Ahmad

Ahmed

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RFID TECHNOLOGY

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First Supervisor: Mr. Nick G. Riley

Second Supervisor: Dr. Kevin S. Paulson

Abstract

Radio frequency identification (RFID) is the most attractive technology that enables companies to better track assets tools and inventory. RFID technology can also be used in different applications such as air port baggage and express parcel logistics across every industry. RFID technology is seen by some scientists as the inevitable replacement for bar codes. Since it offers different advantages over bar codes as it is ability to two ways of communications, non-optical proximity communication, and the higher information capacity. RFID system mainly consists of interrogator (reader) and transponder (tag) and it is allocated in different bands of frequencies (Lower, high, ultra high and microwave bands). There are three types of RFID systems which are divided according to these bands of frequencies. RFID systems which are working in (LF and HF) band called active RFID systems, while in UHF bands are known passive UHF RFID systems and in microwave bands called semi-passive RFID systems. Passive UHF RFID system is the most popular system in RFID systems. This is due to the long read range, Lowe cost and the small size that they offer. However, this system is facing different challenges that effect it is performance. One of these critical challenges is it is difficult for UHF RFID tags to be placed on metallic surfaces. Since metallic surfaces affect the tag antenna parameters such as the impedance matching, the radiation efficiency and the radiation pattern. This led researches to carry out some studies to find out solution for this problem.

This thesis discussed the passive UHF RFID system and its propagation range as well as studied the performance of UHF RFID tags when they are placed in close proximity to metallic objects and liquids. This study involves measuring the read range of the tag when the tag is placed in different distances from metallic surface, and studies the effect of liquids on the performance of the tag as well. Experiments were carried out to achieve this study. Three types of metal with different sizes were tested and the performance was evaluated. The results have shown that distance less0.025λ the performance of the UHF tag will be significantly affected. Whereas, distances of 0.05λto 0.25λ from the metallic surface could make the UHF RFID tag performance be acceptable. Moreover, the results of examining the effects of liquids on the read range of the tag have shown that liquids have remarkable affect on the read range.

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CHAPTER 1:

INTRODUCTION:

1.1 Overview and Motivation

Radio Frequency Identification technology is one of the most attractive technologies for researchers nowadays. RFID technology is used to track objects by using tags to communicate information about the object to the readers wirelessly. (RFID) Radio Frequency Identification technology is similar to barcode , which is a digital series representation (0 or 1) and the series is designed as a number of black bars with a number of white gaps and is used to identify an object. To obtain the digital data that stored in barcode labels Optical laser scanners are used (Roberts, 2006).However, RFID technology is regarded as an improvement over bar coding due to many reasons such as: it is ability to two ways of communications, non-optical proximity communication, and very high information capacity. RFID readers can read multiple tags simultaneously. They can read tags from a long distance reach to ten meters. RFID systems use radio frequency to identify objects and microchip to store data. These stored data then are can be acquired using readers.

Radio frequency identification (RFID) enables companies to better track assets, tools and inventory. It can also be used in several applications such as air port baggage and express parcel logistics across every industry. RFID system consists of: an RFID device (tag), a tag reader with an antenna and transceiver, and a host system or connection to an enterprise system. The reader send RF signal through it is antenna, and receives RF waves that reflected from the tag. The reflected RF waves carry information about the object this information represent in a unique serial number related to each tag. RF waves can be absorbed and reflected by different materials these effects can impact the performance of tags especially in high frequencies.

There are three types of RFID system, active, passive and semi passive systems. These systems work in different bands of frequencies from low and high frequencies to ultra high frequencies and microwave bands. Active systems are self powered they have built in battery as an energy source, while Passive system field powered, these tags use the incident RF signal that transmitted by reader as an energy source. The RF energy is received by the tag's antenna AC signal, which is then rectified to form the DC voltage, which is used to power the integrated circuit. Recently, the UHF RFID systems are gaining more and more popularity in modern chains supply, this due to the long read range that they provide as well as the lower cost and the smaller size than active systems (Steven, S., (2005) .

However, the increasing implementation of the RFID technology in supply chains has faced many challenges; one of the biggest challenges for this technology is the degradation of the performance of UHF systems when tagging metallic objects or operating in environment containing metals. The tagging of objects at pallet, case, etc will most involve Metallica objects. In addition to the metallic the performance of the system is also affected by liquids when tags are attached to bottles of liquids or nearby objects that contain liquids. This has led researchers to pay attention for such problems (Lauri,S.Et al,2008)..

The aim of this project is to look at this technology and how it works in briefly. However, the main focus of this work is to study the performance of passive UHF RFID tags when they placed in vicinity of metallic surfaces and liquids. There will be some experimental work to examine theses effects, and investigate mitigation technique.

1.2. Aims and Objectives

1.2.1. Aims

It has been shown that the performance of passive UHF RFID tags is significantly affected when they placed in vicinity of metallic surfaces as well as liquids. Since both materials reduce the transmitted power by the reader towards that tag which in turn will operate the IC chip. Consequently the IC will not be able to reradiate the data information of the object to the reader.

Consequently, the aims of this work shall be to investigate the effects of metallic surfaces and liquids on the UHF RFID systems by experimental work and will look at some mitigation techniques.

1.2.2 .Objectives

- To understand the basics of RFID technology.

- To understand the mechanism and limitation of the passive UHF RFID system.

- To study the effects of the metal and fluid on the read range of UHF RFID tags practically.

- To investigate mitigation technique.

1.3. Structure of the dissertation:

The overview of the project and the motivation for the work is provided in Chapter 1. This section also describes the aims and objectives of the project.

In Chapter 2, the background about RFID technology is presented.

Chapter 3 presents theory of Backscattering from passive UHF RFID tags.

Chapter 4 presents an over view on the read range of passive UHF RFID systems and its limitations. The second section in this chapter provides theoretical approach on the electromagnetic waves near metallic objects. The following section is about the effects of metallic surfaces on the read range of UHF RFID tags as well as Metal & fluid affect on the range. The last part in this section discusses how the read range depends on the impedance of the tag antenna.

Chapter5. Presents experimental works regarding the effects of metallic objects and liquids on the read range of UHF RFID tags, and discuss mitigation techniques to overcome the affect.

Finally, Chapter 6 concludes the work and also presents a number of suggestions for further work.

CHAPTER 2:

INTRODUCTION TO RFID TECHNOLOGY:

2-1 Background

Radio frequency identification (RFID) systems have been used widely for detection and identification of items in several applications. RFID systems provide an automatic means to identify objects without direct line of sight communication using electromagnetic waves exchange. In addition the huge amount of data that can be read at much greater distances than that used to be. RFID system consists of: an RFID device (tag), a tag reader with an antenna and transceiver, and a host system or connection to an enterprise system. There are three types on RFID system, active, passive and semi passive systems. These systems work in different frequency ranges from low and high frequencies to ultra high frequencies and microwave bands, also the difference include the power supply for each of these systems. Active systems have battery built in it while Passive system without power supply and depends on the signal that sends from the reader as an energy source.

UHF RFID system is the most popular and preferable in supply chains currently. Since it is cheaper than active once as well as its smaller size which it can be hidden, also it offers good read range reach to ten meters using tags work without battery. However, these tags must receive sufficient radio frequency signal to active the chip in order to transmit signal back to reader to analyses the received data. The performance of UHF RFID tags can be affected be the surrounding environment on the tag such as metals or liquids. This led researches to study these effects and how can they overcome such problem. Therefore, this work will concentrate on UHF passive RFID systems and their performance in present of these materials.

2-2 History of RFID technology:

The basics of invitation RFID technology can be traced back to World War II, when the radar was introduced. In addition to radar there are also system was used to identify the enemy planes from the friend planes this system is known IFF (Identification Friend or Foe) system this system is long range transponder. These two systems represent the main roots for introducing RFID technology. Since the first RFID passive system was discovered by the German when they noted that if pilots rolled their planes as they returned to base, it would change the radio signal reflected back. “This crude method alerted the radar crew on the ground that these were German planes and not Allied aircraft” (Konstantinos, 2007).However, Introducing theory for RFID system has taken period of time till the 1950s when the American, Japanese and European scientists finished their researches, and published paper introducing the process that can make RF energy could be used to track the objects.

The first system was applied by some companies was anti-theft systems. This system knows if the goods have been applied or not by using radio waves to define that. Also in check point and Sensormatic systems with electronic article surveillance (EAS) Tags, this tag based on 1-bit to detect wither the costumer has paid for the item or no. If paid the bit is turn off if not turning on and the person cannot leave the shop because the alarm will work if this person tries to go outdoors Roberts (2006).

Great attention from scientists and researches was begun in 1970s. Mainly, many governments used this technology in military equipments in this period. Then this interest attracts developers from different organisations represent in Los Alamos Scientific Laboratory and the Swedish Microwave Institute Foundation. The period of 1980s represent the period of full implementation of RFID technology (Landt ,2001). With the Developments in semiconductor technology, different development achieved in RFID tags such as reducing the size and cost. Furthermore, due to introducing low voltage, low power logic circuits CMOC the functionality of RFID systems improved substantially. CMOS integrated circuit used for building tags by combining it with discrete components. This led to significant reducing in the size of the tags(Landt ,2001).

Over the last decade RFID technology is used in different applications in Europe and USA such as animal tagging as well as toll roads rail applications and access control. As a result of the huge demand in the usage of RFID systems, Standardisation activities were required in the 1990s most of these were conducted by the International Standards Organization (ISO) and International Electrotechnical Commission (IEC). Table 2.1 shows the history of RFID technology from it is first introducing until last decade.

Table 2.1The decades of RFID Technology (Roberts, 2006)

Decade	Event
1940-1950	Radar refined and used major World War II development effort. RFID invented in1948.
1950-1960	Early explorations of RFID technology, laboratory experiments.
1960-1970	Development of the theory of RFID. Start of applications field trials.
1970-1980	Explosion of RFID development. Tests of RFID accelerate. Very early adopter implementations of RFID.
1980-1990	Commercial applications of RFID enter mainstream.
1990-2000	Emergence of standards. RFID widely deployed. RFID becomes a part of everyday life.
2000-	RFID development and applications continue

2.3 RFID transponders/tags:

RFID systems consist of: RFID tags or transponders attached to objects and RFID readers. Tags consist of chip and antenna they use a silicon microchip to store a unique serial number and usually some additional information. The following parameters represent the performance of the tags: read range, transmission speed (data rate), bulk-read capability, and the impacts caused by surrounding objects. The read range of the RFID tags can be determined by the orientation to the reader field, the frequency, the design and the size of the antenna. RFID transponders are either active or passive. Active tags have much longer range than passive tags since they have internal power supply that does not found in passive tags (R. Want, 2004).

