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Read Range of UHF Passive RFID

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***Abstract*—This paper is an attempt to find a general expression for the Read Range of UHF passive RFID System for any EIRP or ERP, at a given frequency. This paper presents a generalized derivation to measure the Read Range of UHF RFID. It also presents the experimental results related to Read Range in anechoic chamber with more complex architectures like metal environment, RFID tagging to metal with some isolators like thermocouple or thick rubber sheet**

***Index Terms*— ERP, RFID, UHF**

I. Introduction

Over the last few years, the potential of current technology of distant identification, which has become very attractive, is RFID Technology (Radio Frequency Identification). Though the business application of RFID Technology has already began during the Second World War where the British planes were radiated and the response of the reflected signal was awaited to know if the plane belongs to their own custody or to their enemy through identification the precedents began with a great Scientist named Tesla.

One of his dreams was to transmit sufficient energy to activate motive and in fact the first experiments of Marconi, were to receive the signal from the Receiver which is two meters away from the transmitter with the concept of magnetic field coupling i.e near field. In this paper also, the behavior of the signs of RF is used to transmit the signal at certain distance with the concept of far field.

Today in a Global market, the RFID Technology represents a great business opportunity and lots of applications like Tracking of baggage in airport, vehicle tracking, Library management system, POS, Sports field, Supply chain management, Access Control etc.

The selection of appropriate passive RFID system for a particular business application is also a good art depending upon the near field and Far field where the Read Range is proximity type for Near Field and vicinity for Far field.

For example, the RFID system for the lower Frequencies at 125 KHz and 13,56 MHz are mostly used in Metal environment and library management system where the Read Range is desired to be very less i.e hardly few inches and is due to near field.

The UHF like 868 MHz, 915 MHz and 2.4 GHz are mostly used for Supply management system where RFID System is designed with various business logic for the Gate Portal for shipping and receiving the bunch of unit carton or each item.

For this such RFID passive system, it is required of far field concept where the signal is due to the Electromagnetic waves whose Read Range is approximately 4 -5 meters for 1 - 2 Watt Power The near field technology has stable pattern and has minimum problem and is due to magnetic coupling effect instead of Electromagnetic waves like Far field.

Nevertheless for the far field the distance of reading of the small RFID passive tags that they must receive sufficient energy (50 μW) to activate the integrated circuit that contains its corresponding identification and to send the signal back to the transmitting antenna. It is the challenge and also a great opportunity for RF engineers in next few years to study and analyze more deeply about the applications of Near and Far field based RFID systems.

The different materials like skin, metal, pasteboard, plastic, liquids and even animals and Human being interference affects the performance of passive RFID system. The technologies of near field (HF or LF) have demonstrated to be very good for the majority of these materials, but the technologies of far field, seem to be more complex and performance of RFID system gradually degrades because of its absorption, refraction and reflection properties, for such materials.

A way to overcome for these phenomenons is either to use Active RFID system or Semi-passive RFID systems. These compensate the behavior of RF absorption, reflection and refraction properties with higher read range. At the same time, the active RFID device becomes more costlier than the Passive RFID systems.

The present paper, shows a generalized expression to measure the Read Range with commercial and Far Field based well-known RFID equipment, for band of 902 - 915 MHz (US based RFID system with EIRP 1W) and 865.5 - 869.5 MHz (European based and Indian based with EIRP 0.825 W).

II. Basics

The antenna radiates the radio signals to activate the tag and read and write data to it. Antennas are the conduits between the tag and the transceiver, which controls the system's data acquisition and communication. Antennas are available in a variety of shapes and sizes; they can be built into a door frame to receive tag data from persons or things passing through the door, or mounted on an interstate toll booth to monitor traffic passing by on a freeway.

Often the antenna in RFID is packaged with the transceiver and decoder to become a reader (as an interrogator), which can be configured either as a handheld or a fixed -mount device. The reader emits radio waves in ranges of anywhere from one inch to 100 feet or more, depending upon its power output and the radio frequency used. An attempt has been made to derive in this article to find general expression for the Read range of RFID System at UHF depending upon Power output and the shape and size of antenna used.

The experiments were performed for Motorola XR400 and XR 480 RFID System at RF Anechoic chamber, where a set of four High Performance RFID Antenna were placed as a Gate Portal, two antennas on either side separated with a distance of 6 – 7 meters. The Gate portal was constructed with thick wooden material taking consideration that the wooden materials never absorbed or reflected the Electromagnetic Signal.

