New Dipole Slot Antenna Design for RFID Communications

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***Abstract*— New design of a dipole antenna with H-shaped slot at two operating bands for Radio Frequency Identification (RFID) is presented. By using an H-shaped slot over a rectangular patch at the middle associated with four T-shaped slot, the proposed antenna has a wide and dual measured return loss bandwidth. Besides, the omnidirectional radiation pattern of the antenna cover the entire frequency range including Ultra High Frequency (UHF, 915MHz) and microwaves (2.45GHz) bands has been obtained. Tuning techniques of the design parameters are proposed, and tag performance in both frequency bands is evaluated numerically an experimentally in detail.**

I. INTRODUCTION

Recently, wireless communication and personal area network technology grew up fast and wide markets have been raised and developed, Radio Frequency Identification (RFID) specially. RFID is a rapidly developing technology for automatic identification of objects, people tracking, supply chain management, security access to controlled areas, etc. It has been emerging over the past decade as a substitute for bar code in dirty or environmentally challenging environments.

RFID is a short-range radio technology used to communicate mainly digital information between a stationary location and a movable object or between movable objects. A variety of radio frequencies and techniques are used in RFID systems. RFID is generally characterized by use of simple devices on one end of the link and more complex devices on the other end of the link. The simple devices (often called tags or transponders) are small and inexpensive, can be deployed economically in very large numbers, are attached to the objects to be managed, and operate automatically. The more complex devices (often called readers, interrogators) are more capable and are usually connected to a host computer or network. Tags can be powered by a battery (active tag) or by rectification of the radio signal sent by the reader (passive tag). A passive tag is composed by a transponder chip and a matched antenna enabling it to either capturing electromagnetic energy from an interrogating field or communicating with an RFID reader. Today, most of the commercially exciting developments in RFID focus on size and cost reductions [1].

Passive RFID at UHF band (860-960 MHz) and Microwave (2.45 GHz) communicate using the modulated scattered technique, where the reflected signal from the tag is modulated by the chip connected directly to the antenna. To obtain the maximum power transfer to the chip, a tag antenna is typically designed to be conjugate matched to it. In order to reduce costs and size, matching networks or other lumped elements are avoided. Moreover, the microchip is usually presenting highly capacitive input impedance, thus the antenna input impedance should be intrinsically inductive. As a consequence, the design of tag antennas that can be effectively integrated with the IC transponders is one of the major constraints. Passive RFID systems are requested in all those applications where large-scale low-cost tagging is required. At the same time they may also provide adequate flexibility to allow for effective inventory management, interoper-ability and adaptation to changing situations. In this scenario, passive transponders that may operate indifferently at both UHF and microwave frequencies may improve upon the flexibility characteristics of a passive RFID system.

Recently various dual band antennas have been studied and reported for RFID communications. The majority of this tags antennas combining the HF (13,56MHz) and UHF [2-3] or UHF and microwaves frequency [4-6]. Structures combining UHF and microwaves bands remain few, and are very difficult to match to a complex impedance chip.

In this paper an optimized dual band slot-type tag antenna operating at the frequencies of 915MHz and 2.45GHz is presented.

II. ANTENNA STRUCTURE AND DESIGN

Fig.1 shows the geometry of the proposed antenna for RFID dual-band application. The antenna is symmetrical to the orthogonal axis of the feed point, and consists of an H-shape slot extended by four T-slots on both sides. The size of the conductor plane is (57x42) mm² and the height of the slot is 1.52mm. It is printed on low cost FR4 substrate of relative permittivity of 4.32.

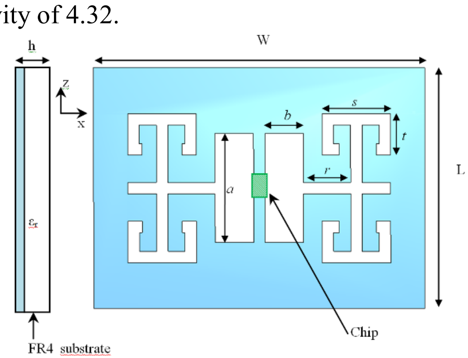


Fig. 1 The geometry of the proposed antenna

III. PARAMETRIC STUDY

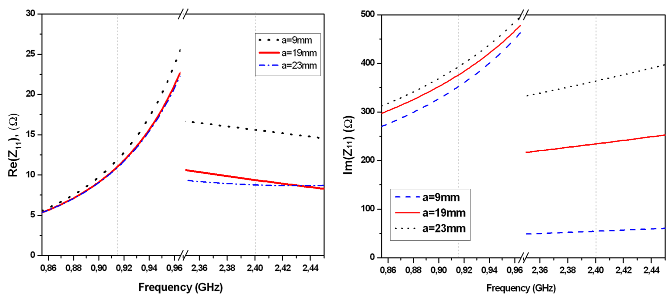
The impedance matching between the antenna and the chip plays a crucial role in passive RFID tag design. The matching condition directly affects the maximum distance at which a RFID reader can detect the backscattered signal from tag. To ensure the complex conjugate matching, an H-shape slot is used. The length "*a*" and width "*b*" of the designed structure are the key geometric parameters to control it.