This is the main different between the two types; active tags are more expensive and have size larger than passive tags. Therefore their application is different. Passive Transponders contain a microchip and an antenna and they do not have an internal battery. Most passive UHF tags use dipole antennas. Since UHF frequencies are electric in nature, while most LF and HF tags use coiled antennas due to their frequencies being magnetic. Tags has Varity of shapes each form depends on it is own application.

Figure 2.1 Different shapes of RFID tags (http://www.actag.com/tags.php).

The activation processes of the transponders based on the RF signal that send from the reader tags transmit back these signal when it is completely powered. The response of tags represent on data stored on the tag these data contain unique ID. When this data is sent back to readers then the reader translate these data by looking for information on it is data base in order to identify complete information about the item or the object which is this tag attached to. There are also semi-passive and battery-assisted RFID tags, which are can be used for specific applications.

The operation of the tags is based on which frequency band they are working in. Mainly there are four common ISM(Industrial, scientific and medical) bands of frequency have been used in that tags operation these represent in Low Frequency (LH) 128KHz, High Frequency (HF) 13.56MHz and Ultra High Frequency (UHF) 860 to 930MHz and 2.4to 5 GHz .

Low frequency (LF):

Low frequency tags operate at frequency ranges less than 135 kHz and their operation process is similar to the operation of electrical transformer since it uses magnetic coupling theory, ie near field coupling. In this process the electro-magnetic force (EMF) in the tag which is induced by the alternating current (AC) in the reader activates the microchip in the tag. Then the RF signal that transmitted by the reader modulate the data which stored in the tag, after that this signal is retransmitted back to the reader through the load modulation. When the data reach the reader then the reader decodes this signal which is containing information about the object. LF tags have a short range up to (1.5m) depend on the reader antenna (R. Want, 2004).

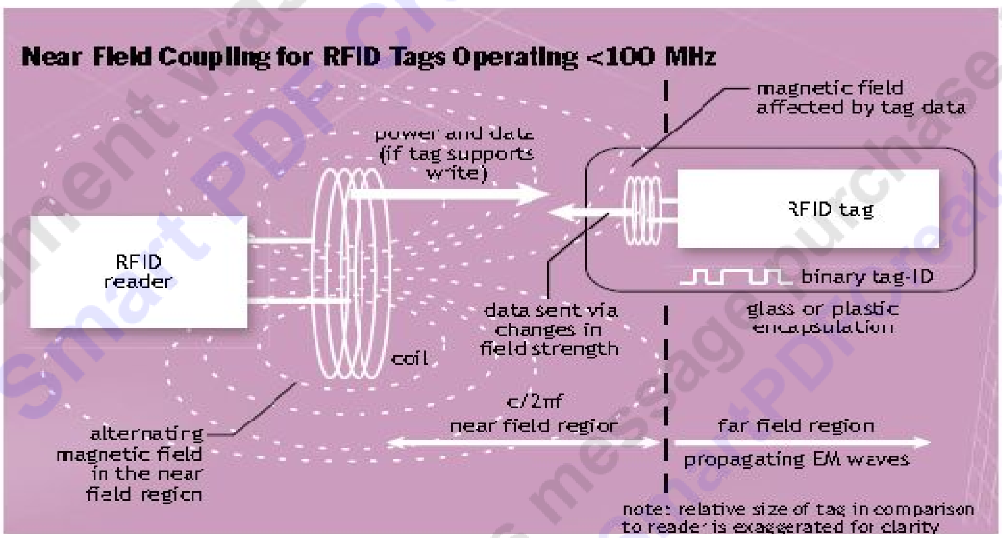


Figure2.2 the operation of LF and HF RFID systems (R. Want, 2004).

High frequency (HF):

HF RFID operates in the ISM frequency bands centred at 13.56MHz, and the operation process here is the same as in the LF RFID tags in the sense the both use magnetic coupling. Tags that work in this band of frequency have read range up to 1.5 m depends upon the antenna sizes. The major advantage in this system is that it is ability to operate even in present of water objects. However, this is not work with present of metal objects; also the read rate of HF tags is much faster than LF tags do since it can read up to 800 tags /s. The usage of such tags these days is in many applications such as in smart cards, access control systems, vehicle immobilization systems, subway cards, and the Mobile Speed pass system (Mark, Mickey, 2006).

Ultra High frequency (UHF):

UHF RFID systems operate in the range of 860MHz-930MHz. The operation of tags in this band differs from than in the LF and HF bands. Since the operational principle in this type is based on electromagnetic coupling communications, i.e., backscatter communication in the far field of the RF radiation as figure 2.3 illustrates the reader send electromagnetic wave to the tag then the tag use this energy to activate the microchip and then modulate this signal and resend it to the reader. This type of tags called passive tags that have no built in battery as in active tags. Instead, they draw power from the reader, which sends out electromagnetic waves that induce a current in the tag's antenna. The read range in this sort of RFID system can reach to 20 m however well work at 5-10m.

The major challenge in this type of tags that it is unlike LF and HF which are not affected by metal and water, UHF tags do effect by both materials since the liquids absorb the signal that being send from the reader and the metal reflect this signal especially for far field tags. Therefore, for these negative effects to be avoided objects must not be between the reader and the tag during the reading operations. However, there are some exceptions include thin and insulating layers and materials with low attenuating and inductive capacities, such as paper, loose materials, and expanded polystyrene . Mark, Mickey (2006).The readability of tags can be obtained also if tags situated beneath a dry cover not a wet cover. Since tags cannot be read in present of a wet cover. The read rate in this type is faster than other types as well as the lower cost and the small size. Consequently, it is deployed wildly in supply chains and retail. This led researchers to have a big attention to improve the readability.

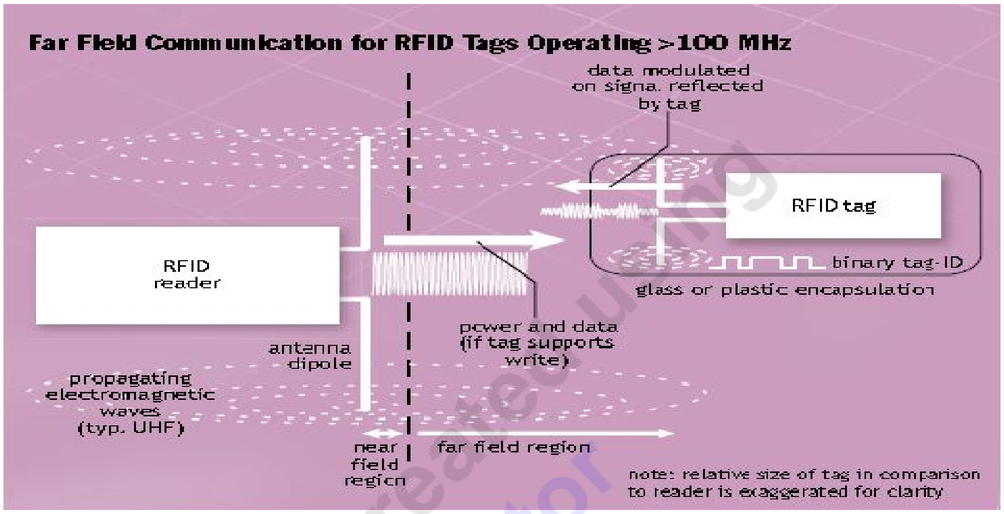


Figure 2.3 The operation of UHF RFID on far field coupling (R. Want ,2004).

Microwave frequency:

Microwave tags works in frequency bands at 2.45 GHz or 5.8 GHz. The operation principle in this sort of tags is based on far field communications as a result of which electromagnetic coupling is employed. The read rate here is faster than that of LF, HF and UHF. However, the read range is shorter as well as the size is very small.

In general, it can be noted that as the higher the frequency the longer the read range, also the effects of material increases as the frequency band is increases. In this study will concentrate on these effects in more details (R. Want ,2004).

2.3.1 Tag classifications:

RFID technology has many different types of systems with different characteristics, each system has it is specific field of application. Therefore, present classification for these systems will help people to understand this technology and it is importance as well as makes people be aware the reason behind using both active and passive RFID systems in specific fields. Tags can be classified according to range of parameters such as the source of operating, the power of communication, the communication process and computational capabilities. Classification of RFID tags can be split into three categories: active, passive and semi-passive tags.

2-3-1-1 Active tags:

Active tags depend on their own source of power since they contain internal battery, they can generate and transmit electromagnetic signal. The performance is very high as well as the large memories in this type. However, this type of tags is sophisticated, and naturally is more expensive, and they have large shapes as well as the limited sources of power which limit their lifetimes (Konstantinos, 2007). Therefore this type is used in limited applications.

2-3-1-2 Semi passive tags:

Semi passive tags like active tags they have built in battery, but the communication method which is used in semi-passive system is different since their communication techniques with the reader are based on backscatter communication or load modulation technique. The most common type of semi-passive tag today is a battery assisted passive tag operating in the UHF band. Using the property of built in battery in the operation of the chip of the tag in semi passive systems make them take advance over passive systems in terms of the communication process with the readers.

2-3-1-3Passive UHF RFID tags:

UHF passive RFID tags consist of microchip(IC) and tag antenna. The IC is connected to the tag antenna which acts as coupling element. A substrate which usually plastic film is holds the chip and the tag antenna together. The tag IC has memory which stores the data that uniquely identifies the tag. Most of passive tags can store up to 90 bit. passive UHF RFID tags differ from active once in many aspects, passive tags do not have built in battery and it depend on the signal the transmit from readers as a source of power, and use this energy to active the chip and for the operation process they use passive communication techniques called backscatter, to communicate with the reader.

