Metal Mountable Microstrip Patch UHF RFID Tag Antenna

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***Abstract*—This paper relates the development of a simple metal mountable RFID tag designed for ETSI band. One important aspect given by this design is using a simplistic structure that can be adjusted for different type of IC chip impedances that exists on the market. The antenna is simulated and measured and the obtained results reveals that the tag can be compared with other prototypes, achieving good performance when is attached to a metallic surface. Using an 8dBi antenna gain for the reader and an output power of 30dBm, is obtained a maximum reading distance of 4.8m when is attached to a metallic surface and 3.1m in free space.**

I. Introduction

In the last years, RFID systems have captured a significant attention in the wireless identification field, being used in many applications and in special for supply chains and logistics where the traceability and identification of objects is needed.

The high speed communication, non line of sight (NLOS), large storage capacity, high identification rate of tagged objects and low price of a tag are a few of the advantages that make RFID systems being used on a large scale.

The RFID systems have two main components: the reader used for interrogation and the tag (which can be passive, active or semi-passive depending on the system used) that is attached to the objects that must be identified. The tag can carry information's like identification number, product specification and sometimes the location of the tagged object [1]. The data received from the tag can be processed by a human supervisor using a PC or can be stored for later processing.

Depending on the operating frequency and the communication protocols, RFID systems can be categorized into four groups: low frequency (LF), high frequency (HF), ultra high frequency (UHF) and microwave (MW). First two groups, LF and HF respectively, communicate using near field and inductive coupling. The reading range is small, up to 1 meter, depending on the output power transmitted by the reader. Also the data transfer is low, reaching up to 848 kbps because of protocol limitation [2]. The last two groups, UHF and MW respectively communicate using electromagnetic coupling and have long read ranges that can reach up to 100 meters. Since most of the existing applications needs long read range and low cost solutions, UHF systems are preferred because they can use passive tag for identification comparing with MW systems that uses only active tags.

A tag has two main parts, the IC chip and the antenna. The chip receives energy through the antenna from an incident continuous wave transmitted by the reader. Commonly used are dipole antennas do the cheap fabrication cost and for easy manufacturing [3], [4].

The objects that need to be identified can have various shapes and can contain or consists materials like plastic, paper or metal. However, using a dipole antenna for identifying metallic objects it's not possible due to the cancelation of the current induced in the antenna by the image current induced in the metallic object, according to eddy current theory [5]. This will cause changes in the resonance frequency, decreasing of gain and altering radiation pattern for the antenna.

In order to achieve the maximum energy transfer, is critical to maintain impedance matching between the IC chip and the tag antenna and to use antenna models that have high dielectric substrate materials. In recent years they were developed different type of antennas using high-dielectric substrate materials [6-8], but the simplest one remains the microstrip patch antennas.

In this paper is designed and prototyped an antenna model used for UHF RFID tags in ETSI band. The proposed tag antenna is thin, have a simple design that doesn't use shorting pins. The read range and the antenna gain values reveal the performance of the proposed model and is acceptable taking into account the simplicity of the model.

II. Design and Characteristics of the Proposed Antenna Model

The antenna model for the UHF RFID tag that can be metal mountable is depicted in Fig. 1.

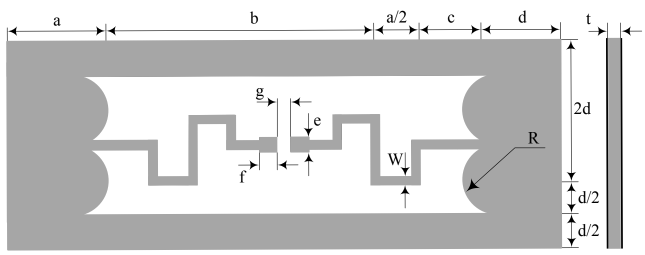

Figure 1. Physical dimension of the antenna

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The IC chip used is Alien Higgs-3 from Alien Technology, having -20dBm power sensitivity and a chip impedance X_{chip}=(16-j190)Ω at 868MHz [9]. In order to achieve the impedance matching, the antenna is tuned so the final impedance can match with the IC chip impedance.

The final dimensions are related in Table 1. The main parts of this antenna are: radiating path, microstrip lines for feeding the IC chip and a ground plane. The microstrip feed lines are meandered and symmetrically placed from the center of the antenna to the edges, being connected to the radiating path of the antenna.

