustrates the simulated reflection coefficient curves with varied length of the second monopole L_1. As can be seen from Figure 5, the center frequency of the second band decreases with the increase of L_1.

Figure 7 shows the simulated reflection coefficient of the antenna as a function of frequency for the different values of Lg while other parameters are fixed. It can be seen from the Figure 7 that the length of Lg permits to obtain a good impedance matching at both operating frequencies.

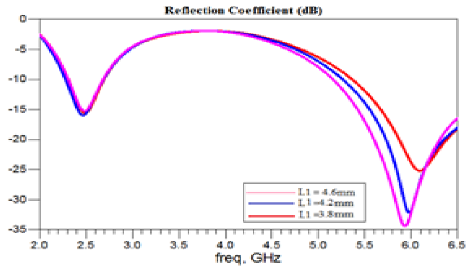


Figure 6. Simulated reflection coefficient of the proposed dual band antenna with varied (L_1) while other parameters fixed

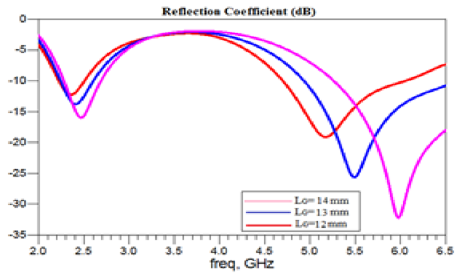


Figure 7. Simulated reflection coefficient of the proposed dual band antenna with varied (Lg) while other parameters fixed

In order to compare the results in Figure 3, electromagnetic solver ADS software "Advanced Design System" [17] is used. Figure 8 shows a comparison of the simulated return loss versus frequency for the proposed antenna using CST and ADS.

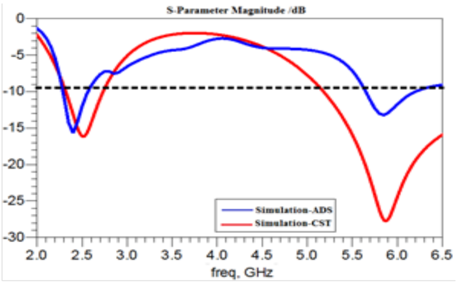
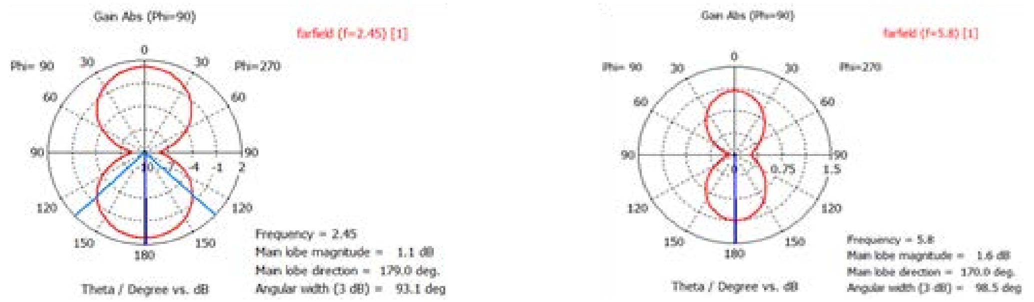


Figure 8. Comparison of simulated return loss S11 for the proposed dual-band antenna using CST and ADS

We can observe a difference in return loss obtained with CST and ADS due to the technique of calculation used in each simulation software. CST is 3D EM simulator based upon Finite Integration Technique (FIT) while ADS is 2D EM simulator based upon the Method of Moment (MoM).

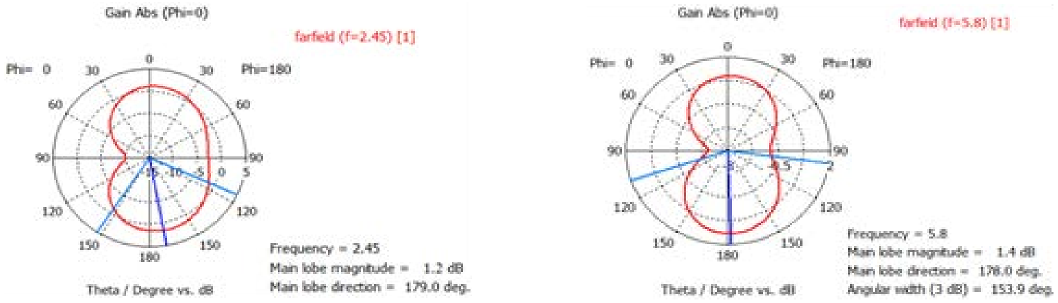
For a reflection coefficient less than -10 dB, we can deduce that the antenna operates in two frequency bands (2.35–2.74 GHz) and (5.2–6.5 GHz). The maximum reflection coefficient of -14.5dB and -26.7dB is obtained at the resonant frequencies of 2.45 GHz and 5.8 GHz respectively. The 2D radiation pattern is given by Figure 9 in the E-plane, which shows a stable and bi-directional radiation pattern for the two resonant frequency bands.

