Design of a Miniaturized Microstrip Patch Antenna for a Passive UHF RFID Tag

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***Abstract*— This paper present a design and miniaturization of rectangular patch antenna with balanced feed. The miniaturized patch antenna for a passive radio frequency identification (RFID) tag witch can operate in the ultra-high frequency (UHF), the resonant frequency is 915MHz.The simulation was performed in High Frequency Structure Simulator Software (HFSS). The miniaturized antenna has an acceptable results in terms of efficiency, size, return loss (S11), and Input Impedance.**

Keywords—RFID; Passive Tag; Micro-strip patch antenna; Miniaturized atenna; I-slotted antenna.

I. INTRODUCTION

Radio Frequency Identification (RFID) can be defined as follows: Automatic identification technology which uses radio-frequency electromagnetic fields to identify objects carrying tags when they come close to a reader. RFID system in the ultra-high frequency (UHF) band becomes more attractive for many industrial services because it is able to provide the high reading speed, capable multiple accesses, long reading distance compared to other frequency band RFID systems, Therefore it has been widely used in many service industries, purchasing and distribution logistics, industry, manufacturing companies and material flow systems [1].

In passive UHF RFID systems, the reader, primarily as a transmitter, transmits RF energy to sense the tag, a the tag consists of a chip and an antenna and is powered by energy from the received signal, if there is sufficient energy to power up the RFID IC, then the tag responds to the reader and the information contained the tag chip is backscattered from the tag to reader along with data form the RFID chip [2].

The RFID chip is integrated on the patch via an inset balanced feed line that is positioned in a way to deliver the conjugate impedance matching between the antenna and the chip [3].

The miniaturization of RFID UHF tag antennas has a very great interest for several reasons: Allow the identification of small objects, reduced cost, less material and faster manufacturing [4].

In this paper, we introduce a miniaturized antenna, its miniaturization achieved by inserting a I-shaped slot in the patch [5, 6].

The I-shaped slot aim to reduce the size of the tag antenna with a shift in the resonant frequency. To correct this shift, it is possible to change the dimensions of the patch to control the resonant frequency and to get it back to 915Hz [7][8][9].Comparing with the other antenna (optimized antenna), the antenna has a smaller size with a dimension of 68.4mm×75.1mm and also a simpler structure that ensures an easy and low-cost fabrication.

II. DESIGN SPECIFICATIONS

The three essential parameters for the design of a rectangular Microstrip Patch Antenna RFID are:

- Frequency of operation fr = 915MHz.
- Dielectric constant of the substrate εr = 4.3.
- Height of dielectric substrate h = 1.58mm.

Step 1: Calculation of the Width (Wp): The width of the Microstrip patch antenna is given by the following equation [10]:

$$Wp = \frac{c}{2fr\sqrt{\frac{(\varepsilon_r+1)}{2}}} \qquad (1)$$

Substituting $c = 3 * 10^8$m/s, $\varepsilon_r = 4.3$ and fr = 915MHz, We get:

Wp = 100.7mm

Step 2: Calculation of Effective dielectric constant ε_{reff}: The following equation gives the effective dielectric constant as [10]:

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \qquad (2)$$

Substituting Wp = 100.7mm, $\varepsilon_r = 4.3$ and $h = 1.58\,mm$ we get:

$$\varepsilon_{reff} = 4.16$$

Step 3: Calculation of the Effective length (L_{eff}): The effective length is given [10] as:

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$$L_{eff} = \frac{c}{2fr\sqrt{\varepsilon_{reff}}} \quad (3)$$

Substituting $c = 3 * 10^8$ m/s, fr =915MHz and $\varepsilon_{rff} = 4.16$

$$L_{eff} = 80.3mm$$

Step 4: Calculation of the length extension (ΔL): Equation below gives the length extension [10] as:

$$\Delta L = 0.412h\frac{(\varepsilon_{rff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{rff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (4)$$

Substituting$\varepsilon_{rff} = 4.16$, Wp =100.7mm and h=1.58mm we get:

$$\Delta L = 0.73mm$$

Step 5: Calculation of actual length of the patch (Lp): The actual length of the antenna can be calculated [10] as:

$$Lp = L_{eff} - 2\Delta L \quad (5)$$

Substituting $L_{eff} = 80.3mm$ and $\Delta L = 0.73mm$ we get:

$$Lp = 78.9mm$$

III. Input Impedance of the RFID Chip

The RFID impedance can be modeled as shown in Fig. 1 It is a large resistor of in parallel with a small valued capacitor, the input impedance of the chip is Zc= R-jX [3].

