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Designing of UHF- Radio Frequency Identification (RFID) Antenna

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Abstract: ***Radio frequency identification (RFID) as a rapid developing automatic wireless data collection technology, set interest for industrials and government applications. The demand on the automated supply chain and logistics has been pervasive, aiming to replace the tedious bar-code labeling, and has driven an increasing number of research activities on the RFID as alternative solution. Regardless of the type, all RFID tags have two main components: an antenna which transmits and receives data and an integrated circuit (IC) called transponder that handles the data processing, data storing and signal modulating. This paper gives an insight look on RFID technology, concept theory for passive RFID antenna, impedance matching, and antenna size reduction techniques. The designing and simulation for passive UHF-RFID antenna is presented.***

Keywords: Antenna, Radio frequency identification (RFID), Tag, Impedance matching.

1. Introduction

An RFID system consists of readers and tags, the tags include an antenna and a microchip transmitter with internal memory. A typical system has a few readers either stationary or mobile and many tags which are attached to the objects. A reader communicates with tags in its wireless range and collects information about objects to which tags are attached. RFID technology has brought many advantages over the existing barcode technology [1], it can be embedded in an item rather than the physical exposer requirement of barcodes and can be detected using radio frequency (RF) signal. Key volume applications for RFID technology have been in market such us access control ,sensors and metering applications, payment system, communication and transportation, parcel and document tracking, distribution logistics, automotive systems, livestock/pet tracking, and hospitals/pharmaceutical applications [2].

The RFID technology consists of several frequency bands; Low frequency (125-134 kHz), high-frequency (13.56 MHz). Ultra-high-frequency (860-860 MHz) and microwave (2.4 GHz and 5.8 GHz). Ultra-high-frequency and microwave systems involve electromagnetic interaction among true antennas and permit longer communication links, and they are the emerging technology [3]. The paper provides remarks on the testing methodology of tag antennas' input impedance, gain, pattern and reading distance. At the end conclusions will be presented.

2. Concept Theory For Passive RFID Antenna Design

The passive RFID don't have their own source of power and therefore the tag reader is responsible for powering the communication with the tag. Power can be transferred in two different ways. The first one is magnetic induction method and second is electromagnetic wave transfer method by using the EM

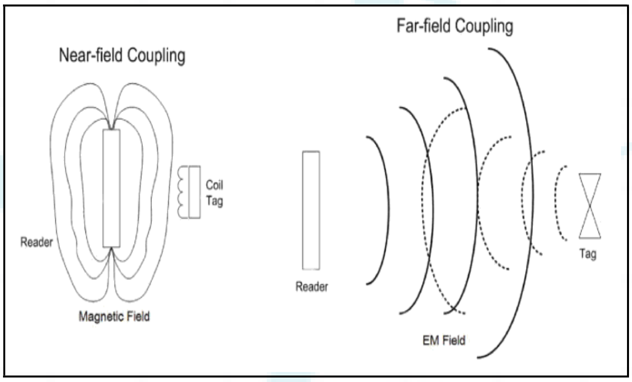

Figure 1: Near-field and far-field RFID coupling mechanism

The received electromagnetic energy activates the chip through the antenna and the chip provides the stored information to the antenna and sends the data conveyed in the RF energy back to the reader. The interaction between the reader and the tag can be interpreted as what is made in the radar system [1]. The only difference between the radar and RFID systems is that the RFID system concerns the impedance matching.

Using Friis transmission equation [4] and assuming the impedance and polarization matched between the reader and the tag, we derive the formulae on the power received by the chip in the tag and the power the reader will get as the re-radiation from the tag to determine the values of the antenna gains for the reader and the tag and input power at the beginning of the RFID system design.

$$P_c = \frac{P_{in} G_{re} G_{ta} \lambda^2}{(4\pi R)^2} \quad (1)$$

$$P_{rec} = \frac{P_{in} G_{re}^2 G_{ta}^2 \lambda^4}{(4\pi R)^4} \quad (2)$$

Where;

P_c – Power received by chip in the tag
P_{rec} – Power received by the reader (via re-radiation)
G_{re} – gain of the reader
G_{ta} – gain of the tag