A parametric study of RFID antenna on the main parameters of the patch radiator has been optimized. Simulations are performed using commercially available packages such as Designer from Ansoft.

A. The Effect of the Rectangular Slot Length

Firstly, we vary the length "*a*" to study the variance of the input impedance, the others parameters were fixed at *b*=8mm, *s*=12mm, *t*=12mm and *r*=8mm.

As shown in Fig.2a and 2b, the impedance characteristics as function of frequency for the RFID antenna was simulated for different length (*a*=9, 19, and 23mm). It is noted that the real impedance doesn't change greatly at 915MHz and fluctuates around 10Ω, but at 2.4GHz it decreases slowly from 17Ω to 8Ω as "*a*" increases, while the imaginary part gradually reduces from 390 to 350Ω at 915MHz and from 364Ω to 54Ω at 2.4GHz.



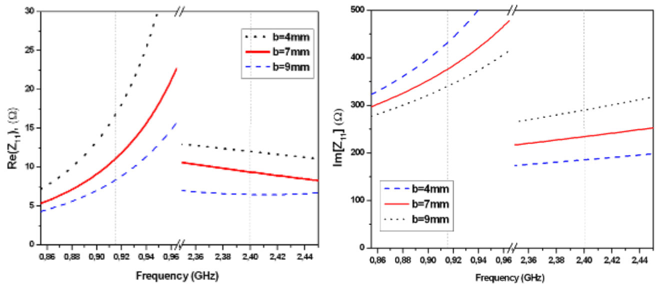
(a) Real part *(b) Imaginary part*

Fig. 2 The effect of the rectangular slot length

For the proposed antenna, it can be noted that this parameter influences the reactance of the input impedance of the tag antenna more strongly than the resistance, for both bands.

B. The Effect of the Rectangular Slot Width

The rectangular slot width "b" is varied to obtain optimum reactance and resistance matching. As shown in Fig. 3, the real and the imaginary parts as a function of frequency were simulated for different width of "*b*" (*b* =4, 7, and 9mm). The others design parameters are *a*=19mm, *s*=12mm, *t*=12mm and *r*=8mm. It is shown that the impedance of the antenna varies remarkably with the variation of the length *b*.

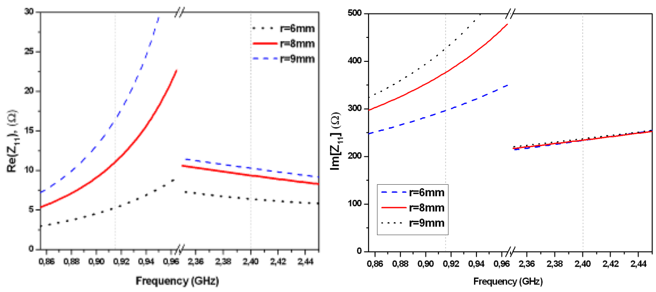


(a) Real part *(b) Imaginary part*

Fig. 3 The effect of the rectangular slot width

C. The Effect of the Parameter "r"

The "*r*" parameter is the distance between de two slots H-shape and the T-shape. The parameter *r* is varying from 6mm to 9mm. Also it is seen that the input impedance is sensitive to the variation of the parameter *r*. Fig.4a and 4b illustrate the real part and the imaginary part respectively of the input impedance. We can notice that the real impedance is more infected by this parameter.

