International Journal of the Physical Sciences Vol. 6(12), pp. 2776-2781, 18 June, 2011
Available online at http://www.academicjournals.org/IJPS
DOI: 10.5897/IJPS11.608
ISSN 1992 - 1950 ©2011 Academic Journals

Review

Effects of polarization loss factor, form factors and reader transmitting power on the range of paper and plastic UHF tags in a free and metallic environment

J. S. Mandeep[1,2] and Hilary[1]

[1]Department of Electrical, Electronic and Systems Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600UKM, Bangi, Selangor Darul Ehsan, Malaysia.
[2]Faculty of Engineering and Built Environment, Institute of Space Science, Universiti Kebangsaan Malaysia, 43600UKM, Bangi, Selangor Darul Ehsan, Malaysia.

Accepted 18 May, 2011

Passive RFID has come to dominate all facets of modern life and thereby making auto-identification a daily occurrence in our daily activities. From the complex application of nuclear waste tracking to supply chain management, RFID passive tags have come under various form factors ranging from paper to plastic tags. What determines what form factor to be used and best angle between the tag and the reader is analyzed in this paper. The objective of this paper is to determine the effects of reader transmitted power, form factors and as well as cross and linear polarization on ultra high frequency (UHF) passive tags in a free and metallic environment as seen in real life environment not a controlled environment. The settings of this experiment were based on real life environment where RFID tags are deployed. Rotor which has the capacity to change every 45° was used to position the tag in different angles to enable readings to be taken in the ranges of 0, 45, and 90, 135, 180 clockwise and same angles in anticlockwise. Results have shown "paper" tags tend to be affected less in all these factors than the plastic tags and also, it was discovered that at lower power of -2 dB, the tags read more than the maximum power of 0 dB. The maximum distance of paper tag was also noticed to read more close to 100 cm in metallic environment while in free environment, the read distance of paper tags are limited to 80 cm. In this paper, it has been able to prove the existence of read range deterioration in RFID tags when they are in direct contact with metals whereas, it increases in the presence of metals. Also, the existence of polarization loss factor (PLF) has been proved beyond any reasonable doubt.

Key words: Radiation pattern, E and H fields, cross polarization, polarization loss factor.

INTRODUCTION

Radio-frequency identification (RFID) has been gaining popularity in the recent times due to its wide application. Areas where we can find this application include the grocery shop near you, the transport system, the hospital management system and the far-away space agency. AIDC (auto Identification and data capture) which has marked the modern era of technology has its root from RFID. RFID is more suitable in the supply chain because of its non line of sight over the barcode. RFID can be read even when it soiled with dirty and oil which makes it to be deployed even in the oil and gas sector. Also they carry more information more than the normal barcode (Kwon and Lee, 2005).

RFID consists of several frequency ranges which fall under the ISM (Industrial scientific and medical) band. 125 to 123 KHz and 13.56 MHz have been reserved for "inductive" tags which operation in this range of frequency. Experience has shown that this low frequency is useful because it has longer wavelength and thereby penetrate water and metal more easily using inductive coupling rather than electromagnetic coupling associated with UHF (ultra high frequency) tags that operate in 860

*Corresponding author. E-mail: mandeep@eng.ukm.my

to 960 MHz. Microwave tag operates at 2.45 GHz (Mandeep and Hilary, 2010). It is important to point that the more the frequency of the tag increases, the lesser the tags becomes in size (Griffin et al., 2005).

PROBLEM DESCRIPTION AND RESEARCH MOTIVATION

RFID is not standalone equipment. It is normally attached to objects it purports to support. Many of the supported objects may include metal, water and these materials have adverse effects on the performance of a UHF RFID tags (Widad et al., 2008). It is a common sentence to hear about the (water, low gain and metal) problems of UHF tags. The metal problem is so severe that when you place a UHF tag wrapped in an aluminum foil, you will not detect any read range from the tag due to the reflection of the radio waves by the metal foil. Not much work has been done and published ascribing to antenna detuning (Kuo et al., 2008). This paper is dedicated to show the read range of a particular type of commercial tag in a free environment and close proximity to a metal. The motivation of this paper is presented by having a series of experiments to help to understand the limitations and opportunities for contributions in passive UHF RFID where there are opportunities for improvements in technology.

