Design of Passive Ultra-High Frequency Radio-Frequency Identification Tag

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Abstract

There is a growing interest in the Radio-Frequency Identification (RFID) technology since the development of the low cost passive Ultra-High Frequency (UHF) RFID technology. This technology is giving rise to new applications as it as advantages compared to other identification technologies. This paper presents the UHF RFID chip characteristics and electrical modeling before introducing the design of the passive UHF RFID tag antennas illustrated by an example.

1. Introduction

A Radio Frequency Identification (RFID) system consists of: tags on each object to be tracked; a reader that requests/receives information from the tags; and a database that gathers the information to be processed. RFID systems involve frequencies ranging from 125 KHz to 2.45GHz. Most RFID system works at High Frequency (HF: 13.56MHz) and Ultra-High Frequency (UHF: 860-960MHz). UHF tags have a higher data rate and read range than HF tags. Before 2000, RFID tags were mostly HF and used for ticketing, payment, and item level identification. Since 2000, the UHF RFID is growing rapidly with the definition of the UHF ISO standard EPC generation 2. It is mainly used for tagging pallet and cases for transportation, shipping, distribution and tracking.

This paper introduces the design of passive UHF RFID tags, i.e. ones that don't possess any kind of internal energy source. A passive UHF RFID tag consists of an antenna and a microchip containing the Identification Data (ID). It is activated and powered by the electromagnetic waves radiated or coupled by the reader. It responds via the modulation of its backscattering aperture. A detailed description of the physical concept can be found in [1].

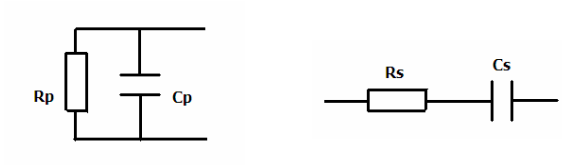
This paper presents the electrical model and input impedance measurement of a passive UHF RFID chip. The design of UHF RFID antenna is then introduced and illustrated with an example.

2. Electrical Equivalent Model of Passive UHF RFID Chip

The RFID chip mounted on the tag antenna should be activated with low power at a maximum range. To improve the power transfer to the chip, the antenna input impedance Za has to be the complex conjugate of the chip impedance Zc. Each chip exhibits different complex input impedance depending on its technology, design, package and mounting. For this reason, the modeling and measurement of the chip input impedance is crucial. This particularity makes each antenna design to be chip-specific.

2.1 Electrical Equivalent Model

RFID chip input impedances are complex values. Their real part can vary from a few ohms to a few hundred ohms. Their imaginary part are negative due to the capacitive effect of the chip power rectifier circuits converting the coupled electromagnetic power to the DC power needed to supply the chip. The electrical equivalent model of the input impedance can be modeled either by a series or parallel circuit composed of a resistance and a capacitance (Fig. 1).It should be noticed that this input impedance is varying with the input power mainly because of a shunt circuit protecting from overvoltage. The overall RFID system as to be optimized for the higher range determined by the lowest permitted power. Therefore the antenna has to be designed considering the input impedance of the chip at low input power.



(a) (b)

Fig. 1. Equivalent electrical circuits of UHF RFID chip input impedances. (a) parallel circuit, (b) series circuit.

2.2 Input Impedance Measurement of Passive UHF RFID Chip

RFID chips exist in many package formats. The EPCglobal Class 1, Generation 2 standard chip considered in this measurement is mounted on a strap. It is fixed to the antenna through a Pressure Sensitive Adhesive (PSA). The presence of the strap and the PSA change the input impedance. The chip impedance was measured using the method proposed in [2]. Fig. 2 shows a picture of the test board that was designed on FR4 substrate. The chip input impedance was measured with a HP8720D Vectorial Network Analyser (VNA) using a user-defined calibration kit consisting of the three loads shown on Fig. 3: an open circuit, a short circuit and a 50 Ω load. Using this setting an average value of Zc = 28 - j148 Ω at 915 MHz for the chip on strap impedance was measured in contrast with the value of Zc = 20 - j255 Ω specified for the chip without the strap. The series equivalent element circuits are Rs = 28 Ω and Cs = 1.175 pF. Fig. 4 shows a plot of the chip input impedance (Zc) measurement and of its equivalent series circuit ($Zceq$) over frequency.