The tag antenna plays significant role in passive tags since it is contribute to absorb the energy from the RF filed of the reader to power up the chip in order for passive tags to communicate data back to the reader (Steven, 2005).The extent to which power is transferred from the reader's electromagnetic field to the antenna and from the antenna to the microchip is provided by the coupling efficiency of the antenna. The impedance matching between the chip and the tag antenna is of significance since the power delivery to the chip is dependent on the matching circuitry. Therefore, the read range in passive tags is limited at best no more than few meters (Lauri,S.Et al,2008).

Tags classification is based on computational capabilities this classification has been outlined by the Auto-ID centre. These classes represent in six classes from class0 to class5 (www.radio-electronics.com).

Class 0 Read only tags.

Class 1 Passive write once, read many tags.

Class 2 Passive rewritable tags.

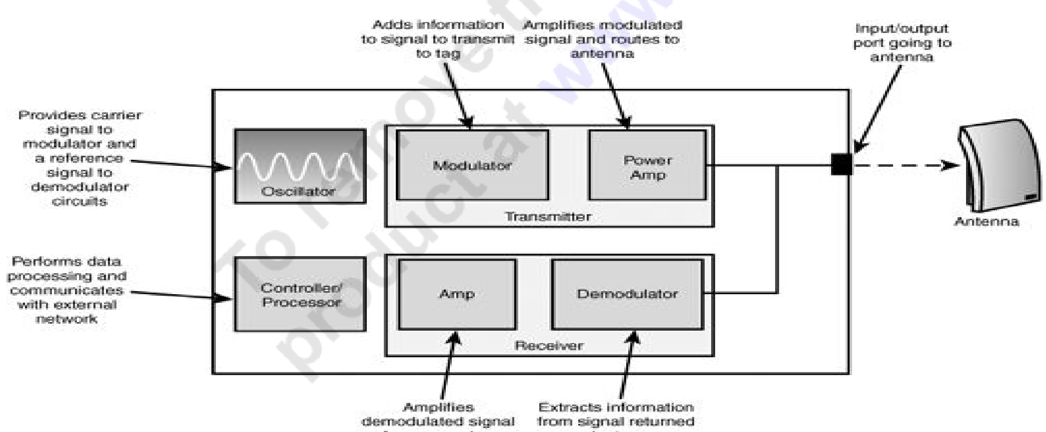
Class3 Semi-passive tags.

Class4 Active tags power up itself.

Class 5 Active tags ability to power up other tags as well.

2.4 Interrogator / Readers:

Readers or interrogators in RFID system are devices that generate and receive interrogation signal which is naturally RF signal this signal work as a power source for UHF tags. by sending electromagnetic wave to the tags which in turn pick up these signals to activate the chip. when the chip is fully activated then this signal retransmitted back to the reader. The reader captures this signal and analyses it to identify full information about the object. This amount of power that transmitted by the readers is limited by regulations (Mark, Mickey, 2006).



Figur2.4 Basic RFID interrogator anatomy (www.informit.com)

The control unit within the reader modulates the amplitude and the frequency of the wave that is generated by the reader. The antenna used by the reader transmits out the modulated data carrying RF signal. While the reader is waiting the response from the tag it is send wave signals continually. The received signal from the tag expends through the antenna of the reader by the amplifier in order to be processed. Then the original information extracted by the demodulator from the coming signal. The role of the controller /processor is to process the data and to communicate with the external network. The reader antenna comes after the controller in the reader system. Since it transmits and the RF signal from the reader as well as receiving it from the tag. Higher gain and directivity are the most important characteristics for reader antennas. The common type of antennas that used in UHF RFID readers is patched antenna (Mark, Mickey ,2006).

High directional antenna in the transmission and the receiving process is important because the transmitted and the received signal by the reader must be concentrated in specific area. In addition this will prevent the major problems such as collision and interference with other readers. The antenna gain is a measure of both the efficiency and the directivity of the antenna. In order to the reader antenna to be effective antenna it must be deliver enough power to the tag to activate it and to respond also the reader antenna must be able to detect the responded signal from the tag in the case of reception .Another important factor in RFID readers which play key role in the communication process between the reader and the tag is polarization. Proper matching between the polarization of the reader antenna and the tag antenna is required for effective communication between the two antennas (Mark, Mickey, 2006).

Readers have different capabilities depends on the type of the interrogator itself these capabilities represented on the following:

Reading and writing data to tags.

Operating on either a signal or multiple frequencies.

Performing anti-collision processing (Mark, Mickey, 2006).

The communication process from reader to tags as mentioned before in this chapter it is mainly depends on the type of the system whether the system is active or passive or even semi-passive system. In active systems the operation is different from that in passive and semi passive systems. The tag does not depend on the signal from the reader as a source of energy since it has it is own battery and it does not reflect this signal to reader to identify the object. This sort of tags can send it is data many times as long as it is defined by the system.

On the other hand, passive systems communicate by back scattering technique that will be discussed in more details in the next chapter since it will represent part of this work.

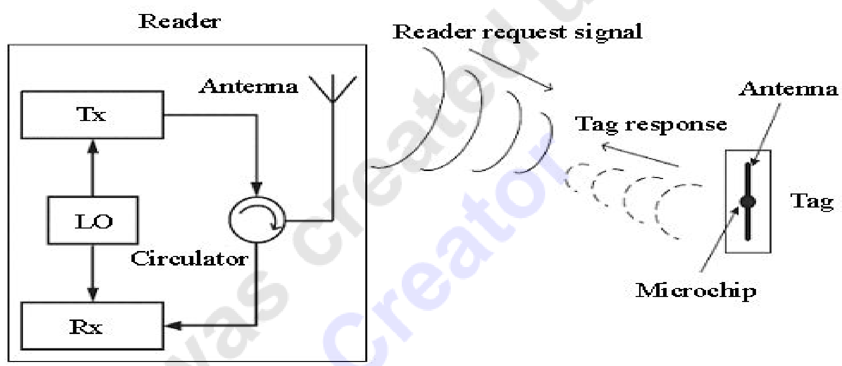


Figure 2.5 communicate by back scattering technique (Stockman. H, 2006)

The communication between the interrogator and the tag is basically depends on the two factors: The distance between the reader and the tag and the time at which the tag in the RF filed of the interrogator this time is known dwell time.

Two read ranges the interrogator has read and write ranges. The read range is the distance between the reader and the tag in which the tag can be read. Write range is the maximum distance at which the microchip in tag can receive and store the information within the RF signal that transmitted from the reader. Writing to tags requires more power than reading to it. Therefore, in the writing process the tag must be near to an antenna that in the reading process (Stockman. H, 2006).

There are three types of RFID interrogators:

- **Fixed interrogators:**

Can read and write to tags based on the type. They Can be mounted to walls, doors and other structures, and Can be integrated with stationary devices, such as conveyors, door portals, manufacturing lines, and others.

An external power source required.

Ability of multiple antennas accommodation

Ability for connection to local area network either wired or wirelessly.

- **Handheld interrogators:**

These interrogators have two different types: tethered or wireless hand held interrogators:

The size of this type is much smaller than fixed interrogators. They can be used to read from write to tags. Contain built in antenna. Due to their portability and capabilities the primarily used for exception processing.

Can be used in low-volume applications for tag data verification, case, and pallet association or tag searches

Work for both barcode and RFID.

- **Mobile interrogators:**

From their name they have different forms like mobile phone, PDA, and vehicle mounted.

Can connect to laptops and PCs since it can have PCMCIA cards.

The size and the form are different from handheld interrogators.

Have built in battery.

The ability to wireless connection (Stockman. H, 2006).

2.5 Global Standards:

Creation of standards associated to RFID systems is to ensure safely operation of these systems as well as to prevent interference with neighbouring systems which are their operation is based on RF such as cellular mobile phone, television stations and mobile radio services.There are several standards controlling RFID systems. However, there are two major organisations that set standards for RFID systems on data, air interface, conformance and its applications. These organisations are The International Standards Organization (ISO) and Electronic product code EPC global (Roberts, 2006).

2.5.1 Electronic product code standard (EPC):

This standard concentrates on different classes of UHF tags and readers. The EPC standard is based on the global trade item number (GTIN).

The main role for this standard is to adjust electronic product code which has a unique number for every item in the supply chain.

2.5.2 The International Standards Organization (ISO):

ISO has many standards used to mange supply chains such as 11784 which show how the data structured on the tag. ISO 11785 defines the air interface protocol; ISO 14443 is for proximity cards, ISO 15693 for vicinity cards all of these standards are for HF frequency. Also for automatic identification and item management ISO 1800 was created. Table 2.5 shows some of this standard (Roberts, 2006).

Table 2.2 Some ISO standards for RFID systems (www.rfidjournal.com).

ISO Standard	Title
ISO 18000 -1	Generic parameters for the air interface for globally accepted frequencies
ISO 18000 -2	Parameters for air interface communications below 135 kHz
ISO 18000 -3	Parameters for air interface communications at 13.56 MHz
ISO 18000 -4	Parameters for air interface communications at 2.45 GHz
ISO 18000 -5	Parameters for air interface communications at 5.8 GHz
ISO 18000 -6	Parameters for air interface communications at 860-930 MHz
ISO 18000 -7	Parameters for air interface communications at 433 MHz
ISO 15693	Identification cards- contactless integrated circuit(s) cards vicinity cards for 13.56 MHz
ISO 10374	Freight containers – automatic identification
ISO 17363	Supply chain application for RFID – Freight containers
ISO 18185	Freight containers – radio frequency communication protocol for electronic seal

CHAPTER 3:

PASSIVE UHF RFID SYSTEMS:

3.1. Introduction:

Over the last years UHF RFID systems have become the most attractive technology for researchers as well as industrial sectors. The advantages of RFID UHF systems over others in terms of the high capacity, loge read range as well as the small shapes have made them to be a disruptive technology in a significant number of markets. However, the major problem disturbs this technology is that the performance of passive RFID tags in supply chains is poor in some conditions.

This poor performance to a large part results from poor signal to noise performance at low passive RFID signal powers which effect readability of passive RFID systems. Since the operating abilities of Passive UHF RFID systems are based on the capability of the tag to capture enough energy from the reader signal and the strength of the desired backscattered signal. Therefore, it is important to understand how readers and tags communicate and the nuances behind the working of UHF RFID system.