Background

This paper is focused on practical read range and radiation pattern of plastic and paper tags of a commercially available tag. Similar work has been done (Kuo et al., 2008) focusing on the general environmental effects of metal water problem of RFID but this paper is of a novel idea by drawing the radiation pattern in different power of the reader using non fixed reader and in a real life condition not a controlled environment. RFID system consists of a transponder ("tags") and interrogators (reader). An RFID tag is said to be "passive" if it has no internal power source and "active" when it is incorporated with its own power circuitry. Passive tag uses a technique known as energy harvesting to supply power to the internal circuitry, and backscatter modulation to communicate to the reader. EPC global Inc has developed the air interface, protocol, numbering convention, reader API and network lookup service all of which are well documented (Aroor and Deavours, 2007). At UHF frequencies, tags propagate by means of electromagnetic coupling, which means that readers couple with tags primarily with propagating (TEM mode) electromagnetic energy in the far field, which is how the tags are able to achieve long distances 90 and 95 cm (Aroor and Deavours, 2007). Depending on the tag enclosure, large quantities of tags are been used in the supply chain and active tags have a relatively short life, useful life or shelf life, it becomes imperative that the tags must be of low cost to encourage commercial consumption. This often leads to very simple antenna designs such as dipole meander antenna as was used in this experiment. Widths of ½ and 1 inch are most common. Antennas are commonly made using materials like copper, aluminum or silver ink, with low cost manufacturing techniques such as lab on chip and coil on chip (COA). Aluminum is not easy to work with so commercially available RFID tag antennas are normally made with copper and silver ink. Antenna is normally attached to a PET (polyethylene terephthalate) film substrate thereby making the tag flexible. The IC is prepared for attachment to the antenna by small metallic bumps to the pad and connected to the pads and connected to the antenna through a flip-chip assembly method and bond with an epoxy.

The IC can also be first bonded to a small interposer (strap) and then the interposer is then bonded to the antenna (Aroor and Deavours, 2007).

RFID antenna as a receiving device

RFID antenna is said to be a receiving device when it picks up incident wave and converts it to a voltage known as voltage standing wave ratio (VSWR). This voltage is fed into the transmission line and subsequently terminates in an absorbing load, the detector in the case of RFID tag is the RFIC. The amount of energy which will be converted to voltage absorbed by the RFIC tag will depend on the orientation of the tag and the polarization of the wave. In specifying the performance of an RFID tag, we presume that the polarization and characteristic impedance of the tag is such that maximum power is absorbed. The absorbed power can be expressed as the power on the incident on an effective absorbing area called the "receiving cross section," or "absorbed cross section" A_r of the RFID tag. If S is the power flux density in the incident wave, the absorbed power is:

$$P_r = SA_r \tag{1}$$

The receiving cross section will depend on the direction in which the plane wave is incident on the tag. We may then write:

$$A_r = Ar\ (\theta, \emptyset) \tag{2}$$

Where θ and θ are the spherical angles of the incidence of the wave.

We performed two sets of experiments with a commercial available tag with the following dimension 8.5 × 5.5 cm