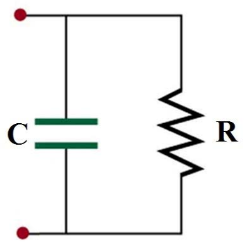

Fig. 1. Circuit model of the RFID chip impedance.

$$Z_c = R \parallel X_c \quad (6)$$

$$X_C = \frac{-j}{2\pi f_r C} \quad (7)$$

The chip used in this configuration has an input impedance of Zc = (28-j148) Ω (Strap XRAG2) [11] at the frequency 915 MHz, In order to deliver the maximum power from the antenna to the chip, the input impedance of the antenna, Za should be complex conjugate of the chip impedance, Zc (Zc = Za*). Therefore, the antenna is designed for Za = (28 + j148) Ω.

IV. Antenna Design

A. *Design of the RFID patch antenna optimized*

The microstrip antenna thus designed is completely planar in nature and does not have any cross-layered structures, the microstrip antenna with balanced feed [3].

The antenna is printed on a FR4 substrate witch thickness h=1.58mm, dielectric constant $\varepsilon_r = 4.3$ and loss tangent $\delta = 0.001$, the dielectric substrate placed on top of the group plane to form the microstrip antenna. The original structure Fig.2 is introduced in [3] [12]. Design parameters are shown in TABLE I.

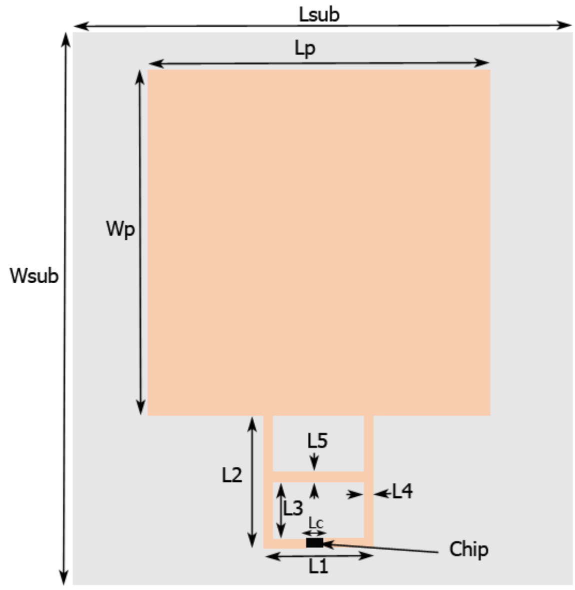

Fig. 2. The Geometries of the original structure [3][12].

TABLE I. Dimension of the patch antenna optemized.

Parameter	Dimension(mm)
W_{sub}	132.1
L_{sub}	88.3
W_P	100.7
L_P	78.9
$L1$	20.1
$L2$	21.9
$L3$	4
$L4$	2.01
$L5$	3.7
Lc	3

B. *The miniaturized antenna*

To miniaturize the above antenna, we initially introduced an I-slot on the patch as shown in Fig.3.The dimensions of the final design are given in TABLE II.

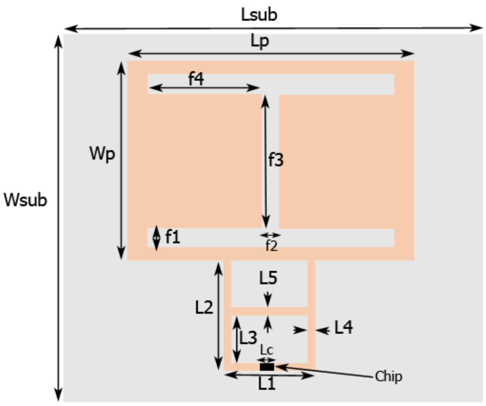

Fig. 3. Miniaturized antenna with I-shape slot.