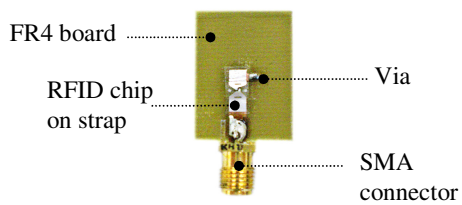
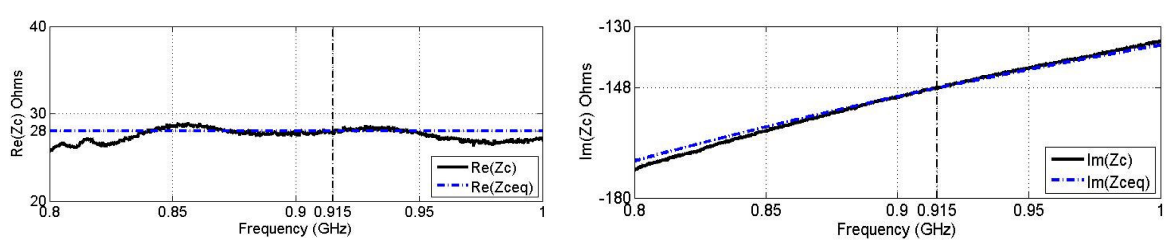


Fig. 2. The test board used for the input impedance measurement of the RFID chip.

(a) (b) (c)

Fig. 3. The boards used for the VNA calibration. (a) open circuit, (b) short circuit, (c) 50 Ω load.



(a) (b)

Fig. 4. Plot of the measured chip input impedance (Zc) and of its equivalent circuit ($Zceq$) over frequency. (a) Re(Zc) and Re($Zceq$), (b) Im(Zc) and Im($Zceq$).

3. UHF RFID Antenna Design

UHF RFID tag antenna has different functionalities: recover and transfer power to the chip, enable data transfer in the forward link and modulate the reflected EM-field through the backscatter technique to transfer data in the return link. Several parameters should be first defined: size/shape, frequency, impedance and bandwidth. Then the material properties as the substrate permittivity and dielectric losses [3], the background properties (and tag placement), and the conductor conductivity [3] have to be determined. An RFID antenna has many parameters making its development very complex and time consuming. Runs of 3D EM software and measurement are performed to obtain a good design. During the design, an engineer is going to pay attention and trying to improve the radiation pattern, efficiency and radar cross section of the tag antenna. The measurement is necessary since the simulation doesn't allow taking into account the non linear properties of the RFID chip, and impedance variation due to the chip attachment.

The cost issues on the design are going to be discussed before introducing an example of a passive UHF RFID tag.

3.1 Low Cost Design

Etched copper and aluminum antenna are the most common since the manufacturing process derive from the technology employed for electronics. But UHF RFID tag manufacturers are looking for less expensive solutions and put a lot of efforts to be able to respond to the increasing demand for high volume and cheap RFID label. To respond to this demand, fast and low cost manufacturing process involving printing process has been developed: including screen, flexography and gravure printing. An overview of the RFID label manufacturing is presented in [4]. To reduce the cost, low cost substrates such as PET or paper compatible with those manufacturing process are employed. Narrow and small sized antenna designs are preferred since they decrease the cost per tag as they diminish the amount of material per antenna and increase the production rate.

3.2 Example of a Passive UHF RFID Design

Is this part the design of a UHF RFID tag dipole antenna is introduced. It was simulated on the CST Microwave Studio commercial software on a 0.8 mm thick FR4 substrate for conveniences in its prototyping. The antenna geometry is illustrated on Fig. 5. Its design parameters are: L_{sub} = 130 mm, W_{sub} = 30 mm, L_d = 57 mm, W_d = 3 mm, W_{strap} = 3 mm, L_{short} = 17 mm, R_{short} = 8.8 mm, W_{short} = 1.1 mm.