Several researches have been carried out to understand and optimise the reader request signals and backscattered signal distribution in a passive UHF RFID system. For instance, the researchers investigated an analytical method for the backscattered signals to a reader from a tag using the antenna scatterer theorem. Radar cross-section analysis of backscattering RFID tags has also been carried out. the first part of this chapter provide an overview of the principles of electromagnetic theory of the propagation of the electromagnetic waves followed by section on the theory of the backscattering power from passive UHF RFID tags according to some of these researchers.

3-2 The electromagnetic theory in passive UHF RFID systems:

"An UHF RFID system consists of a reader and tags communicating over an air interface at a particular frequency" by exchanging an electromagnetic waves (Ananyaa, G, 2008).

Therefore, it is important to understand the laws of electromagnetic radiation in order to understand the basics of working the RFID system. Theory of electromagnetic field represents the foundation for any wireless system. The electromagnetic wave consist of electric field and magnetic field these fields represent the mathematical basics for electromagnetic wave propagation. The following section provides an overview of the some physical principles behind the propagation of electromagnetic waves.

3-2-1-Electric Field:

Electric field is generated by an electric charge. It is defined as the vector force exerted on a unit charge. The electric filed can be defined in many different ways. A stationary charged particle in an electric field is a force proportional to its charge (Cheng, D.K ,1992).

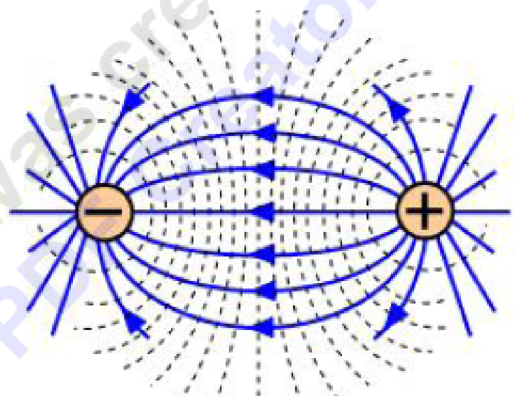


Figure3.1 electric field lines (Ananyaa, G., 2008)

$$E = \frac{F}{q} \tag{3.1}$$

Where F is the force exerted on the charge, and q is the charge of the particle, and E is the electric field strength.

Permittivity of the material (ε), and the amount of flux density are important in the electric filed.

$$E = \varepsilon D \tag{3.2}$$

Where D, is flux density and the flux density vector has the same direction of the electric field, and (ε) represents the property of a dielectric and it is expressed with respect to the permittivity in free space (ε_o) and equal 8.854×10^{-12} F/m, and the relative permittivity or the dielectric constant of the material (ε_r) (Cheng, D.K, 1992).

3-2-2-Magnetic Field:

Definition of the magnetic field is similar of the electric field. Magnetic fields can be generated when the current flows steadily or by magnetic materials. Magnetic field can be defined as a magnetic field strength and magnetic flux density both are related by the permeability of the material (μ) .The magnetic flux is proportional to the current flow.

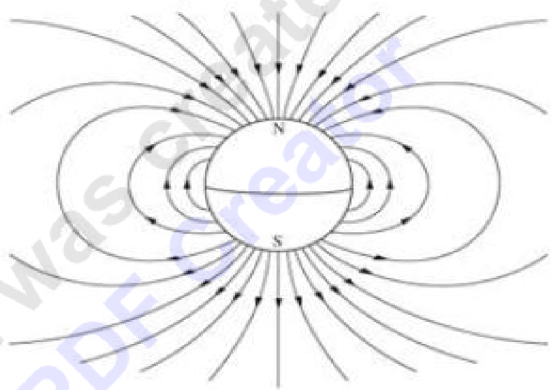


Figure3.2 magnetic field lines (Ananyaa, G, 2008)

$$B = \mu H \tag{3.3}$$

Where $\mu = \mu_o \mu_r$

μ_r is the relative permeability of the material, and μ_o the permeability of the free space and it is equal = $4\pi \times 10^{-7}$ H/m (Cheng, D.K,1992).

3-2-3: Electromagnetic wave generation:

The physics behind the electromagnetic field is the electromagnetism. Movement of the electric charges produce magnetic field, and vibration of eclectic charge creates electromagnetic waves. This vibration creates wave has both electric and magnetic components(Cheng, D.K (1992).

Maxwells equations provide the electromagnetic theory of the electromagnetic wave propagation these equations represented in the followings:

$$\nabla \times E = -\frac{\partial B}{\partial t} \tag{3.4}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t} \tag{3.5}$$

$$\nabla .. D = \rho \tag{3.6}$$

$$\nabla .. B = 0 \tag{3.7}$$

E is the electric field strength (V/m), B is the magnetic flux density (Wb/m^2), H is the magnetic field strength (A/m), D is the electric flux density (C/m^2), J is the volume current density vector (A/m^2) and ρ is the volume charge density (C/m^3) (W. Stutzman , G. Thiele,1989).

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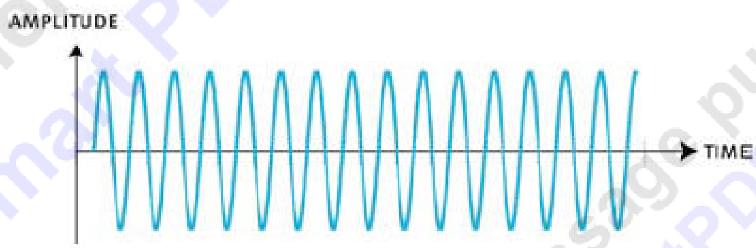
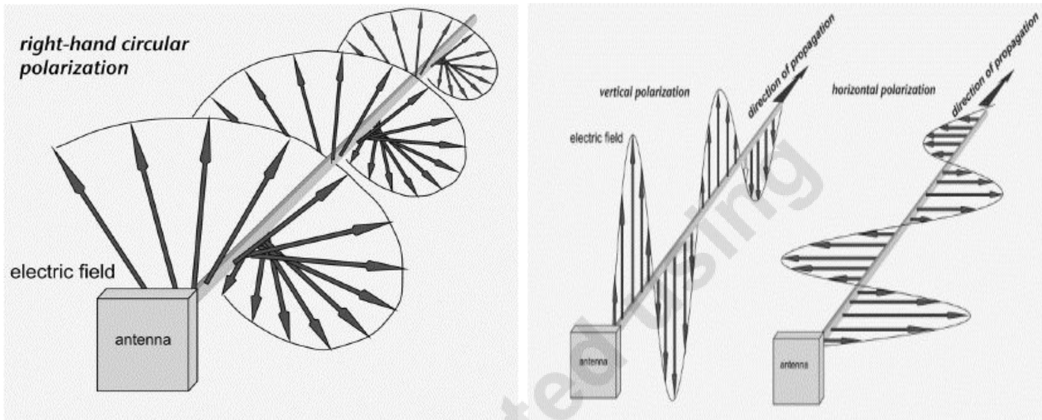


Figure 3.3 wave propagation(Ananyaa, G., 2008)

Time varying electric field produces a magnetic field, and vice versa the directions of the Electric field, magnetic field and the propagation direction are orthogonal to each other..

3.2.4 Polarization:

Polarization is defined as the orientation of the electric field of an electromagnetic wave as well as characterizes of electromagnetic wave. There are two types of polarization linear and circular polarizations. In case of linear polarization the electric field vector remains in the same fields. Whereas, in case of circular polarization the electric filed vector rotates about the propagation direction (Daniel, D, 2008) as figures 3.4a, b shows:



(a) (b)

Figure 3.4 (a) circular polarization,(b) linear polarization (www.rfidtribe.com)

3.2.5 Propagation loss:

Propagation loss can be defined as the attenuation in the electromagnetic wave as it travels in free space. Propagation loss is caused by many factors such as reflection, diffraction, refraction, absorbing and scattering from surrounding environment such as movement of people, vegetation, and buildings. The power in RFID systems can be affected by this loss, due to the distance between the readers which decreases the power by the inverse square of this distance (Ananyaa, G., 2008). The power density received at a distance (d) is given by this formula:

$$S = \frac{P_r}{4\pi d^2} \quad (3.8)$$

Where P_r is the transmitted power by the reader, and d is the distance between the reader and the tag.

3.3 Theory behind the Backscattering of UHF RFID Tags:

The process of reflecting the incident electromagnetic wave on the tag is known as Backscattering. The reflection of the electromagnetic waves by objects is usually with dimension greater than half the wave length of the wave. The reflected wave has a proportion of the incident power. Then the reader antenna detects the reflected wave from the tag antenna. The ability of the tag antenna to reflect the incident wave from the reader is dependent on the radar cross section or the reflection cross section of the incoming wave (RCS)(P. Nikitin, K. Rao ,2006). In the following section we explain the fundamentals behind of backscattering of UHF RFID tags.

In this process the reader transmits continues wave (CW) to the tag to activate the chip, and then sends commands that are modulated onto the signal. When the tag receives the signal, it retransmits its identification data back to the reader by using backscattering of the modulated electromagnetic wave as figure 3.5 illustrates. Tags comprise an antenna and microchip both with complex impedances, and no battery source in UHF tags. They get all the energy from the electromagnetic waves that are emitted by the reader through a rectifier, a voltage multiplier and a voltage modulator present within the chip itself in order to activate the chip.

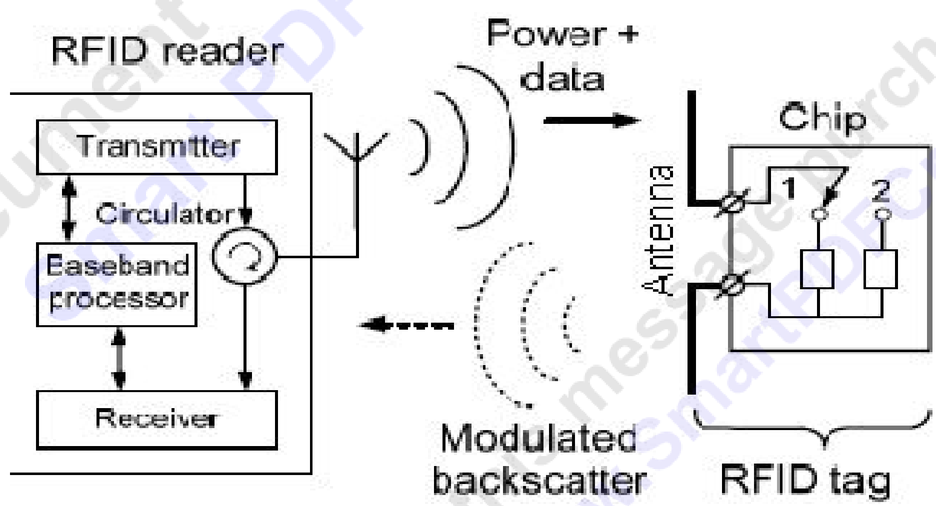


Figure 3.5 The Operation principle of passive UHF RFID (P. Nikitin, K. Rao, 2006).