The 2D radiation pattern is given by Figure 10 in the H-plane.



(a) (b)

Figure 9. 2D radiation pattern in E-plane for the designed structure at resonant frequency, for (a) 2.45 GHz and (b) 5.8 GHz



(a) (b)

Figure 10. 2D radiation pattern in H–plane for the designed structure at resonant frequency, for (a) 2.45 GHz and (b) 5.8 GHz

In order to complete the study of the proposed antenna a calculation of the gain variation over the operating frequency band is performed through the Far Field by using CST-MW at 2.45 GHz and 5.8 GHz. The graph result in Figure 11 shows that the proposed antenna provides a peak gain at 2.45 GHz around 1.36 dB and a peak gain at 5.8 GHz around 2.3 dB.

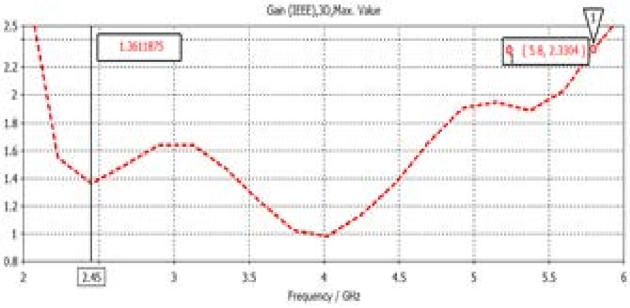


Figure 11. Simulated antenna gain vs frequency

4. Measurement Results and Discussion

After the conception and optimization of the dual-band antenna by using ADS and CST, the prototype of the investigated antenna was fabricated on FR4 substrate using the Chemical etching machine, then measured to verify the performance of the results obtained from simulation. The photograph of the fabricated monopole antenna is given in Figure 12.

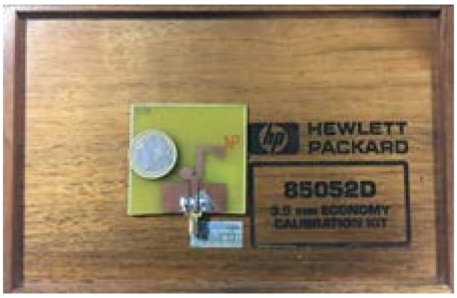


Figure 12. Photograph of the fabricated structure

The return loss was measured by using Vectorial Network Analyzer (VNA) PNA-X from Agilent Technologies. The kit of calibration used is 3.5 mm from Agilent Technologies composed from Open, Short and Load components; losses in the different transitions are taken into account (Figure 13).

Figure 13. Calibration Kit 3.5 mm

After the calibration, the return loss for the achieved antenna as shown in the Figure 14 is tested. In the same time, both the simulations on ADS and CST with measurement results are compared.

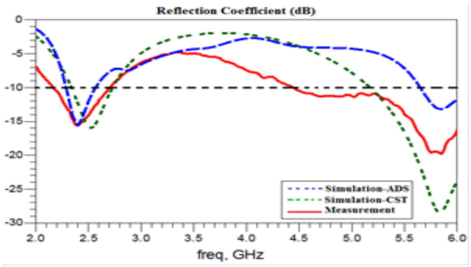


Figure 14. Comparison of simulated and measured return loss

Small discrepancies between the measured and simulated results are observed, due to cable effects, SMA connector and fabrication imperfection.

The simulated impedance bandwidth (for return loss less than 210 dB) is reaching 500 MHz (2.1–2.6 GHz) and 800 MHz (5.2–6GHz), simultaneously.

The radiation patterns were measured in anechoic chamber as shown in Figure 15.

(a) (F1=2.45GHz) (b) (F2=5.8GHz)

Figure 16. Measured radiation pattern at 2.45GHz and 5.8GHz in the E-plane

(a) (F1=2.45GHz) (b) (F2=5.8GHz)

Figure 17. Measured radiation pattern at 2.45GHz and 5.8GHz in the H-plane

The proposed antenna has an acceptable quasi omnidirectional and stable radiation pattern required to receive information signal.

The following table sums up the advantages of the proposed antenna compared to other antennas proposed in the literature. It can be seen that the proposed antenna is significantly smaller, offers an important bandwidth and a good gain compared to its dimensions.

5. Conclusion

In this study, we have performed the design and the simulation of a new low cost dual band monopole antenna with a 50 Ohm CPW Fed. This validated antenna is suitable for RFID applications which can be used in the released frequency band 2.45 GHz and 5.8 GHz. The good agreement between simulation and measurement results validate this antenna to be used for compact RFID handheld reader for dual-band operation.

