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Design of a Miniaturized Meandered Dipole Antenna with Defected Ground Structure for Passive UHF RFID Tags

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Abstract- A new compact dipole antenna with octagon slotted ground plane has been presented for passive ultra-high frequency (UHF) radio frequency identification (RFID) tag applications. The antenna with Rogers RO5880 substrate has a miniaturized size and a low profile. The overall tag antenna dimension does not exceed $31x31x1.575mm^3$ ***at the operating frequency of 915MHz. Various simulation results such as return loss, radiation pattern and voltage standing wave ratio (VSWR) are carried out and discussed.***

Keywords: Compact antenna, dipole antenna, octagon slotted ground plane, passive UHF RFID, miniaturized size, low profile.

1. INTRODUCTION

RFID is as of now a noteworthy empowering innovation. It's in effect broadly utilized as a part of numerous different sorts of applications and it's a standout amongst the most encouraging wagers for the advancement of the Internet of Things (IoT) technology [1], [2].

Different aspects of RFID systems can be distinguished based on different criteria such us the frequency band range, the means used to provide energy to the tags and the used protocols to communicate between the interrogator and the transponder [3],[4].

Passive UHF RFID systems are very promising thanks to the simpler design, the lower unit costs and the long life time of their tags as there is no need to use a battery [5]. In addition, the UHF band provides high data transfer rate and broad readable range [6], [7], [8].

Considering the development in the passive UHF systems and the progress in their applications, tags antenna conception with limited size, maximum read range and good gain under the used chip restraint have been the main challenge for researchers [9],[10].

The purpose of this work is to design a new small passive UHF tag antenna operating at 915 MHz with improvable performances with respects to its size.

2. ANTENNA CONFIGURATION

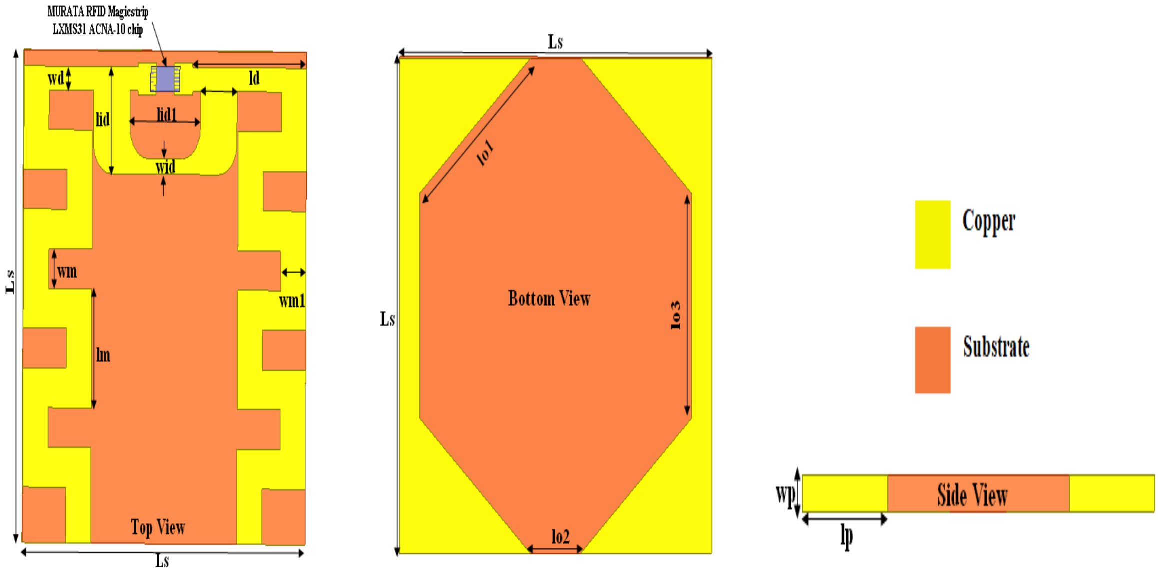
The proposed antenna is presented in Figure 1 It is designed on a 1.575mm thick RT/Duroid 5880 substrate with a loss tangent of 0.0009 and a relative permittivity of 2.2.