TABLE II. DIMENSION OF THE PATCH ANTENNA MINIATURIZED.

Parameter	Dimension(mm)
$W_{substrate}$	68.4
$L_{substrate}$	75.1
W_{Patch}	39.5
L_{Patch}	59.8
$L1$	20.1
$L2$	16.9
$L3$	4
$L4$	2
$L5$	2.7
Lc	3
$f1$	2.5
$f2$	1.78
$f3$	29.1
$f4$	20.1
Lc	3

V. RESULTS AND DISCUSSION

A. Return Loss

The simulated return loss results of the optimized and miniaturized antenna are shows in Fig. 4.

The antenna miniaturizes has a coefficient S11 better than the other, The minimum value of the simulated return loss (S11) at the resonance frequency 915.4MHz from the miniaturized antenna is -61dB.

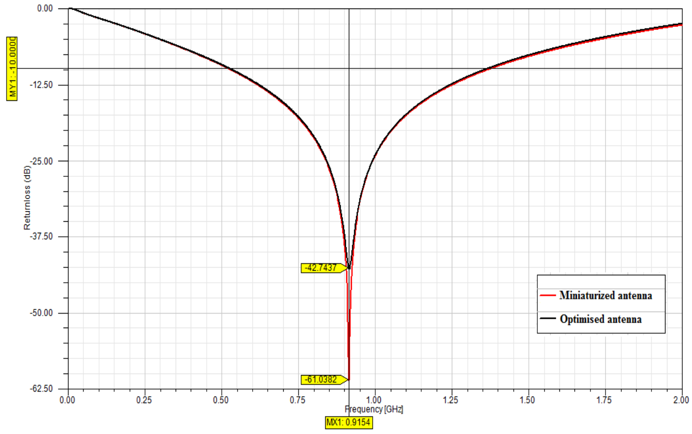

Fig. 4. Simulated return loss (S11).

B. Input Impedance

Fig. 5 and Fig. 6 shows the simulated input resistance and input reactance of the optimized and miniaturized patch antenna.

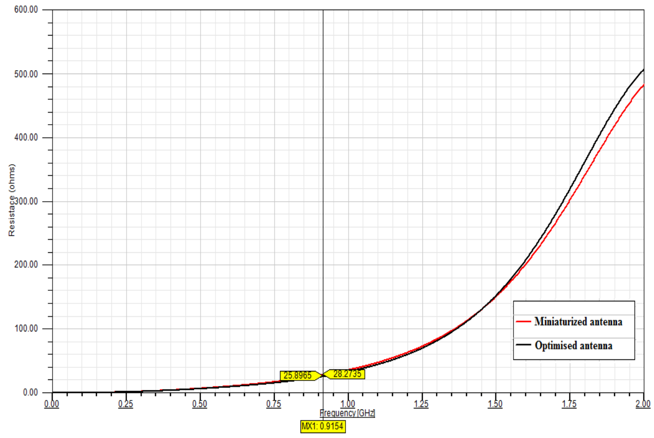

Fig. 5. Simulated input resistance.

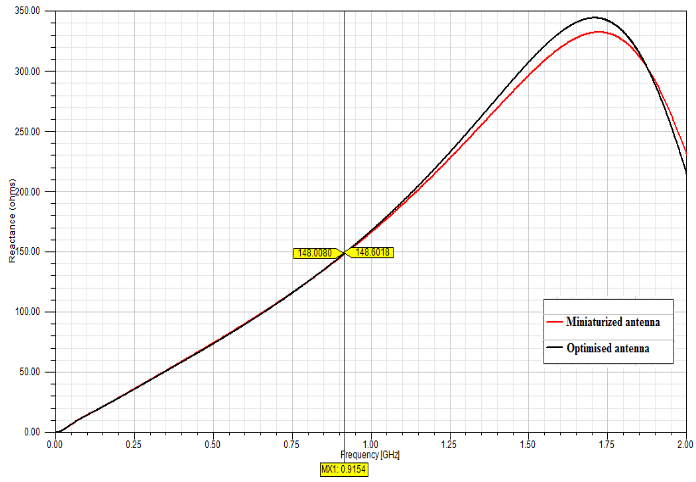

Fig. 6. Simulated input reactance.