The operational or central frequency for XR 400 is 915 MHz for the band of 902-928 MHz and is based on US standard while the central frequency for XR480 is 866.5 MHz for the band of 865 – 869 MHz. The XR480 RFID System is based on European standards but it resembles with India's allocated frequency for RFID system. In general, both the RFID system transmits the power (PT) with gain (GT) detects the RFID Tag at a maximum distance (rmax) with a gain of (GR). When an RFID Tag comes under the envelop under the electromagnetic radiation emitted by the RFID Reader and transmitting antenna with the total Power (PT), it detects the reader's activation signal with the Received Power (PREC). The Received Power for RFID Passive UHF Tag is fixed with 50 µW and gain of 2.15 dB.

It is also desired to know the Forward Link and Return Link by using the concept of Friss's Transmission Law assuming the main beams of reader antenna and tag are aligned each other, then one could easily find the Forward Link and Return Link

Forward Link

The Received power (P_{REC}) is calculated as:

$$P_{REC} = P_T \times G_T \times G_R \times \frac{\lambda^2}{(4\times\pi\times r)^2} \tag{1}$$

$$P_{REC} = EIRP \times G_R \times \frac{\lambda^2}{(4\times\pi\times r)^2} \tag{1A}$$

Here G_R = 2.15 dB = 1.64 & P_{REC} = 50 µW

a) f = 902 – 915 MHz at Centered frequency

f_o= 915MHz , EIRP = 1 W;

r_{max} **= 4.727 m**

b) f = 865.5 – 869.5 MHz, at Centered frequency

f_o= 867.5 MHz ERP = 0.5 W;

EIRP = 1.65ERP = 0.825 W;

r_{max} **= 4.529 m**

Return Link

$$P_{REC} = P_{refl} \times G_{rec} \times \frac{\lambda^2}{(4\times\pi\times r)^2} \tag{2}$$

Where $P_{ref} = S \times RCS \times \frac{\lambda^2}{(4\times\pi\times r)^2}$ &

$$S = \frac{EIRP}{4\times\pi\times r^2}$$

$$\therefore P_{REC} = EIRP \times RCS \times G_{rec} \times \frac{\lambda^2}{64\pi^3 r^4} \tag{3}$$

With Receiver Sensitivity = RCS =10^{-3} m^2 and

G_{rec} = 6 dB = 3.98;

a) For f_o= 915MHz, EIRP = 1 W;

r_{max} = 4.727 m; P_{REC} **= – 73.8 dBm**

b) For f_o= 867.5 MHz; EIRP=0.825W;

r_{max} = 4.529 m; P_{REC} **= – 63.2 dBm**

For XR400 & XR480, the Reflected Power is limited to 250nW. The signal transmission when operating at UHF RFID works on Far Field concept (EM signal)

The Read Range r_f for Forward Link is

$$r_f = k\left\{\frac{EIRP \times G_T G_R \lambda^2}{(4\pi)^2 P_{REC}}\right\}^{1/2} \tag{4}$$

And the Read Range r_r for Return Link is

$$r_r = k\left\{\frac{EIRP \times RCS \times G_{rec} \times \lambda^2}{(4\pi)^3 P_{REC}}\right\}^{1/4} \tag{5}$$

Therefore the read range for UHF (Far Field) varies. For Forward Link, the receiving power (PREC) varies inversely with squared power of read distance (r 2) while the receiving power (PREC) varies inversely with fourth power of read distance (r4). There is a factor called as k factor which effects the performance of Read Range of UHF RFID system which mainly depends upon Reflection, Refraction, Absorption (loss), environment and climatic condition, Dielectric material used in Antenna, Quality factor, Complex propagation, etc.

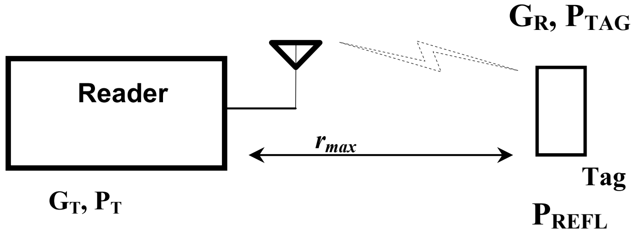

Fig: 1 A simplified RFID system

III. Conclusion

This paper reports our experiments results for RFID passive UHF system and it also explained a generalized Read Range for RFID UHF system on the basic of simple principle of Friss's Transmission theory. The comprehensive lists of experiments with more complex architectures were conducted without detailed descriptions have been experimented in anechoic chamber both in vacuum condition as well as metal and other materials environment.

The Interrogator transmitter phase noise and quality factor, known to be a big concern for the long-range UHF interrogation systems, and observed that it does not seem any serious affects of degradation of performance of RFID system in RF Anechoic chamber.

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