Transfer the data identification from the tag antenna to the reader using back scattering is based on load impedance modulation. A small amount of power transmitted from the reader antenna reach the tag's antenna. Then part from the incoming power reflects by the tag's antenna. The reflection characteristics of the antenna are affected by changing the load connected to the antenna. Retransmitting the data from the tag's antenna can be obtained by switching the load impedance of the tag between two states one is matched to the antenna and another one is completely mismatched to provide a significant difference in the backscatter signal which modulates the backscattered signal. In each state of these states a specific radar cross section can be produced by the tag see figure 3.6.

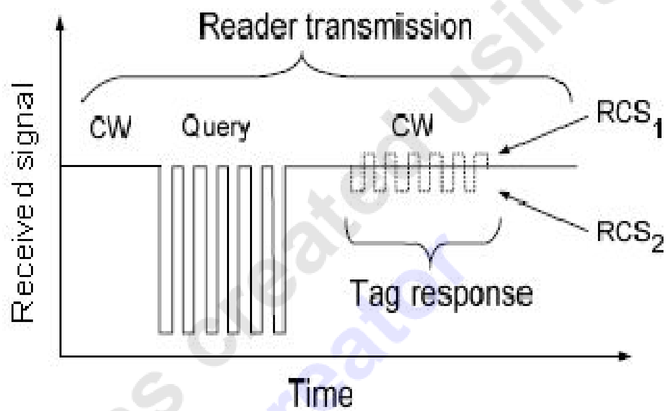


Figure 3.6 reader transmitted data and tag responded data (P. Nikitin, K. Rao, 2006).

Tag's antennas play a major role in making good performance of back scattering RFID system possible. For good tag antenna the following points should be considered:

Should be dimensioned to fit the identified object.

Have omni-directional or hemispherical coverage.

Provide maximum possible signal to the microchip.

Have polarization that is compatible with polarization of reader antenna.

Be robust and as low cost as possible.

3.3.1 Radar Cross-Section of an RFID Tag:

The amount of the back scattered power by the tag is usually described by its Radar Cross Section (RCS). The changing IN the radar cross section is referring to the difference in the backscattered signal by the tag between the two states modulated or non-modulated (C. Yen, Et al.2007). The RCS is the ratio of the backscattered power by the tag to the incident power on the tag.

$$\text{RCS}\,(\sigma) = \left(\frac{\text{Power reflected by the tag}}{\text{Power incident on the tag}}\right) \qquad (3.9)$$

The power received by the reader from the tag can be calculated from the following formula:

$$P_R = \frac{P_T G_T A_e}{4\pi d^2} \quad (3.10)$$

Where $P_T G_T$ is the reader transmitted power and the reader antenna gain respectively m, A_e is the effective aperture of the tag antenna, and d is the distance between the tag and the reader.

Where $$A_e = \frac{\lambda^2}{4\pi} G. \quad (3.11)$$

$$P_R = \frac{P_T G_T G_R \lambda^2}{(4\pi)^2 d^2} \quad (3.12)$$

the power reflected by the tag is the power dissipated by the radiation resistance of the Antenna and it can be calculated by (C. Yen, Et al ,2007):

$$P_{reflected} = \frac{P_T G_T \sigma}{4\pi^2 d^2} \quad (3.13)$$

The power density at the reader is given by the following equation:

$$P_{received} = \frac{P_T G_T \sigma}{(4\pi)^2 d^2} \quad (3.14)$$

The power received by the reader, P_r can be represented in the following formula:

$$P_r = \frac{P_T G_T \sigma A_e}{(4\pi)^2 d^4} \quad (3.15)$$

We can derive A_e from the equation 3.3 then we get:

$$P_r = \frac{P_t G_t^2 \sigma \lambda^2}{(4\pi)^3 R^4} \quad (3.16)$$

Rearrangement equation 3.8 the RCS (σ) is given by:

$$\sigma = \frac{P_R (4\pi)^3 d^4}{P_T G_T G_R \lambda^2} \qquad (3.17)$$

The change in the value of the RCS is the difference between the two states modulated and non-modulated of the backscattered signal (C. Yen, Et al, 2007). Higher change leads to deep backscatter modulation of the signal from the tag thereby long read range from the tag to the reader.

3.3.2 Impedance matching of RFID tag:

In passive RFID tags the chip directly connected to the antenna in RFID tags as the Thevenin equivalent circuit shown in figure (3.7).

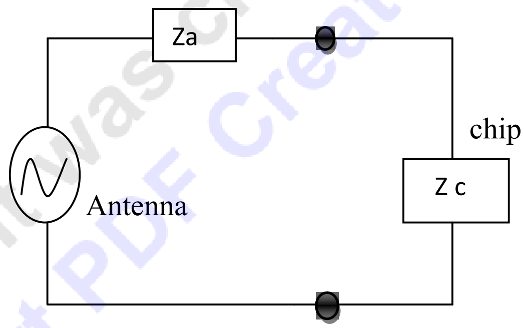


Figure 3.7 The Thevenin equivalent circuit of a tag (Lauri,S.Et al,2008).

In order to maximize the received power from the tag, the antenna impedance must be matched to the complex impedance Conjugate of the chip in the operating frequency of the tag in other words ($Z_a = Z^*_c$). The real part of both impedances must be equals, and the imaginary part of the antenna input impedance must be equal to the opposite of the imaginary part of the load's impedance. Thus maximum read range can be achieved (Lauri,S.et al,2008).

3.3.3Threshold power level and backscattered signal strength of UHF RFID tag:

Transmitting the power to the IC chip in the tag is usually limiting the read range of the tag. The communication regulations play main role in determining the power that transmitted by the reader, and the tag's antenna design determine the power delivered to the IC chip at a given distance. In order to the IC chip to be activated it must receive a certain amount of power, a proper design for the tag's antenna and it's matching structure can achieve this power . In addition, the properties of the antenna and the IC chip can be affected by the material objects in the vicinity of the tag. The threshold power level of the tag indicates the lowest power in dBm at given distance, to activate the tag. However, the backscattered signal strength that is detected at the receiver of the reader is another factor that the operating rang and the reading reliability is depending on. The ability of the reader to detect and decode the minimum signal strength is presented as the sensitivity of the reader it is from (-70dBm to -90dBm) for commercial readers (Lauri,S.et al,2008).

CHAPTER 4:

THE READ RANGE OF PASSIVE UHF RFID SYSTEM:

4.1 Introduction:

The maximum distance at which the reader can write or read information of the tag is called tag range which represents the most important characteristic in RFID system performance. The tag rang based on a certain read/write rate (percentage of successful reads/writes).This percentage varies with distance and depends on RFID reader characteristics and propagation environment.

Tag ranges are different according to the amount of power that received by the tag's antenna to operate the chip, where this amount of power varies with variation of some conditions such as: the reader characteristics and the surrounding environments. Ideally, an RFID system has tag read/write range of a 100% up to a certain distance and 0% beyond that.

The first section in this chapter presents an overview of limitations imposed on the range performance of passive UHF RFID systems by such factors as tag characteristics, propagation environment, and RFID reader parameters. The next section of this chapter will look at the electromagnetic waves near metallic surfaces, and then will be followed by a section on the effects of metallic surfaces on the performance of RFID tag antenna

4.2 Tag Limitations:

Tag limitations are represented in the following factors:

Chip sensitivity:

The chip sensitivity plays main role in the tag's limitations. Typically it indicates to the ability of the tag to receive the minimum power that can operate the chip and it called the threshold power (P_{th}) as mentioned in the last chapter. Lower sensitivity means that the tag can be detected at the long distance (P,Nikitin . K. Rao,2006).

Antenna gain (G):

Antenna gain is also important limitations in the tag. High antenna gain means high tag antenna range, but higher antenna gain limited by the antenna size as well as the frequency operation (P,Nikitin . K. Rao,2006).

Antenna polarization:

Tag antenna polarization is another most important parameter. The radiated energy by the antenna contains electromagnetic wave that has an electric and magnetic field. Both fields are orthogonal to one another and to the propagation direction. Polarization is described by the electric field of the electromagnetic wave. For instance, linear polarization happens when the direction of electric field is constant in time. Whereases, circular polarisation of the wave happens when the electric field rotates around the axis of propagation without varying magnitude. Polarization has a direct impact on the voltage induced to operate the IC chip to allow the tag to communicate with the reader. If the electric field is along the direction of the tag antenna, it induces a voltage to power up the IC chip thereby allow s it to response to the reader. However, if the electric filed is perpendicular to the direction of the tag antenna, it induces insufficient voltage that cannot operate the IC chip (Daniel, D, 2008).

In order to achieve long range the antenna polarization of the tag must be matched to the polarisation antenna of the reader. The match can be characterized by the polarization matching coefficient (χ).

Impedance match:

The matching between Impedances of tag's antenna and the IC chip (whose complex impedance varies with the frequency and the power absorbed by the chip) has direct effect on the tag range. It can be characterized by the power transmission coefficient (τ) whose maximum value is 1. For tag range maximizing the impedance matching can be achieved at different chip power levels such as at minimum threshold power (P,Nikitin . K. Rao, 2006).

The Following equation gives the power (P tag) received by the tag:

$$P_{tag} = P_T G_T P_L G_R \chi \tau \geq P_{th} \tag{4.1}$$

$P_T G_T$ Is reader transmitted EIRP (in EU, the transmitted power allowance is 0.5W ERP),

P_L is propagation path loss. τ is the power transmission coefficient.

χ is the polarization matching coefficient.