Acknowledgement

We thank Mr. Mohamed LATRACH Professor in ESEO, Engineering Institute in Angers, France for allowing us to use all the instruments and solvers available in his laboratory.

References

[1] Finkenzeller K. RFID Handbook: Fundamentals and Applications in Contactless Smart Cards and Identification, 3rd Edition, John Wiley and Sons Inc, New York, 2010.
[2] Konstantinos Domdouzis, Bimal Kumar, Chimay Anumba. Radio-Frequency Identification (RFID) applications: A brief introduction. 2006 Elsevier Ltd. Advanced Engineering Informatics 21. 2007: 350–355.
[3] Chen YN, Fang F, Ding DH, Zhu XH, Yang YK. Organic RFID Based on Traceability System of Rice Supply Chain. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2014; 12(5): 3769-3776.
[4] Dominique Paret, Rfid En Ultra Et Super Hautes Fréquences Uhf-Shf, Théorie et mise en oeuvre, Dunod, 2008.
[5] M Naser, I Aldmour, R Budiarto, P Peris-Lopez. SLRV: An RFID Mutual Authentication Protocol Conforming to EPC Generation-2 Standard. *TELKOMNIKA*. 2015; 13(3): 1054-1061.
[6] Foster P, R Bueberry. Antenna problems in RFID systems. *IEE Coll. on RFID Technology*. 3/1–3/5, 1999.
[7] C Guesmi, A Ferchichi, A Gharsallah. A Modified Fractal Bow Tie Antenna for an RFID Reader. *International Journal of Electrical and Computer Engineering (IJECE).* 2014; 4(3): 441-446.
[8] Hattan F Abutarboush, H Nasif, R Nilavalan, SW Cheung. Multiband and Wideband Monopole Antenna for GSM900 and Other Wireless Applications. IEEE Antennas and Wireless Propagation Letters. 2012; 11.
[9] P Mihułowicz, D Kawalec, M Węglarski. The Idea of Enhancing Directional Energy Radiation by a Phased Antenna Array in UHF RFID System. *Intl Journal of Electronics and Telecommunications*. 2016; 62(2): 115-120.
[10] Zhai H, Ma Z, Han Y, Liang C. A compact printed antenna for triple-band WLAN/WiMAX applications. *IEEE Antennas Wirel. Propag. Lett.* 2013: 65–68.
[11] Pei J, Wang AG, Gao S, Leng W. Miniaturized triple-band antenna with a defected ground plane for WLAN/WiMAX applications. *IEEE Antennas Wirel. Propag. Lett*. 2011: 298-301.
[12] Huang CY, Yu EZA. Slot-monopole antenna for dual-band WLAN applications. *IEEE Antennas Wirel. Propag. Lett.* 2011; 10: 500-502.
[13] QQ He, BZ Wang, J He. Wideband and Dual-Band Design of a Printed Dipole Antenna. *IEEE Antennas and Wireless Propag. Lett*. 2008; 7: 1-4.
[14] A Balanis, Antenna Theory Analysis and Design, 2nd edition (John Wiley & Sons, Inc., 2003).
[15] Simons RN. Coplanar Waveguide Circuits, Components and Systems. Wiley-Interscience, 2001.
[16] CST Studio Suite version 2010 : http://www.cst.com/Content/Products/DS/Overview.aspx
[17] Advanced Design System (ADS): http://www.home.agilent.com/agilent/home.jsp.
[18] Y Seo, J Jung, H Lee, Y Lim. Modified Dual Monopole Antenna for Wlan Operation. *Microwave and Optical Technology Letters*. 2000; 53(12).
[19] J Wen Wu, Y Der Wang, H Ming Hsiao, J Han Lu. T-Shaped Monopole Antenna with Shorted L-Shaped Strip-Sleeves for Wlan 2.4/5.8-GHz Operation. *Microwave and Optical Technology Letters*. 2005; 46(1).
[20] H Ming Hsiao, J Han Lu, J Wen Wu. Y-SHAPED Monopole Antenna with Dual-Broadband Operation for Wlan. *Microwave and Optical Technology Letters*. 2006; 48(8).
[21] T yang, G wen, G jinsong, F xiaoguo. Compact multi-band printed antenna with multi-triangular ground plane for WLAN/ WiMAX/RFID applications. *International Journal of Microwave and Wireless Technologies*. Cambridge University Press and the European Microwave Association. 2014.
[22] M Ihamji, Elh Abdelmounim, H Bennis, M Hefnawi, M Latrach. Design of Compact Tri-Band Fractal Antenna for RFID Readers*. International Journal of Electrical and Computer Engineering (IJECE)*. 2017; 7(4).