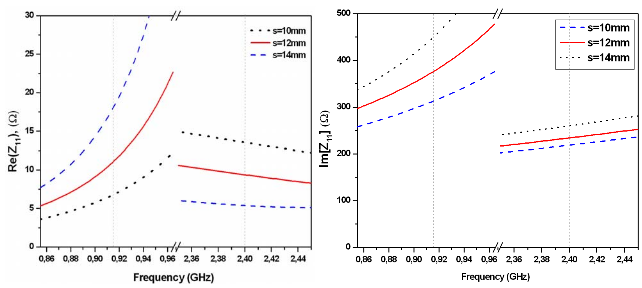


(a) Real part *(b) Imaginary part*

Fig. 4 The effect of the parameter *r*

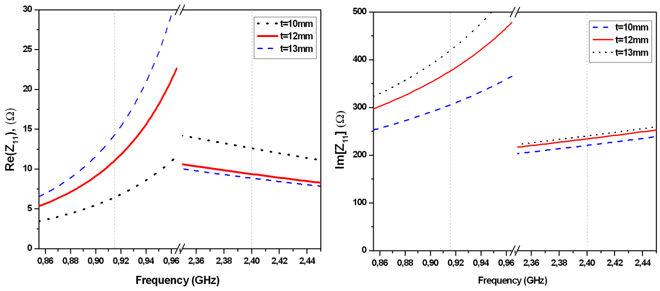
D. The Effect of T-shape Slot Dimensions

Other parameters were investigated which are the length "*s*" and the width "*t*" of the T-shape slot. As we can see in Fig.5 and Fig.6, the input antenna is also sensitive at these two parameters.



(a) Real part *(b) Imaginary part*

Fig. 5 The effect of the T-slot length



(a) Real part *(b) Imaginary part*

Fig. 6 The effect of the T-slot width

For the proposed tag antenna, the combination of all these geometric parameters allows the conjugate impedance matching to a large variety of microchips which present a conjugate input impedance ($5<R_{chip}<18\Omega$) and ($295<-X_{chip}<446\Omega$) at 915MHz; ($6<R_{chip}<17\Omega$) and ($54<-X_{chip}<364\Omega$) at 2.4 GHz.

IV. EXPERIMENTAL RESULTS

The prototype of the proposed RFID dipole antenna with the optimal geometrical parameters was fabricated. It is carefully fabricated using printed circuit technology, on FR4 substrate (ε_r=4.32, h=1.52mm and loss tangent 0.017), to ensure accuracy.

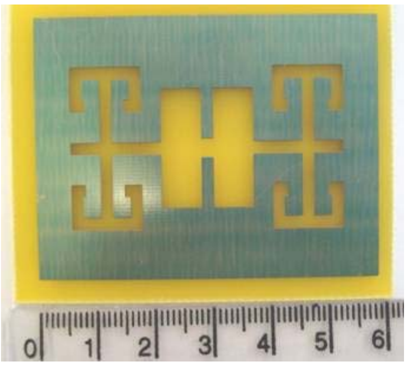


Fig.7 Photo of the realised antenna.

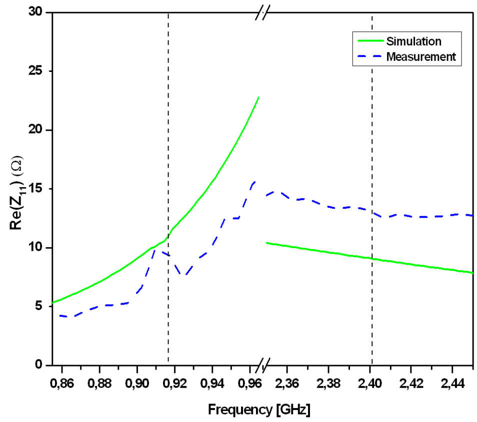
The slot antenna is optimized to be matched with a commercial tag, which has input impedance of (10-j350) Ω at 915MHz and (10-j230) at 2.4GHz. The measurement of the return loss and the input impedance of the antenna were performed using an Agilent 8719ES Vector Network Analyser (VNA).

Since the geometry of the tag antenna is symmetrical and the simulations are performed using symmetrical boundary, the measurement setup is able to use the mirror method demonstrated in [7] to achieve the test.

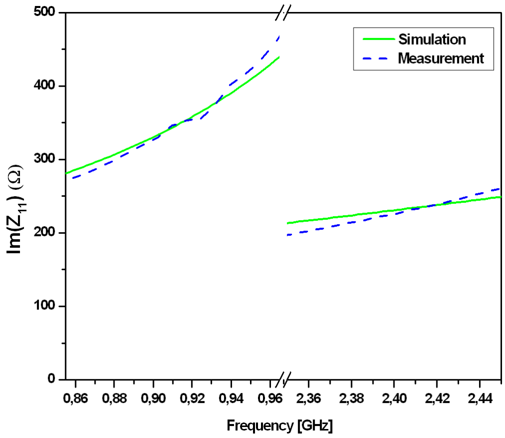
A. Impedance Matching

The measured and simulated antenna's input impedance are shown in fig.8a and 8b. It is noticed, that the measured input impedance is roughly 9+j350 (Ω) at 915MHz and 14+j228(Ω) at 2.4GHz.

Good agreement between the simulation and measurement results is noted, with a little discrepancy for the real part at 2.4GHz.