Input impedance the miniaturized antenna at 915.4MHz is 28+j148 Ω, which provides the good match shown in the return loss between the RFID chip and antenna.

C. Radiation efficiency

The antenna efficiency (or radiation efficiency) of an antenna is a ratio of the power delivered to the antenna relative to the power radiated from the antenna [10]:

$$\varepsilon_R = \frac{P_{radiated}}{P_{input}} \quad (8)$$

The radiation efficiency of the miniaturized antenna as a percentage is 96%.

D. Radiation Patterns

Fig. 7 and Fig. 8 shows the simulated radiation patterns of the miniaturized antenna and initial antenna at 915.4MHz in the H-plane and the E-plane the radiation patters is bidirectional in the H-plane and nearly omnidirectional in the E-plane.

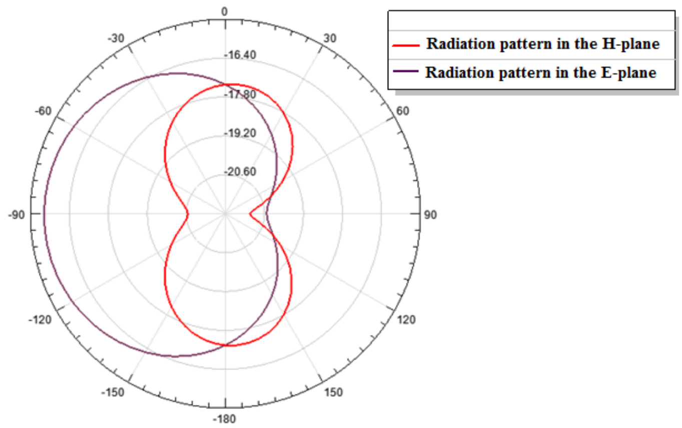

Fig. 7. Simulated radiation pattern at 915.4 MHz for the miniaturized antenna in the E-plane and H-plane.

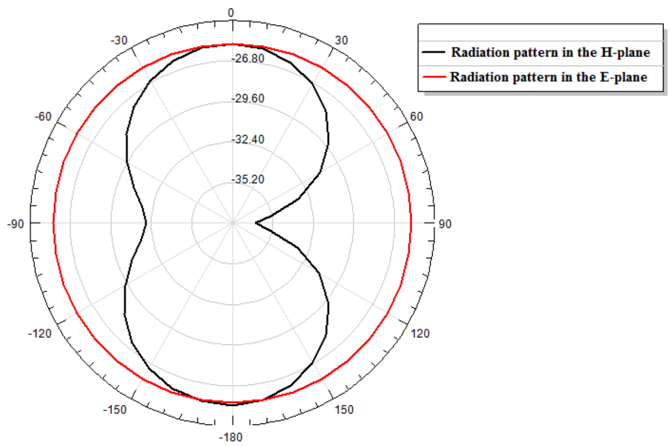

Fig. 8. Simulated radiation pattern at 915.4 MHz for the initial antenna in the E-plane and H-plane.

We can summarize the different results in the TABLE III as follows.

TABLE III. COMPARISON BETWEEN THE NON-MINIATURIZEDAND MINIATURIZED ANTENNA.

Antenna type	**The electrical characteristics of the antenna**			**Antenna size**
	VSWR (dB)	***Return Loss (dB)***	***Input impedance (Ω)***	***Dimension (mm)***
Non-Miniaturized antenna	0.126	-42.7	$25.8 + j148$	132.1*88.3
Miniaturized witchI-shape slot	0.015	-61	$28 + j148$	68.4*75.1

VI. CONCLUSION

In this paper, a patch RFID antenna has been has been designed, optimized and miniaturized.

The miniaturized patch RFID antenna obtained has a size reduction of 68% compared to the initial patch design.

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