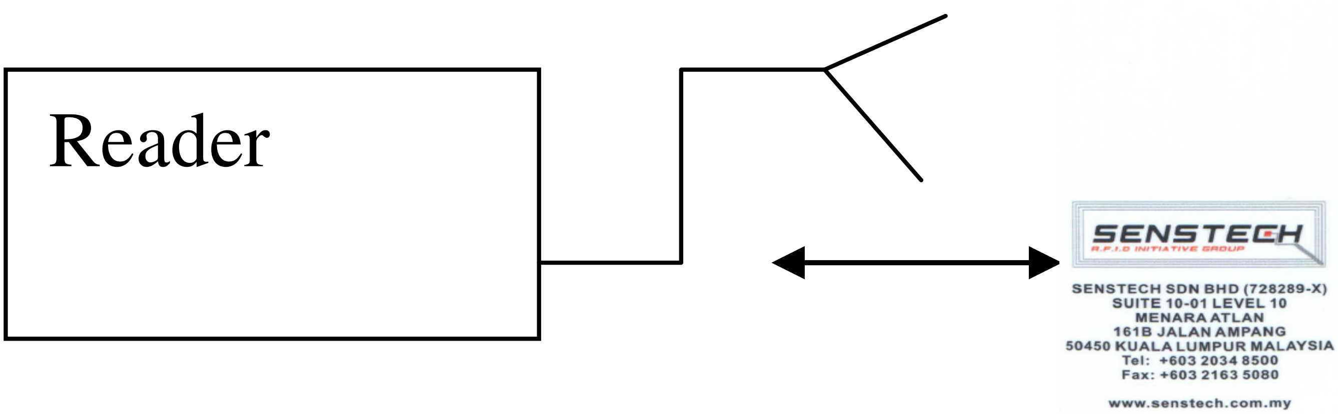

Figure 1. Forward attenuation experiment in free space.

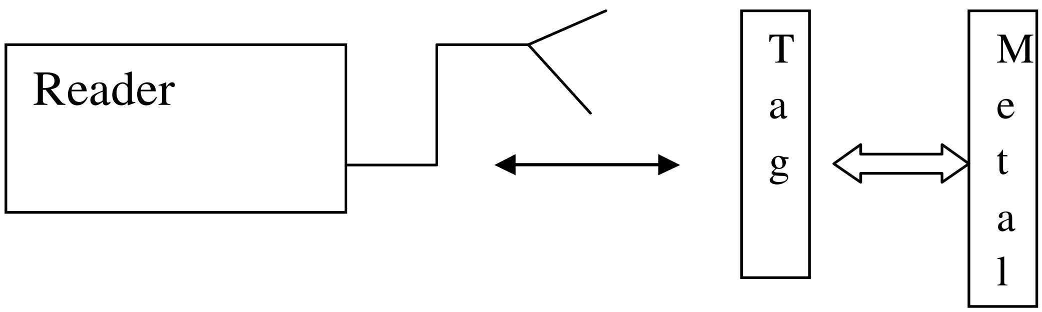

Figure 2. Forward attenuation experiment in the presence of metal.

and a handheld reader whose frequency is 900 MHz. FCC regulations in the USA and similar regulations in other regions stipulate that the maximum allowable reader output power is 1 W with a maximum antenna gain of 6 dBi, yielding a 4 W EIRP. While in Europe, the ETSI regulation specifies a maximum of approximately 3.2 W EIRP. The tags are mounted on a PVC pipe of 125 cm (Figure 2) and rotated in 45° interval until angle 360° is attained. The power of reader antenna is adjusted in intervals of 0, -2, -4 and -6 dB. The linear and cross polarization is measured in cm to determine the maximum distance at various power of the reader and the values are plotted in Figure 1.

Performance of plastic and paper tags in close proximity to a metal (choosing an end user approach)

One of the major disadvantages of UHF tags is that metal significantly degrade the performance of the tag. Setting up an experiment to define this calls for more clear definition of our goal. The term "performance" of tag here denotes the maximum distance measured in centimeters between the tag and the reader in a given environment. This quantitative measure was incorporated in the experiment by varying the output power of the reader as was done in the free environment. This simple end user is sufficient for illustrating the effects of metal in a real life supply chain environment. Some commercially available tag of the dimension of 8.5 × 5.5 cm was used in the absence of any metal material around the vicinity of the experiment. Forward attenuation technique was used as shown in Figure 2. The tag was placed on a PVC tube and hung over the rotor which rotates in every 45° until 360°. First, the plastic tag was wrapped in an aluminum foil and the reader brought close to detect the maximum distance. The reader did not dictate any RF due to the "detuning" of the tags. Secondly, we place the tags in a certain distance from the metal. In our case, we choose 10 cm because it was the least distance observable that we were able to detect the read range of the tags. The tags are placed first in linear polarization with the RFID interrogator and later cross polarization is also taken. The RFID reader is varied in steps of 0, -2, -4 and -6 dB. We see that the paper tag in the presence of metal which is placed 10 cm has a higher gain than in the free space environment. This may be due to the fact that the metal is acting like a reflector of the RF waves which make the