(a) Real part



(b) Imaginary part

Fig.8 Measured and simulated input impedance.

B. Power Reflexion Coefficient

The Kurokawa's method for calculating the power reflection coefficient is adapted to deal with the complex impedance of the tag antenna and the chip. This method describes a concept of power waves travelling back and forth between the tag antenna and the chip by introducing the following definitions for defining the return loss [8]:

$$\text{Retun Loss(dB)} = 20\text{Log}\left(\left|\frac{Z_{ant} - Z_c^*}{Z_{ant} + Z_c}\right|\right) \quad (1)$$

Z_{ant} is related to the antenna impedance and Z_c is the chip impedance.

The measured and simulated power reflection coefficient is shown in fig.9. The dual band is confirmed by measurement, and an acceptable agreement between measurements and simulation is observed. The measured -10dB bandwidth covers two resonance modes: about 2% on the first mode for UHF band and 2.5% on the second mode for microwave band.

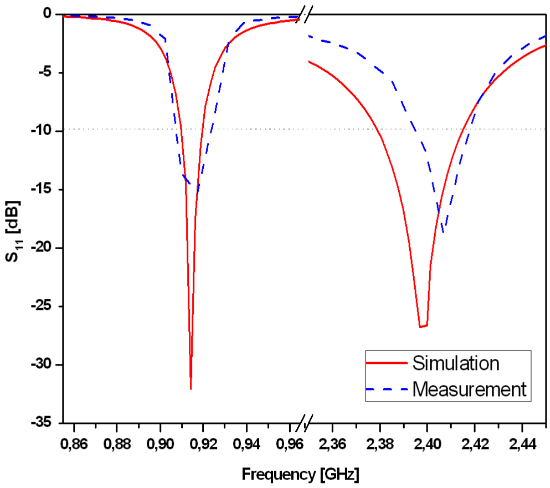
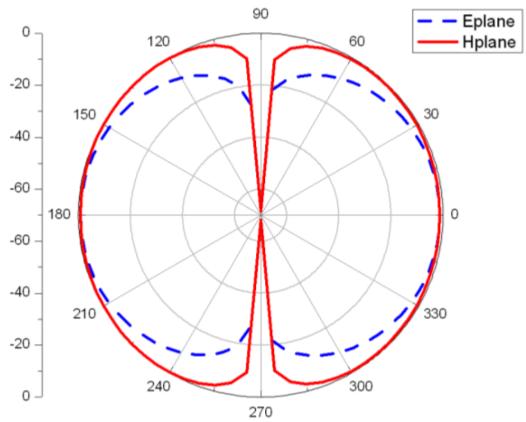


Fig.9 Measured and simulated return loss.

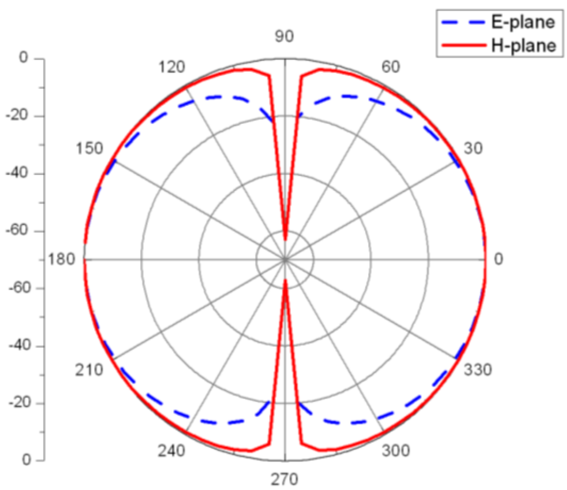


(b) @ 2.4GHz

Fig.10 : Simulated radiation pattern.

C. Radiation Pattern

The simulated antenna's radiation patterns (E&H plane), at 9.15MHz and 2.4GHz, are shown in Fig.10a. and Fig.10b The radiation patterns are omni-directional which is required in RFID tags antennas. The simulated gain of the antenna is about 1.1dBi at 9.15MHz and 1.25 dBi at 2.4 GHz.



(a) @ 9.15 MHz

V. CONCLUSIONS

A novel dual band RFID antenna has been proposed and experimentally demonstrated in this paper. The antenna has been designed for UHF (915MHz) and microwaves (2.4GHz) bands with an overall size of 57mm×42mm. The dependence of the input impedance on the main parameters has been investigated. The antenna impedance has been directly conjugate matched with the essentially complex impedance of the electronic chip. The simulated and measured results demonstrate good agreement and omnidirectional radiation pattern. The advantages of the proposed antenna include small size, low cost, easy fabrication and may find future applications in a wide variety of occasions.

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