TABLE I. DIMENSIONS OF THE ANTENNA

Antenna parameter	Dimensions [mm]
a	14
b	39.2
c	9.8
d	10
e	2
f	2.5
g	2
t	1.52
W	1
R	10

In Fig. 2 can be seen the prototyped model of the UHF RFID tag. This tag antenna is fabricated on a double side FR4 substrate having a dielectric constant of 4.4, a loss tangent of 0.02. The copper foil that covers the dielectric material has a thickness of 35µm.

Figure 2. Prototype of the UHF RFID tag

III. EXPERIMENTAL RESULTS AND DISCUSSION

To obtain an impedance matching, the antenna impedance must be equal to the conjugate value of the IC chip impedance, in this case X_{ant}=(16+j190)Ω. Thus, the antenna is simulated using a full wave electromagnetic simulator based on finite element method and is fine tuned to reach the desired impedance.

The circles from the radiating path are used for changing the values of the antenna reactance. When the radius of the circles increases, the radiating path of the antenna is also increased, affecting the reactance of the antenna. However, the resistance value allows small degradation and can be neglected this time. Several values for circles radius are chosen and the results are depicted in Fig. 3.

For giving an adequate resistance and match the antenna impedance, the meandered feed lines are modified in length and width. This time the reactance can be neglected because having small changes in value. Several values are chosen, in width changing, and the obtained results are depicted in Fig. 4.

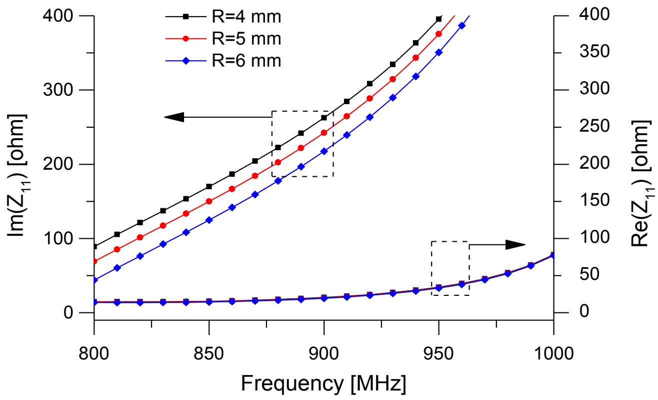


Figure 3. Tuning the reactance of the antenna

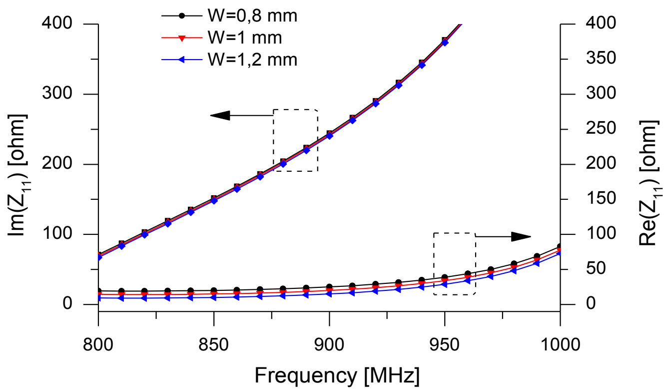


Figure 4. Tuning the resistance of the antenna

There is no standard IC chip on the market, every IC having different impedance [10], [11]. Thus, it's impossible to design and antenna that can match all of them. This antenna can be easily tuned for any type of RFID chip that exists, offering the same good performances.

In order to verify the obtained results from the simulation, the antenna was prototyped (Fig. 2) and measured using a vector network analyzer (Agilent VNA N9912A).