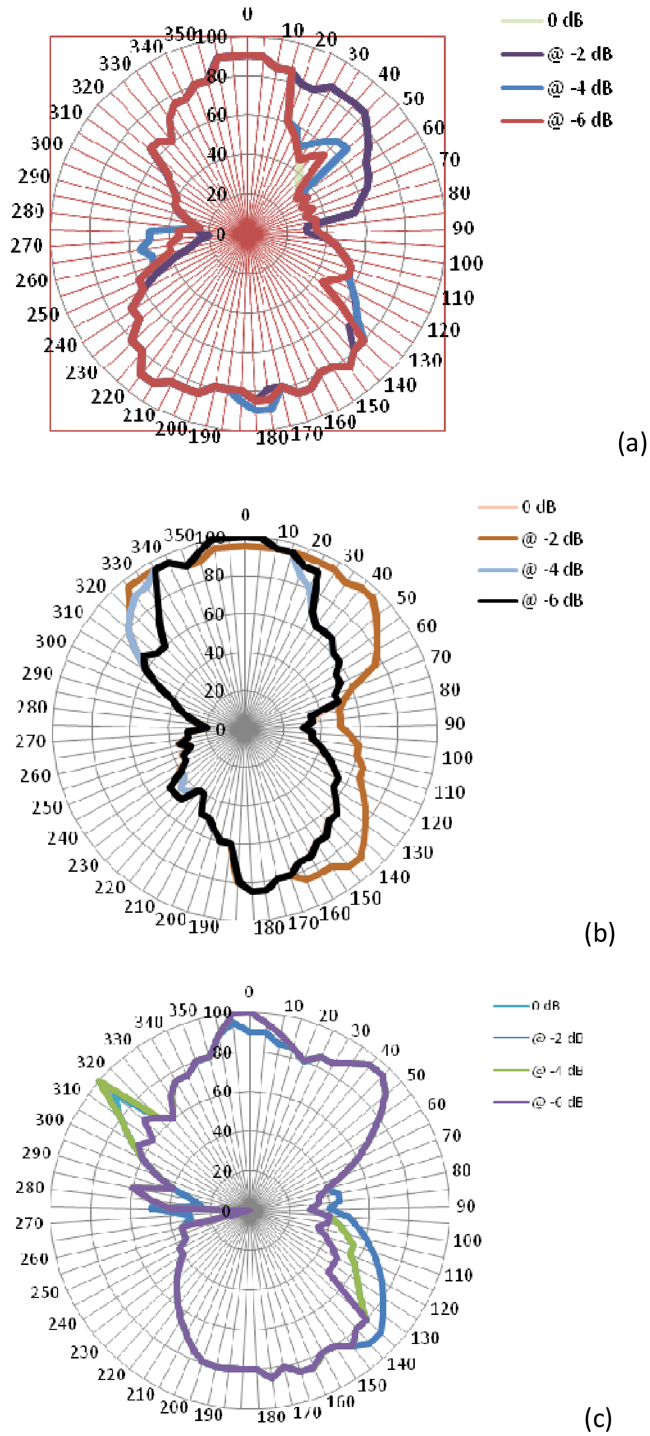

Figure 3. (a) Co-polarization radiation of paper tags in free environment. (b) Co-polarization radiation of paper tags in metallic environment and (c) Cross polarization radiation of paper tags in metallic environment.

read distance to be more. There is also conformance of the polarization loss factor (PLF). It is observed that there is maximum range in 0 and 360° and as the angle deviates more; the read range degrades in conformity.