If mismatch happens to the impedance and polarization, the equations are modified with the factors p (polarization mismatch factor) and Γ_{tag} (reflection coefficient from the tag).

$$P_c = (1 - |\Gamma_{ta}|^2)p\frac{P_{in}G_{re}G_{ta}\lambda^2}{(4\pi R)^2} \quad (3)$$

$$P_{rec} = \frac{pP_{in}G_{re}^2G_{ta}^4\lambda^4}{(4\pi R)^4} \quad (4)$$

3. Impedance Matching

The issue of impedance matching condition has been addressed very essential regarding the quality of the RFID system with the power received by the tag and reader. Figure 2 shows the equivalent lumped circuit of RFID tag where $Z_c = R_c + jX_c$ is complex chip impedance and $Z_a = R_a + jX_a$ is a complex antenna impedance. The voltage source represent an open circuit RF voltage developed on the terminals of the receiving antenna, both Z_a and Z_c are frequency independent, Z_c may vary with the power absorbed by the chip. The antenna is usually matched to the chip at the minimum threshold power level necessary for chip to respond. For the reader, the impedance matching is made to remove the reflection to the antenna from the feeding circuit. Though the matching problems of the reader and the tag are treated separately, the schemes are the same.

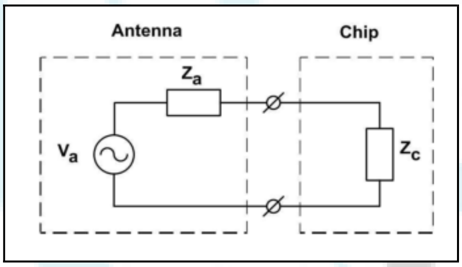

Figure 2: Equivalent lumped circuit of RFID tag

The impedance matching techniques are Shunt stub matching, Inductive loop matching and Nested slot matching. In this paper the Inductive loop matching is discussed

3.1 Inductive loop matching

The chip has the capacitive impedance which has the negative imaginary term. In order to have the best tag antenna efficiency, the input impedance of the antenna should have the inductive reactance, which cancels the capacitance reactance of the chip, when they are connected, Figure 3.

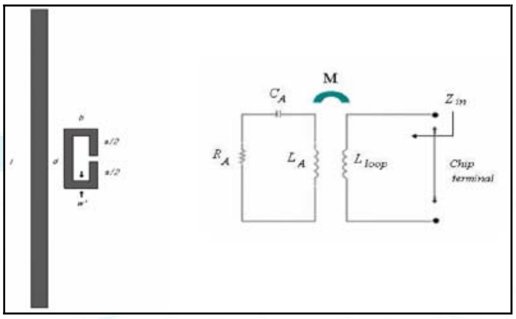

Figure 3: Inductive Loop Matching

The inductive coupling can be modelled by a transformer, and the resulting input impedance seen from the loop's terminal is;

$$Z_{in} = Z_{loop} + \frac{(2\pi fM)^2}{Z_A} \quad (5)$$

Where $Z_{loop} = 2\pi fL_{loop}$ is the loop’s input impedance. Whether or not the dipole is at resonance, the total input reactance depends only on the loop inductance, L_{loop} while the resistance is related to sole transformer mutual inductance, M

$$R_{in} = \frac{(2\pi f_0 M)^2}{R_A(f_0)} \quad (6)$$

$$X_{in}(f_0) = 2\pi f_0 L_{loop} \quad (7)$$

Under the assumption that the radiating body is infinitely long, the loop's inductance and mutual coupling, M, can he expressed in terms of the loop's size and its distance from the dipole through analytical formulas [5]. It is important to note that the mutual coupling and therefore the total input resistance are dependent on both the loop's shape and on the dipole-loop distance, while the reactance, L_{loop} is mainly affected only by the loop's aspect ratio.

4. Antenna Size Reduction Techniques

Since most UHF-RFID tags have to be attached onto small objects, the antenna's geometry needs to be miniaturized without unacceptable degradation of the radiation efficiency [6] [7]. We adapted meandering technique although inverted-F technique can be employed to obtain the same result. The antenna geometry is shown in Figure 4, meandering allowed the antenna to be compact and to provide omni-directional performance in the plane perpendicular to the axis of the meander [8] [9].