4.3 Reader Limitations:

Maximum EIRP, reader sensitivity and propagation environment all of these factors represent the reader limitations (P,Nikitin . K. Rao,2006).

EIRP (Equivalent Isotropic Radiated Power):

EIPR determines the power of the RF signal that transmitted from the reader towards the tag's antenna. The amount of EIPR is limited by national regulations such as (Europe 2W, North America 4W, etc) (P,Nikitin . K. Rao,2006).

Reader sensitivity:

Reader sensitivity is important factor in the reader limitations. It represents the ability of the reader to detect and process the minimum level of the tag signal. The sensitivity is usually defined with respect to a certain signal-to-noise ratio or error probability at the receiver.

There are different factors which affect the sensitivity of the reader such as receiver implementation details, communication protocol specifics, and interference.(P,Nikitin . K. Rao,2006)

4.4 Propagation Environment limitations:

Path loss:

Path loss is important parameter which is completely depends on the propagation environment. It represents the difference between the power delivered to the transmitting antenna and that obtained from the receiving antenna (P,Nikitin . K. Rao,2006).

Tag detuning:

Tag detuning is result when the tag is attached to different objects or adhered to specific materials or when the tag mounted on vicinity of metal objects all these factors can change the characteristics of the tag's antenna. Since detuning perform negative effects on the antenna gain and the impedance matching and thereby affects the read range (P,Nikitin . K. Rao, 2006).

4.5. The performance of UHF RFID systems:

Several studies have been proved that tags cannot work in presence of liquids as well as metals. Especially UHF and microwave tags which are work in frequency bands 860MHz and above with very short wavelength. (Hunt, 2007) metals are electromagnetic reflectors so radio signal cannot penetrate them. Therefore, presence the metal not in the object itself only but even nearby will cause adverse affects on the system's operation as well as changing the antenna's characterises. In addition, RFID systems especially UHF systems are still unreliable particularly in a retail environment. It is very difficult on UHF tags to be read near the human body because of its high water content, since water absorbed the waves. Furthermore, medical productions such as drugs also have effect on the performance of UHF system since it contains water and some types of moisture (Jones and Chung, 2007). In this section I will study the effects of these materials theoretically and practically.

4.5 .1 Effects of metallic surface on UHF RFID tag antenna performance:

Using the RFID tags in different applications has made these tags to face different difficulties one of the most difficulties is when RFID tag is placed on metallic surfaces. Studies have shown that UHF label- tags with dipole-like antennas are the most effected tags from metallic surfaces due to the boundary conditions (Penttila et al.,2006). Several solutions have been planned to reduced these effects one of these ways is to place the label type tag at a distance from the metallic surface. This part will study the performance of UHF tag placed in vicinity to metallic surfaces.

The tag antenna parameters play main role in the performance of the RFID tag. Therefore, in order to evaluate the performance of the tag these parameters need to be calculated. In addition, as mentioned earlier the read range of the tag which is can be determined by two limitations which are the maximum distance at which the tag can receive enough power to activate the IC chip and the maximum distance at which the reader can detect the reflected signal. However, due to the higher sensitivity of the reader than that of the tag, the read range is mainly determined by the maximum distance at which the tag can receive enough power to operate the chip (Rao et al., 2005a).

The maximum read range of the tag can be calculated from Friis equation as follow:

$$r = \frac{\lambda}{4\pi}\sqrt{\frac{P_t G_t G_r \tau}{P_{th}}} \tag{4.2}$$

Where (λ) is the wavelength of the free space, and (P_t) is the reader transmitted power.

G_t is the reader's antenna gain , and G_r is the tag antenna gain, τ is the power transmission coefficient between the tag antenna and the chip, and P_{th} is the threshold power of the chip.

Where $G_r = D_r e_r$ (4.3)

Where D_r and is the directivity of the tag antenna and e_r is the radiation efficiency of the antenna (P. Nikitin and K. Rao, 2006).

Determining the power transmission coefficient (τ), the directivity of the tag (Dr), and the radiation efficiency of the antenna (er) determine the read range of the tag. Since these parameters only can be changed when the tag places near to the metallic surfaces.

The boundary conditions in the high conductive medium like metallic are the prime factor which affects the performance of the UHF RFID tag.

When the electromagnetic waves transmitted by the reader towards the tag's antenna, which is in the vicinity of metallic object the metal surface reflects these electromagnetic waves with 180 a phase change. The resulted wave from the metal surface cancels the incident wave and reduces the received power that can activate the chip. Moreover, based on the image theory if a dipole type antenna is placed close to metallic surface it will create eddy currents to the metallic surface these currents create their own magnetic field that is perpendicular to the metal surface this perpendicular magnetic field cancels the reader is field higher conductive material create higher eddy currents(Mo et al, 2009) .

Furthermore, these eddy currents reduce the radiation efficiency of the tag antenna, as well as change in its impedance matching. Furthermore, the shape, the size of metal surface and how far the tag from the metallic surface change the input impedance and the radiation pattern.

However, according to the basics of the antenna theory, the directivity of the antenna remains high when the antenna is close to the metallic surface since in the dipole antenna the antenna gain or the directivity is enhanced when the distance between the antenna and the metal surface is very small because the metal plate acts as a flat sheet reflector (Mo et al, 2009).

4.5.2 Effects of water and liquids in UHF RFID tag performance:

Using LF and HF bands in presence of water as well as metal the system can work perfectly without any effects waves will not change. On the other hand, using UHF system the energy will effect since it will be absorbed by water and reflect by metal. This is due to the inductive coupling that used by LF and HF system, the size of the reader field is smaller and can be more easily controlled. Whereas, propagation coupling is used in Ultra-high frequency systems which is difficult to be controlled since the energy is sent over long distances. The read range of the tag is decreased when a tag is placed in the water. However, the tag (Alien 9540) operates at LF could be read even if it is submerged fully in the water (Dobkin, 2007).

Several materials absorb UHF power these materials such as water and carbon. Therefore, any type of products which are contain high percentage of water such as fruit or soft drinks as well products which are mainly made of carbon can eliminate the transmitted signal . Furthermore, even movement of people in the stores can attenuate the transmitted signal .Since human body contain high amount of water. In this case the read range of the reader effected and slows down by presence of water as well as reducing wavelength of RF waves when they enters water . The following table shows how present of water affects the read range (Jerry, Les, 2007).

Table: 4.1. Test Results Using the ALN-9540 RFID Tag, Test done by Georgia Tech Research Institute (GTRI)

Test	Placement of the Tag	Maximum Read Distance
1	Without the presence of water	19.4m
2	Next to a glass of water	7.1m
3	Behind a glass of water	6.9m
4	In a glass of water	0.29m

4.6. Theoretical approach on the electromagnetic waves near metallic objects:

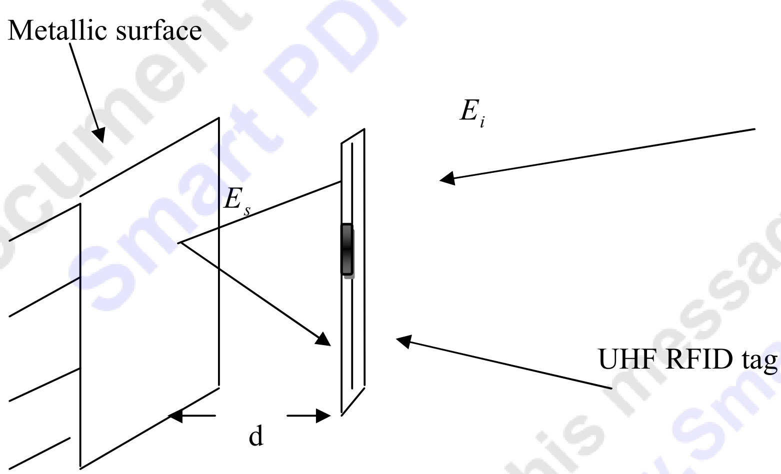


Figure (4.1) analyses for the reflected field from metallic surface.

$$E_{total} = E_i + E_s \qquad (4.5).$$

Where E_i is the incident field, and E_s is the scattered filed by the metallic surface.

$$E_s = E_I \cos\phi \qquad (4.6).$$

$$\phi = \frac{2d.(2\pi)}{\lambda} + \pi \qquad (4.7)$$

Where (d) is the distance from the metallic surface to the tag, and λ is the wavelength. The value of E_s is calculated with different values of (d) these values started from 0 to 0 0.25λ, the distance from the metallic surface to the tag.

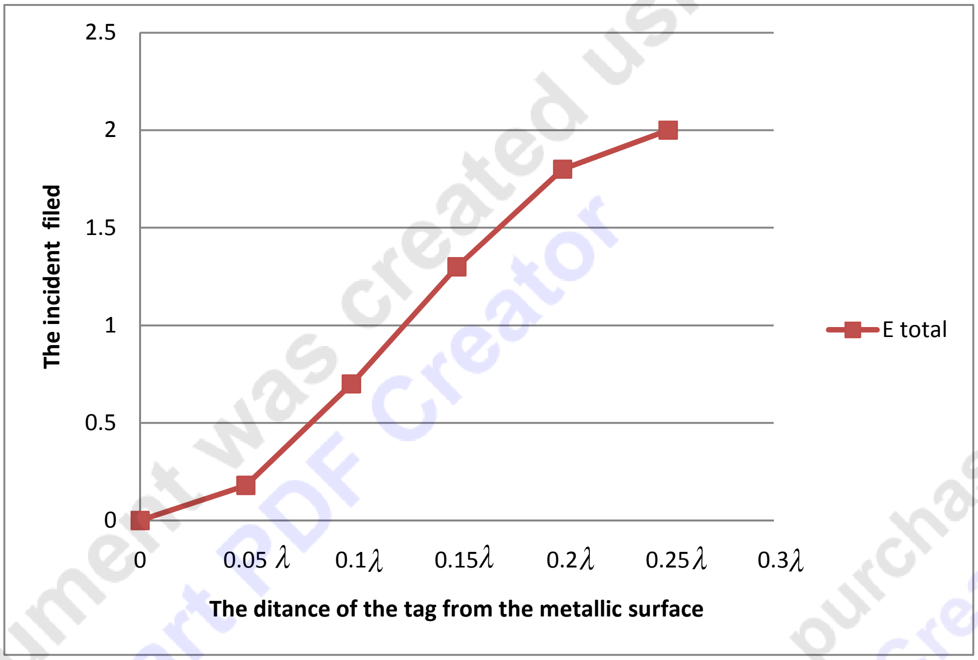


Figure (4.2) results of the total reflected field

From the graph above it can be observe that as the distance(d) increased the value of the total backscattered field increased and vice versa.