The MURATA RFID Magicstrip LXMS31 ACNA-10 chip is used as a RFID chip [11] with an input impedance of (12-j107) Ω at the desired frequency equal to 915 MHz.

The radiating element, printed on the substrate top face, consists of a dipole antenna with meandered arms and an inductive loop with rounded corners in the middle.

The antenna modified ground plane, printed on the substrate backside, consists of an ordinary entire ground plane with an octagon slot with specific geometric parameters. As a result, the ground plane is simply composed of two symmetric structures. Each one includes two triangles which are related to each other with a rectangular strip.

Two shorting plates are used in order to short-circuit the radiating element to the defected ground plane.



(a) (b) (c)

Figure 1 The proposed antenna structure (a) Top view (b) Bottom view (c) Side view.

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Two shorting plates are used in order to short-circuit the radiating element to the defected ground plane. The overall antenna parameters are regrouped in Table I.

TABLE I: Final antenna dimensions.

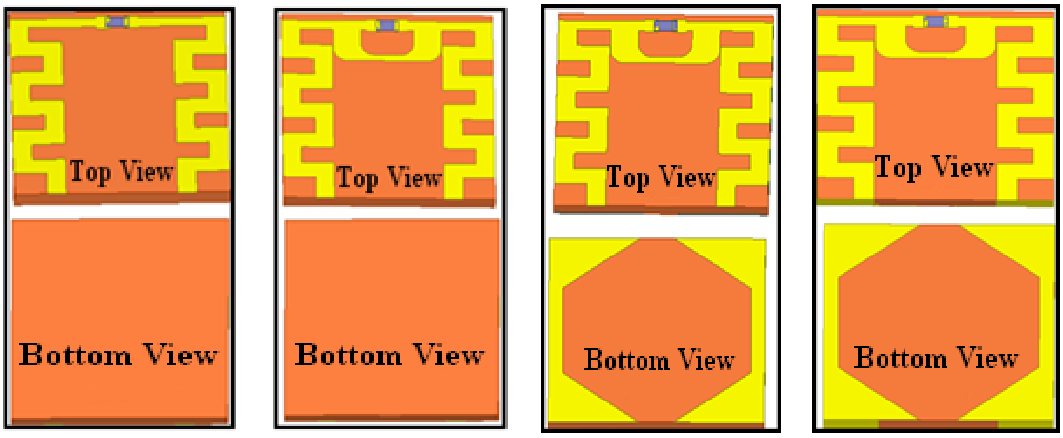
Parameter	Value (mm)	Parameter	Value (mm)
Ls	31	lm	7.5
ld	12.5	wm1	2.5
wd	1.5	lo1	13.88
lid	6.75	lo2	5
wid	0.98	lo3	14.08
lid1	7.75	wp	1.575
wid1	4	lp	7.5
wm	2.5		

3. SIMULATION AND RESULTS

3.1 Antenna Design Procedure

HFSS v.13 “High-Frequency Structural Simulator” simulator based on FEM “finite element method” was adopted in the design to study and analyze the antenna.

The design procedure of the suggested antenna is detailed in Figure 2.



(a) (b) (c) (d)

Figure 2 The proposed antenna design procedure (a) Antenna I (b) Antenna II (c) Antenna III (d) Proposed Antenna.

The return loss variation at each design steps is depicted in Figure 3.

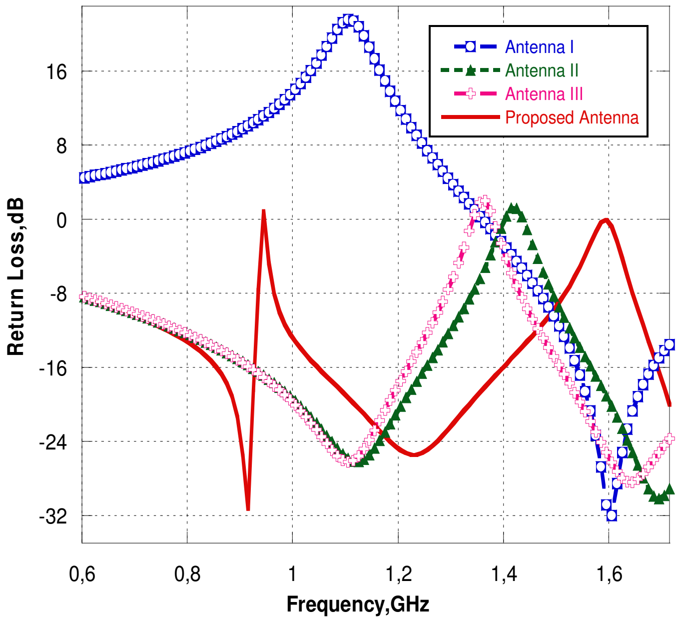


Figure 3 Compared return loss of the designs antenna.