RESULTS AND DISCUSSION

Here, the read range of passive UHF tags is plotted in the vertical direction measured in centimeter while the angle of radiation is plotted in the spherical direction measured in degrees. The various radiation pattern of various variable power of RFID are plotted and shown in Figures 3a, b and c. Radiation pattern which is a very important property of “radio” frequency components indicates the ability of the device to send and receive radio waves. In the case of passive UHF tags, the radiation patterns of both the plastic and paper tags were analyzed and there exist great difference. Analyzing Figures 3a and 4a, which measures the co-polarization radiation of paper tags in free environment and co-polarization radiation of plastic tags in free environment respectively, it became abundantly clear that the read range of paper tags increase tremendously above 80 cm and spread across the whole chart except at angles of 90 and 270°. It was observed also from all the graphs, that the maximum power of the reader which is 0 dB does not contribute more to the read distance of the tag. The most favorable power of the reader was noticed to be -2 and – 4 dB. This observation is of great importance due to the effects of many RF devices that humanity is subjected to in his everyday life which comes in the forms of mobile phones, GPRS, GPS etc. Comparing Figures 3b and 4b, which are on co-polarization radiation of paper tags in metallic environment and co-polarization radiation of plastic tags in metallic environment respectively, as expected the read range of the passive paper tags are higher than that of plastic tags. There also tends to be some measurable read distance at the angles of 90 and 180° for only the paper tags and no measurable distance at angles of 90 and 180° for plastic tags. On further cross examination of Figures 3a and 4a on one hand which measures the read range in free environment, and Figures 3b, and 4b on the other hand which measures in metallic environment. The read range in metallic environment which is when a metal is placed 10 cm from the tags tends to read higher and was observed to read close to 100 cm. This might be interpreted that the metal acts as ionosphere to help in the propagation of the radio waves from the tag to the reader. This principle can be further analyze and use in antenna propagation networks. The graphs of Figures 3c and 4c follow similar pattern as with the explanation earlier. From the graphs plotted both for the plastic and paper RFID tag antennas, it has showed that the antennas are not isotropic in nature, this shows that the antennas propagate maximally in certain direction which are not in orthogonality with the RFID reader. When the reader and the tags are aligned in the same direction, their radiation intensity, directivity and the efficiency