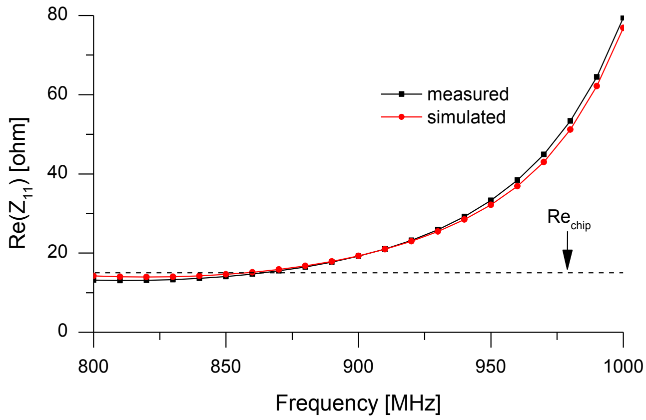


Figure 5. Measured values for the antenna resistance

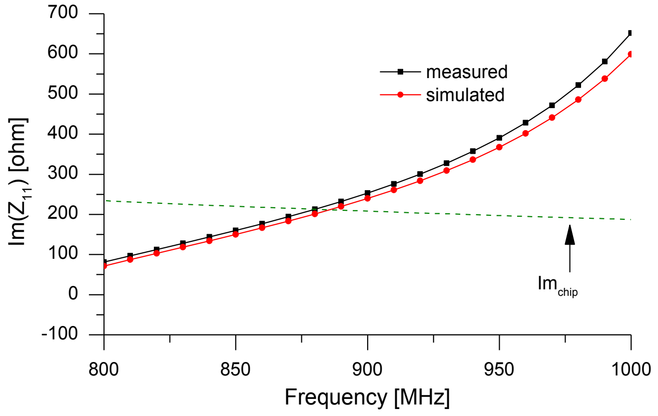


Figure 6. Measured values for the antenna reactance

In Fig. 5 and Fig. 6 respectively, are depicted the values for the antenna impedance. The measured values prove that a good impedance matching is achieved for the prototyped antenna.

To see the resonance frequency of the antenna we need to take into account the power reflection coefficient. The simulated values compared with the measured ones are plotted in Fig. 7.

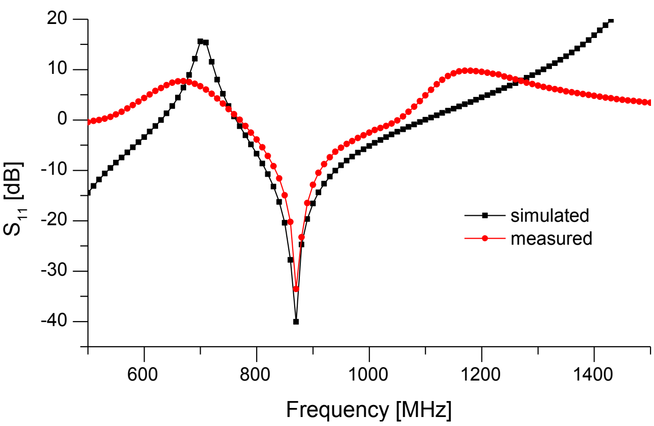


Figure 7. Power reflection coefficient of the antenna

At 868 MHz (RFID ETSI central frequency band) for this antenna is obtained -40dB and -33dB, for the simulated value and for the measured one, respectively. These values are obtained when the antenna is attached to a metallic plate made of galvanized steel with $200mm^2$ and 0.5mm thickness. A simulation scenario with a metallic plate can be observed in Fig. 8.

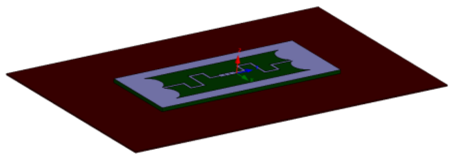


Figure 8. Antenna simulation with a metallic plate

Fig. 9 reveals the current density on the conducting surface, generated due to the metal mountable tag antenna. It can be seen that the highest amplitude is concentrated around the feeding lines. Using 1.52mm FR4 as a dielectric substrate, this material helps keeping isolation between the antenna and the metallic plate beneath it and with that will reduce the cancelation of the current in the antenna.

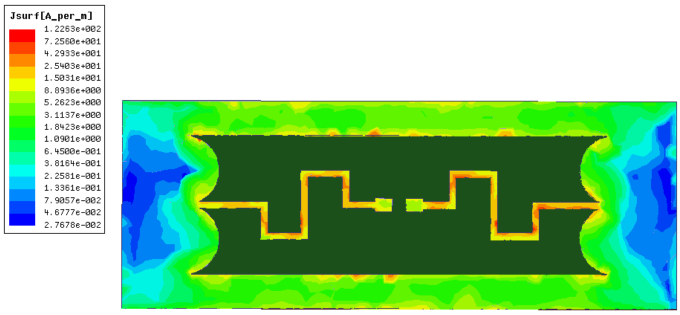
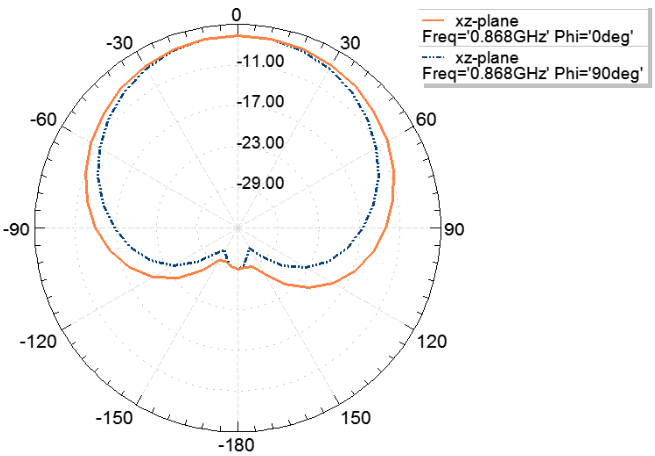
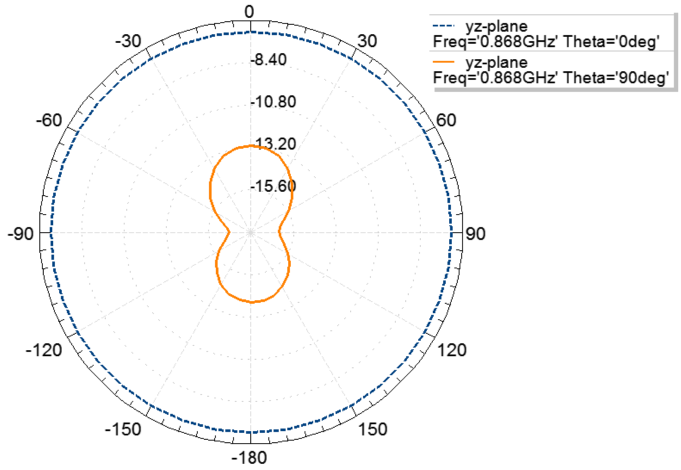