Initially, we started with a conventional dipole meandered antenna as shown in Figure 2 (a), it resonates at 1.605 GHz. In the second step, the addition of the inductive loop with rounded corners as demonstrated in Figure 2 (b), decreases the resonant frequency to 1.125 GHz. Then, Fig.2 (c) illustrates the structure of the defected added ground plane; the antenna resonates at 1.105 GHz. Finally, the inclusion of two shorting plates between the radiating element and the modified ground plane enables the antenna to resonate at the desired frequency 0.915 GHz. As a conclusion, the introduced changes are very useful to make the same area of 31×31 mm^2 initially resonating at 1.605GHz operate at 0.915GHz.

3.2 Octagon slot effect

The effect of the insertion of the octagon slot on the ground plane of the antenna was reported to the Figure 4.

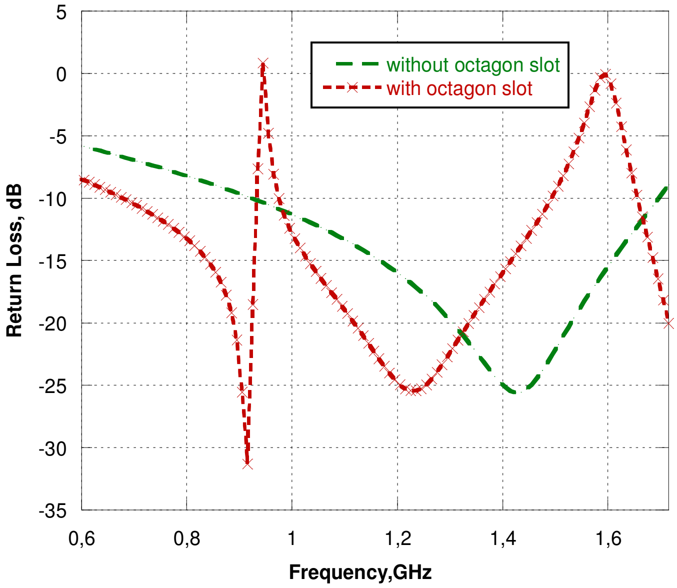


Figure 4 The ground octagon slot effect on the return loss.

We can deduce that the octagon slot on the ground plane affect directly the resonant frequency of the antenna by decreasing it from 1.425 GHz to 0.915 GHz, allowing the miniaturization of our structure.

Therefore, the addition of the octagon slot to the ground plane not only reduces the resonance frequency to lower values but also improves the gain as demonstrated in Figure 5.

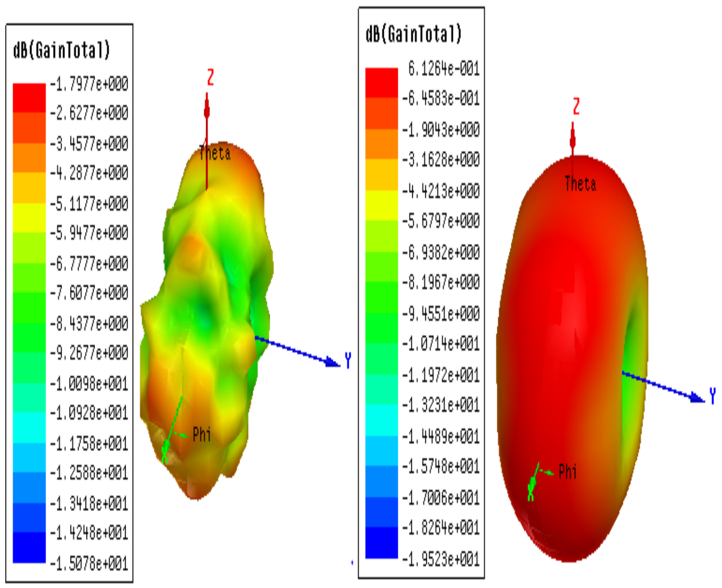


Figure 5 The ground octagon slot effect on the maximum gain: (a) with full ground plane (b) with slotted ground plane.