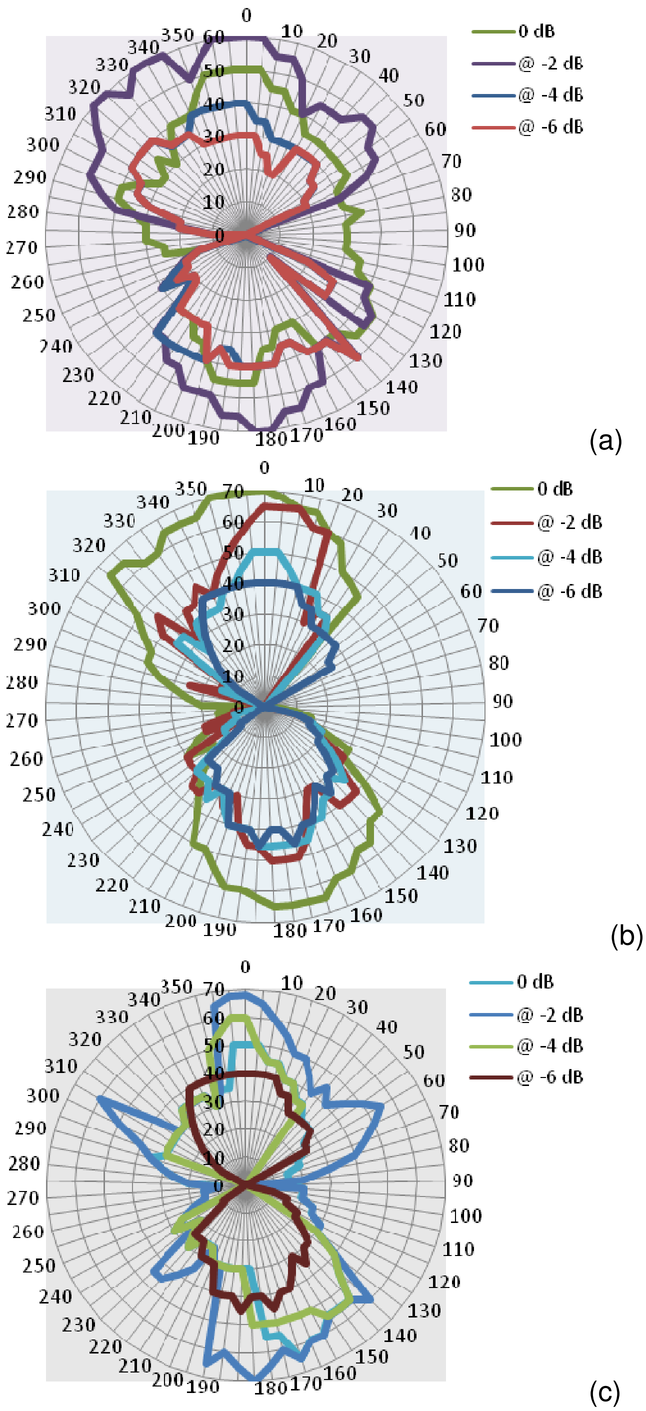

Figure 4. (a) Co-polarization radiation of plastic tags in free environment. (b) Co-polarization radiation of plastic tags in metallic environment and (c) Cross polarization radiation of plastic tags in free environment.

increases.

Polarization loss factor (PLF) which measures the polarization mismatch between the tag and the reader also decreases when the angle of rotation between the tag and the reader is aligned. From the experiments conducted, there is no much difference between the performance of paper and plastic tags except in a metallic environment when the paper tags tends to read higher than in free space. The PLF can be said to be a function of “cosine” rather than sine. Cosine functions as we all know have zero values at angles 90 and 270° are zero while that of 0 and 360° are 1. This can explain the reason while the angle of PLF moves from 0 to 90° in clockwise direction, the values depreciates and also same in anti clockwise. However, the PLF tends to be severe with thick materials than light materials. As can be observed from the paper tags, there tends to exist some measurable distance with paper tags and none for plastic tags. It can mathematically be stated that as form factor thickness increases, the ability to read at PLF decreases. In summary, for maximum distance range of the RFID components, the alignment of the tags and the reader should be taken into consideration.

CONCLUSION

The effects of polarization loss factor, reader transmitting power and “form factors” have been critically analyzed. Paper tags tend to be affected less in all these factors than the plastic tags. This shows that the read range of tags is the function of polarization loss factor and “form factors” rather than transmitting power. For RFID to attain maximum read range, the polarization mismatch has to be reduced to the barest minimum especially for plastic tags. The power of the RFID reader in a mismatch situation is important because, we have seen that the read range in mismatch metal environment is none existence only in certain angles. In conclusion, it can be stated here that the reader transmitting power should be reduced further so as to protect end-users of this equipment from excessive accumulation of radiation that normally comes with RF devices.

ACKNOWLEDGMENTS

The authors would like to thank Universiti Kebangsaan Malaysia and SENSTECH (PKT 1/2010) for supporting this work.

REFERENCES

Aroor SR, Deavours DD (2007). Evaluation of the State of Passive UHF RFID: An Experimental Approach. IEEE Syst. J., 1(2): 168-176.

Griffin JD, Durgin GD, Haldi A, Kippelen B (2005). RF Tag Antenna Performance on Various Materials Using Radio Link Budgets. IEEE Antenn. Wirel. Propag. Lett., 5: 247-250.

Kuo SK, Chen L, Lin CT (2008). An accurate method for impedance measurement of RFID tag antenna. Prog. In Electro. Res., 83: 93-106.

Kwon H, Lee B (2005). Compact slotted inverted-F RFID tag mountable on metallic objects. IEEE Electron. Lett., 10(1): 1308-1310.
Mandeep JS, Hilary KA (2010). Study Reliability of Radiated RFID Tags. Microw. RF., 10: 77-81.
Widad I, Mandeep JS, Saeed J (2008). Secure Multi-access Channel Using UW B for next generation RFID system. Microw. J., 51(9): 63-68.