CHAPTER 5:

PRACTICAL TESTS TO EXAMINE THE EFFECTS OF METALLIC SURFACES AND LIQUIDS IN UHF RFID TAG PERFORMANCE:

5.1 Introduction:

As explained earlier UHF RFID passive tags in close proximity or even nearby to metallic surfaces as well as liquids can be effected and no longer can be read , in other words the shorter the distance between the tag and the metal or liquid the shorter read range can be obtained . It is clear that both materials can prevent reaching the reflected signal from the tag to the reader. For this reason a set of experiments was carried out to examine these effects in this work. Rafsec DogeBone Paper Global UHF C1G2 tag and Smart UHF RFID Reader (Deister) were used in the experiments the working frequency of the reader was between 865 and 868 MHz and the output power was 2W EIRP.

5.2 Practical test to examine the effect of liquids in UHF RFID passive tag performance:

Experiment set up:

The tag was placed in front of bottle of liquid (cooking oil) and the read range of the tag was tested, and then the tag placed behind the bottle of liquid and the read range was observed again. After that, the bottle of the liquid was replaced by part of human body represent in my hand and the read range of the tag was measured when the tag in front and behind the hand.

The reader has three different colours green yellow. The green light and the ton reveal that the tag was detected and it is steady, and the yellow colour indicates that the tag's reading is cannot be detected. Therefore, measuring the read range is based on the green light with the tone of the reader.

Figure (5.1) tag behind bottle of liquid.

Figure (5.2) tag in front of human part (hand).

5.3 Practical test to examine the Effects of metallic surface on UHF RFID tag antenna performance:

Experiment set up:

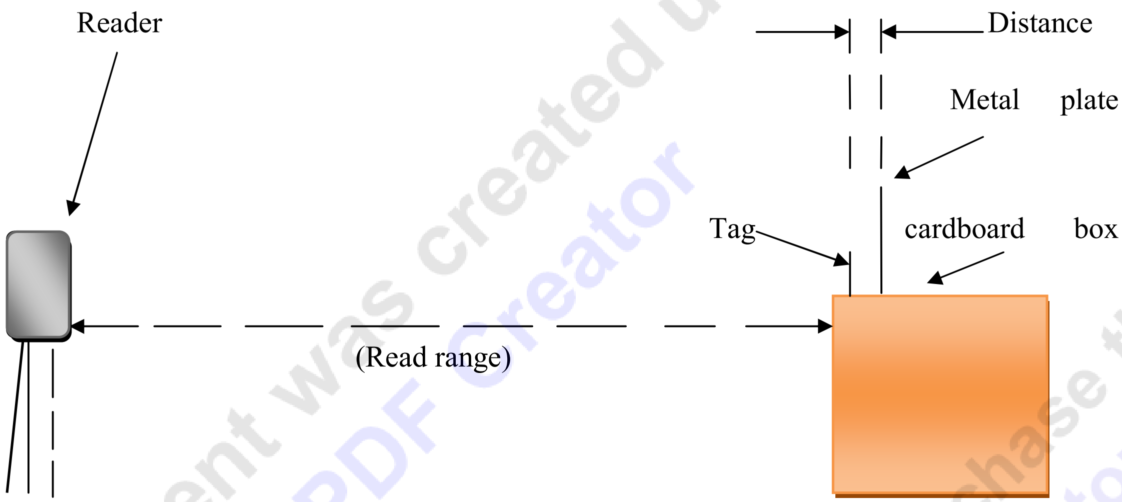


Figure (5.3) the setup for measurement.

The tags were placed on the surface of metal plates with different distances and the read ranges of the tags were tested. Fig.5 shows the experiment setup.

Three different types of metal plates with different sizes, 30cm×30cm and20 cm×20cm, were examined in the experiment. The tags were placed with close distances to the metal plates ranging from 0 to 0.25λ which is 8.6cm with steps from 0.025λ, 0.05λ, 0.1λ, 0.15λ, 0.2λand 0.25λ. The read ranges of the two tags placed close to the metal plates of different sizes are plotted in Fig.6.

5.4 Experimental Results and Discussion:

5.4.1 The results of the practical test to examine the effect of liquids:

Table: 5. 2. Read range of the tag in presence of liquids

Description	**Read range/(cm)**
Tag without the presence of liquids	600
Tag in front of bottle of liquid (cooking oil)	340
Tag behind bottle of liquid	300
Tag in front of my hand	285
Tag behind my hand	256

5.4.2 The results of the practical test to examine the effect of metal:

It is obvious that when the tag was attached directly to the surface of the metal plate, its read range was zero. However, with a small increase of the distance, the read range of the tag increased rapidly. When the distance between the tag and the metal plates was about 0.05λ, the performance was approximately the same as that with no metal plate. When the distance was between 0.1λ and 0.25λ, the performance was better than that in free space. the increasing and the decreasing in the read rang varies from metal to metal for example in presence of aluminium plate it was less than that of other types as figures below shown.

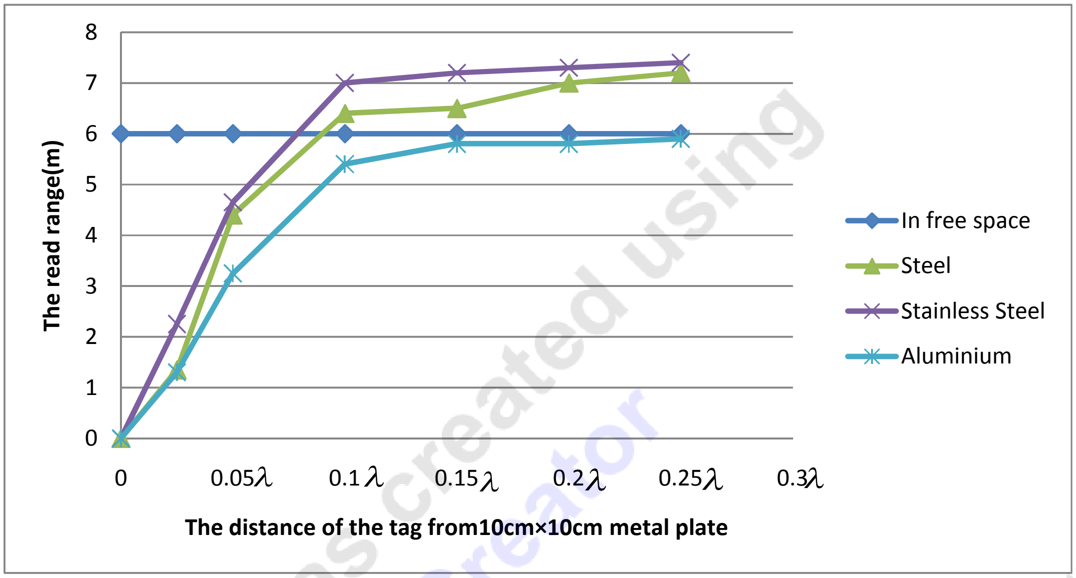


Figure (5.4) the performance of UHF RFID tag near metal plates with size of 10cm×10cm for different types of metals.

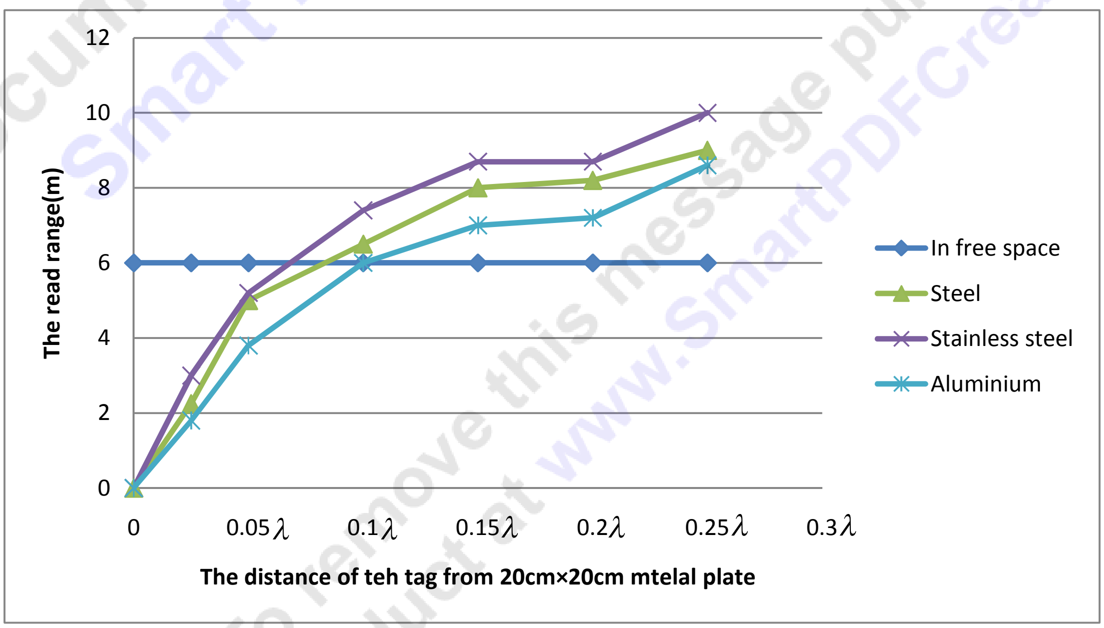


Figure (5.5) the performance of UHF RFID tag near metal plates with size of 20cm×20cm for different types of metals.