Figure 9. Amplitude of the surface current density

2D radiation pattern for xz-plane and yz-plane of the antenna are plotted in Fig. 10 (a) and Fig. 10 (b), respectively.



a) E-plane



b) H-plane

Figure 10. 2D radiation pattern

The radiation pattern of the tag is omnidirectional in yz-plane with a maximum peak of -6.65dB. In xz-plane because of the metallic plate beneath the antenna, the radiation pattern becomes more directional. However, the maximum peak remains the same like in yz-plane.

3D radiation pattern (Fig. 11 and Fig. 12) reveals that the gain decreases when the antenna is not metal mounted. This is due the impedance mismatch that occurs. The antenna is designed for working specially attached by metallic objects, giving maximum performances.

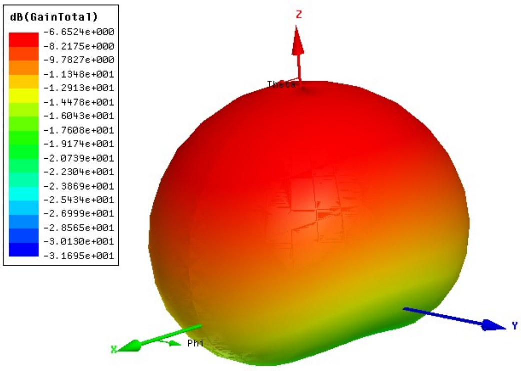


Figure 11. 3D radiation pattern with metal plate

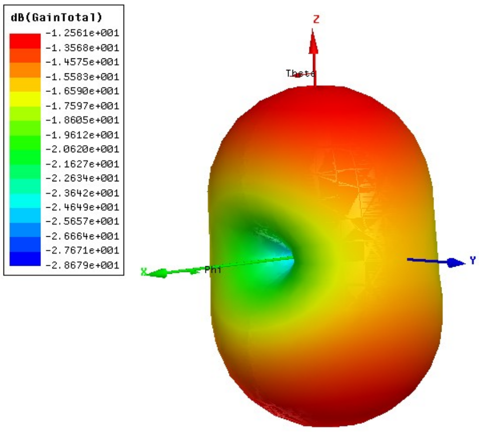


Figure 12. 3D radiation pattern without metal plate

The reading range of the tag is measured using a commercial RFID reader from Alien (ALR-9900+ EMA). The measurements were performed using a circular polarized antenna with a gain of 8dBi connected to the reader through an RF cable having 0.5dB loss. The reader output power is 30dBm. Using this RFID tag without attaching to a metallic surface is obtained a reading range of 3.1 m. Attaching this tag to a galvanized steel plate of 200mm^2 and a thickness of 0.5mm is obtained a reading distance of 4.8m.

The performances of the proposed tag made for being metal mountable can be compared with other type of tags [12]-[14].

IV. Conclusions

A novel antenna used for UHF RFID tags was implemented and tested. This new model mounted on a metal plate reveals good performances in chip impedance matching and a reading distance of about 4.8 m. The simple structure of this antenna, without using shorting pins for the ground plane, makes this new UHF RFID tag to be low cost and efficient. This model can be applied with good performances in the automotive or for the steel industries.

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