To provide a better match for the chip capacitive impedance, one meandered section was further meandered to obtain additional inductance. Lengths of meander trace and loading bar can be varied to obtain optimum reactance and resistance matching. The trimming is realized by punching holes through the antenna trace at defined locations.

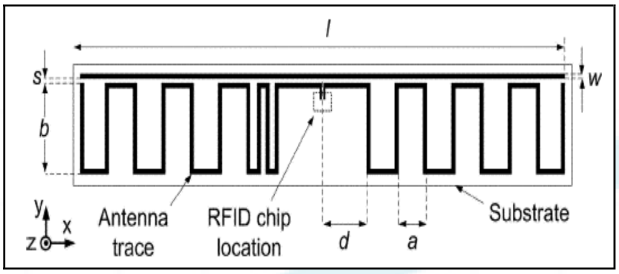

Figure 4: Meandering antenna geometry

5. Simulation Results

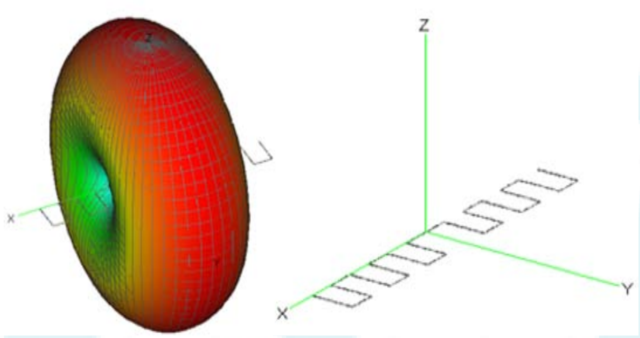

Figure 5: 3D far-field pattern

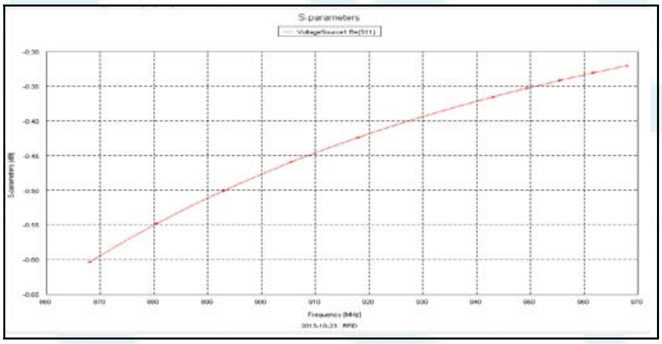

Figure 6: S11 parameter for Frequency range between 668 MHz and 968 MHz

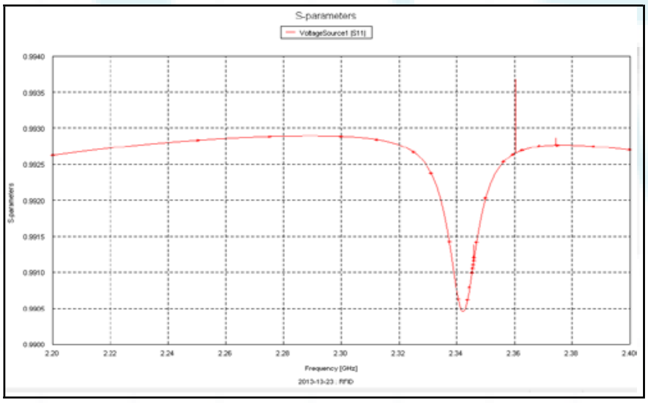

Figure 7: S11 parameter for Frequency range between 2.20 GHz and 2.40 GHz

6. Conclusion

The UHF-RFID antenna is designed for frequency range of (868 – 968) MHz and (2.20 – 2.40) GHz. For the RFID communication service, using UHF band, despite of the magnetic or electric field coupling and polarization mismatch, which reduce the power received by the tag and the reader and the resultant degradation of the RFID system's quality, the electromagnetic wave propagation is preferred to have an increased read-range and capacity of information exchange. For 2.34GHz the incident refracted power (S_{11}) is 0.9905. The simulation result shows good agreement with measurement data.

7. Acknowledgement

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