In fact, the gain value at the resonant frequency is equal to -1.8 dBi with the full ground plane and equal to 0.61dBi with the slotted ground plane as depicted in Figure 5.

3.3 Antenna performances

The reflection coefficient plot obtained from the HFSS simulation of the designed antenna is presented in Figure 6.

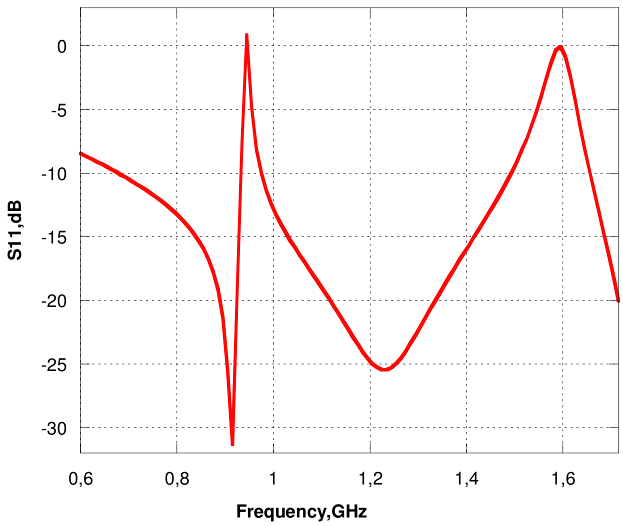


Figure 6 HFSS antenna simulated return loss.

The plot shows that the proposed antenna has a dual band characteristic. The first detected resonant frequency is equal to 0.915GHz with a bandwidth of 0.254 GHz from 0.679 to 0.933GHz and a minimum reflection coefficient of -31.31dB. The second detected resonant frequency is equal to 1.225GHz with a bandwidth of 0.518 GHz from 0.975 to 1.493GHz and a minimum reflection coefficient of -25.44dB. So it clearly seen that the designed antenna can be used in many other kinds of wireless communication systems such as GPS (L2 band) [12].

The variation of the final designed antenna VWSR within the different frequencies is calculated and displayed in Figure 7.

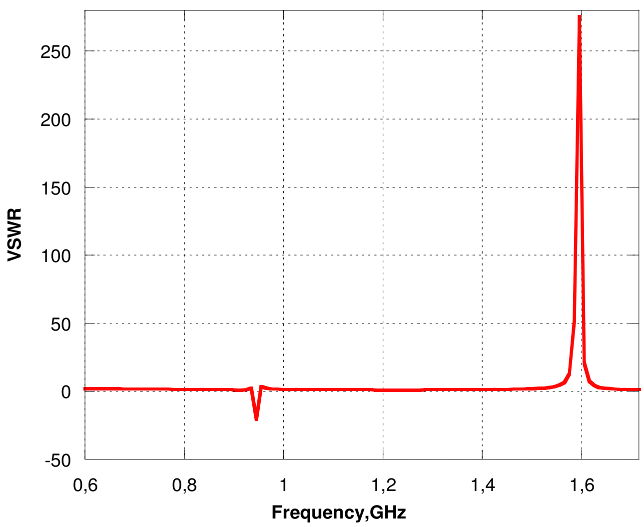


Figure 7 VSWR versus frequency.

If we consider the VSWR ≥ 2, we found three different bands B1= [0.931GHz, 0.935GHz], B2= [0.954GHz, 0.973GHz], and B3= [1.498GHz, 1.654GHz]. So, for the frequencies within the matching bands the VSWR is less than 2 (except an exiguous band of [0.931GHz, 0.933GHz]). VSWR is equal to 1.056 and 1.113 at the first and the second resonant frequency, respectively which is very satisfactory as it is very close to the target value of unity. Figure 8 exhibits the peak gain antenna versus frequency.