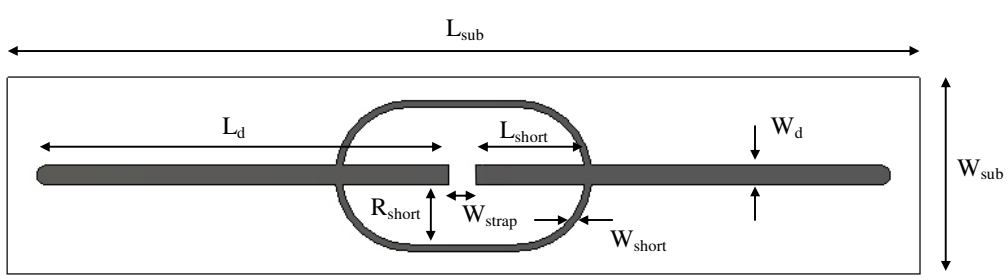


Fig. 5. Geometry of the reported UHF RFID tag dipole antenna.

The tag, illustrated on Fig. 6, is composed of the dipole antenna and the chip mounted at its center. The antenna is matched through the uses of two shorts performing like two parallel inductances compensating the capacitive property of the RFID chip. This design is simple. The real part of the feeding port is mainly depending on the dipole length while the imaginary part is mostly depending on the shorts length.

Fig. 7 (a) shows the E plane and H plane radiation pattern of the antenna. Its radiation characteristics are very similar to the one of a dipole. Its gain is G = 1.9 dBi.

The obtained reflection coefficient *S11* is plotted on Fig. 7 (b) and shows a good matching in between the dipole and chip impedance. The obtained 10 dB bandwidth is about 26 MHz and almost covers the FCC frequency band (902 – 928 MHz).

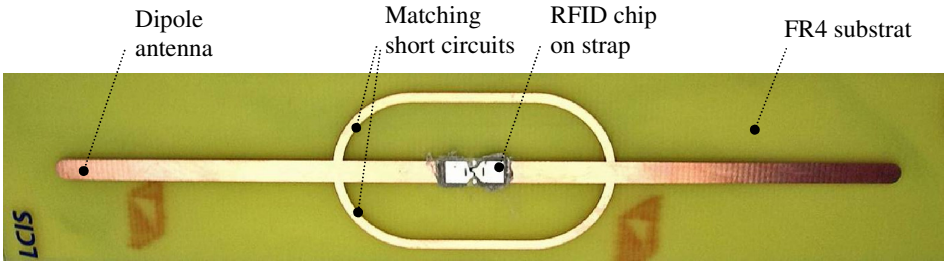


Fig. 6. The fabricated copper etched RFID Tag.

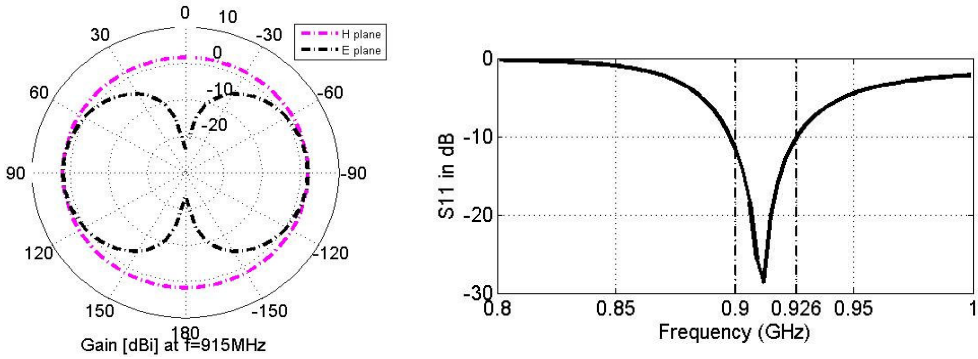


Fig. 7. Simulation results. (a) H plane and E plane radiation pattern, (b) Reflection coefficient *S11*.

4. Conclusion and Perspective

This paper presented the RFID chip impedance characteristics, measurement and electrical modeling before introducing the design of passive UHF RFID tag antennas illustrated by an example of a dipole antenna. The research team is presently working on the design, characterization and measurement of low cost tags.

5. References

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