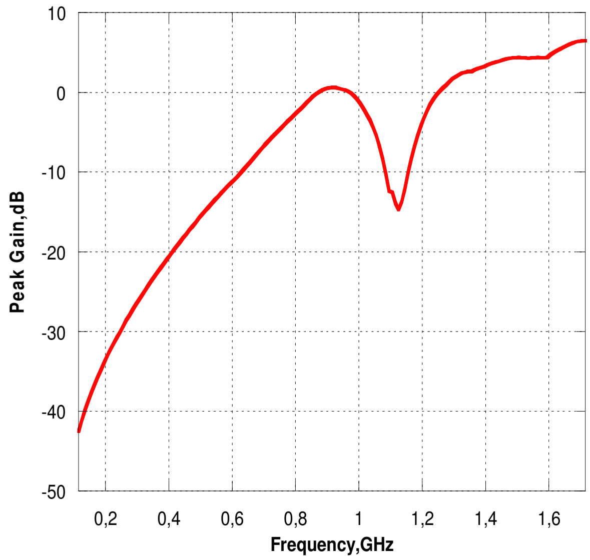


Figure 8 Peak gain against frequency.

At the two operating frequencies 0.915GHz and 1.225GHz, the peak gain has a value of 0.61dBi and -1.55dBi, respectively.

In order to validate our proposed prototype, a second simulation using CST v.14 “computer simulation technology“ microwave studio based on FIT “finite integration technique” has been conducted. Figure 9 illustrates a comparison of the return loss curves between the two simulation tools.

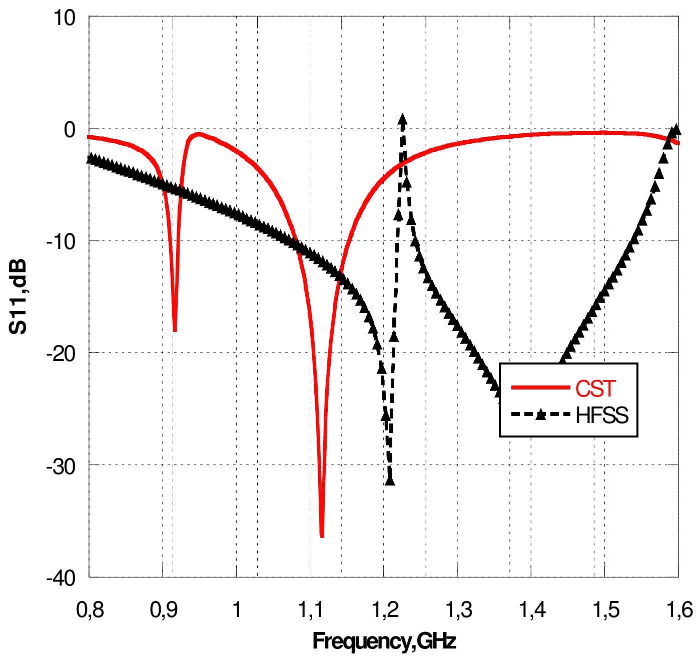


Figure 9 S11 simulation results comparison between HFSS and CST.

It is noticed a good agreement between the two obtained results with a slight acceptable and expected shift.

The size comparison of the suggested tag antenna and other works is summarized in Table II.

TABLE II

SIZE COMPARISON OF THE PROPOSED ANTENNA WITH OTHER EXISTING DESIGNS.

Antenna	Substrate	Size (mm^3)
[13]	RO4003	36.5×36.5×0.508
[14]	FR4	60×60×1.6
[15]	FR4	58.6×58.6×0.4
[16]	FR4	54×54×5.2
[17]	RO4350B	130×130×1.52
[18]	FR4	86×25×1.6
This work	RO5880	31×31×1.575

The size comparison of the proposed antenna and recent research paper in the previous table proves that the designed antenna offers a considerable size reduction which is very required while designing a tag antenna.

4. CONCLUSION

This work presents a new passive UHF tag. The suggested tag antenna is characterized with a broad impedance bandwidth, good adaptation and sufficient gain compared to its small size and low profile. Furthermore, this antenna model provides two operating frequencies allowing it suitable for a diversity of wireless communications applications.

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