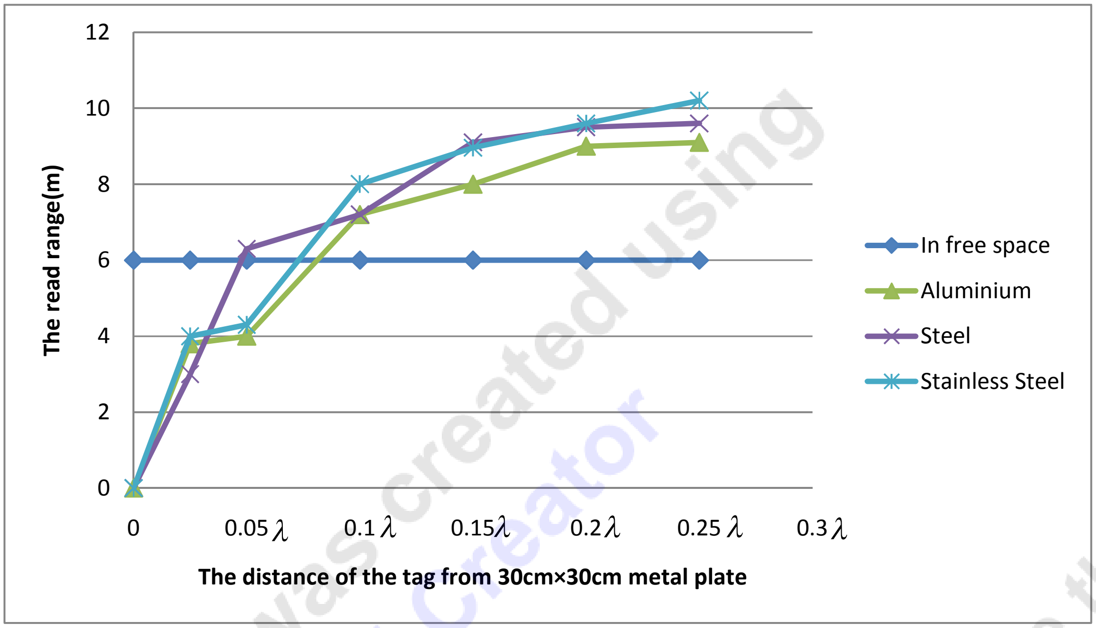


Figure (5.6) the performance of UHF RFID tag near metal plates with size of 30cm×30cm for different types of metals.

From the table 5.2 it is obvious that the presence of liquids wither the liquids is cooking oil or human hand can reduce the read range of the tag. However, the human hand has higher effect on the read range than the cooking oil since it is contain different type of liquids that can absorb the RF waves. In addition, these effects can increase as the human body or the bottle of the liquid are in close proximity to the tag. Furthermore, when the position of the bottle and the hand was changed from back to front the read range was changed. It is clear from this test that energy transmitted by the reader is absorbed and attenuated by these liquids. Thus products with high water content such as fruit and soft drinks or products contain liquids can attenuate the signal reaching the tags on these products.

In the second test when the distance is less than 0.05λ the reader could not work because the impedance matching was affected by the metallic plate. However, these effects reduced when the distance and the air gap were between 0.05λ and 0.1λ, and the performance of the tag increases to be in an acceptable level and sometimes reached longer that when the tag in free space, this due to waves reflected off the metallic surface and provided more power to the tag. The maximum value is located in the range between

0.1λ to 0.25λ. . Thus, if this type of tag has to be placed on metallic objects, the distance between 0.05λand 0.25λ can be used according to the required read range.

The size and the type of the metal play main role in increasing the read range or decreasing it. For instance: in presence of the aluminium plate with size of 20cm ×20cm the read range was less than that of the steel and stainless steel .while with the aluminium plate with size of 30cm ×30cm the read range was longer than the aluminium plate with size of 20cm ×20cm.

When the tag was placed close to Stainless steel plate the read range was the highest compared with other metals since whit the sizes of 20cm ×20cm and 30cm ×30cm the read ranges were 10m, and 10.3 m respectively. It is obvious from the results that the type and the size of the metal play key role in increasing and reducing the read range of the tag. Metals with higher conductivity and larger size have higher effects on tag performance than lower conductivity and larger size metals.

From my study about the effects of these materials on the performance of tag antenna it can be observed that as the distance between the tag and the metal plate increased the read range increased. Therefore, in case of metal if the distance or the air gap between the metal and the tag are considered and made correctly a very good performance better than in free space can be achieved. This because waves will reflect off the metal and provide more power to the tag.

5.5 Mitigation techniques:

In Ultra High Frequency RFID systems that use propagation coupling in the communication process it is harder to control, because electromagnetic waves are transmitted over a long distances. Consequently, waves can bounce off surfaces and reach undesirable tags. In addition, presence any object that contain liquids or water near UHF RFID tags will absorb these waves.

As discussed in previous chapters, the main issue which is concern manufacturing of passive UHF RFID systems is the ability to read RFID tags when they are placed in close proximity to items that made of metals or goods that contain liquids. These two materials are particularly affecting the tag antenna parameters such as impedance matching which if it is changed can detune the antenna. However, if the impedance matching could be designed to be less affected by the metallic surface or be designed specifically for the metallic surface a tag with a proper design can achieve reliable read range even in presence of these materials.

Recently, there are different types of tags that can work on metal. Although, the design of these tags were not easy technically, but has been done successfully. The design of these tags based on using spacer between the tag and the metal. The design has taken into account the advantages that can be obtained from the reflections that caused by metal.

Figure: 5.7 Different types of UHF on Metal Tags (www.confidex-rfid.com)

5.5.1. Plasmonic Structure

Nowadays, one of most reliable technology that can work perfectly in metallic and liquids environments is the new approach that provided by Omni-ID's technology to RFID tag design. Omni-ID's design differs completely from the traditional RFID tag design since it uses innovation called Plasmonic Structure. The basic idea behind innovation of the plasmonic structure started when a team of scientists studied how the wing structure of the BlueMorpho butterfly reflects light to produce its iridescent colour. They adapted this idea and implement it to UHF radio waves by developing the structure to reflect RF energy instead light.

Recently, Omni-ID’s tags that based on Plasmonic Structure are deployed widely in UHF RFID systems to provide better reading in presence of metal as well as liquids.

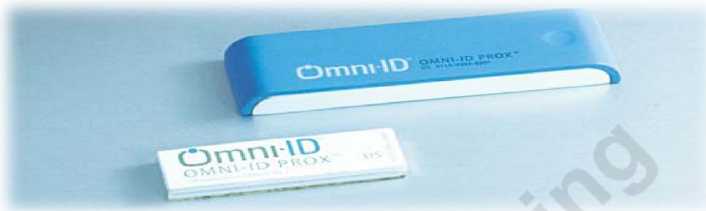


Figure 5.8 Omni-ID Tag (www.omni-id.com)

5.5.2 How plasmonic structure works:

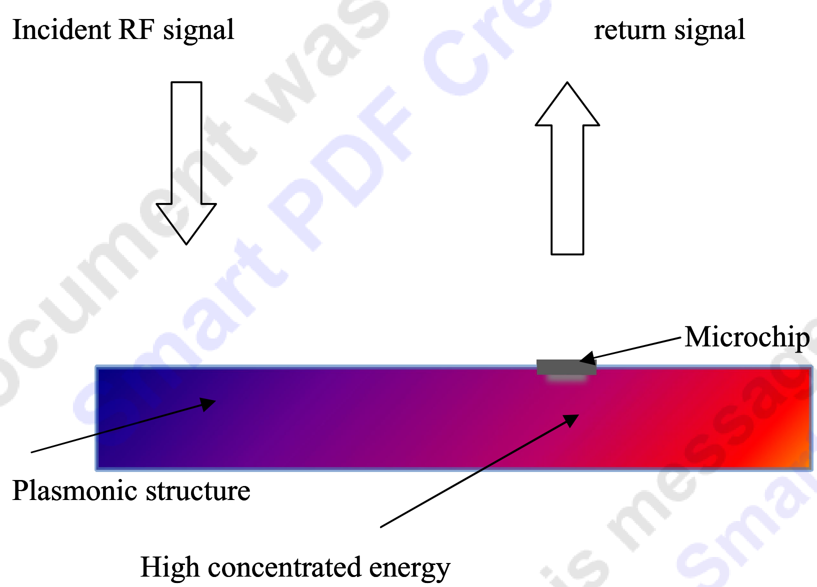


Figure: 5.9 Operation n of (Plasmonic Structure)

The Omni-ID tag captures and holds the incident RF waves from the reader, and keep them within the Plasmonic structure which is impervious to the interference of the outside materials including metal and liquid. These captured waves build up inside the structure and make a region of highly concentrated energy around the RFID chip which in turn activates the chip. Consequently, the chip retransmits the data of the tag t wards the reader.

CHAPTER 6

CONCLUSIONS AND FURTHER STUDY:

6.1 Conclusion:

In this thesis, three major goals were originally stipulated. Firstly, acknowledge about RFID technology with more concentration on UHF RFID system was to be understood. Secondly, the mechanism of RFID systems, operating principle and the application of the RFID system were to be studied. Finally, the performance of passive UHF RFID tags, when they placed in close proximity to metallic objects and liquids, with different separation distances and different sizes with different types of materials was to be examined. These goals have been achieved accordingly.

A set of experiments were carried out in order to test the performance of UHF RFID tag in both environments. Rafsec DogeBone Paper Global UHF C1G2 tag and Smart UHF RFID Reader (Deister) were used in the experiments, and the working frequency of the reader was between 865 and 868 MHz and the output power was 2W EIRP depending on the country regulation. From the experiment work three findings can be concluded as follows: firstly, the read range in free space was measured, and it was between (5.5m to 6m). After that when the tag was placed directly on the metallic objects the reading was zero as long as the distance was increased with a very short distance from the metallic surface, about 0.05λ to 0.1λ, the performance of the tag increases to be in an acceptable level because the radiation efficiency increases rapidly and the directivity remains high. Therefore, if this type of RFID tags has to be placed on metallic objects, a distance between 0.05λ and 0.1λ could be used.

Secondly, the performance of the tag is stay stable when the distance between the tag and the metallic surface changes from0.1λ to 0.25λ. Moreover, and it is also observed the read range increased to become longer than in free space and in some cases become double the maximum read range in free space. This reading was obtained in this range 0.1λ to 0.25λ and it is changes with the size and the material type. Finally, Designing tag antenna with less effective impedance matching by such materials a distance less than 0.025λ from the metallic surface could be achieved with acceptable read range.

In the last part of the project, the study about mitigation technique to overcome the affects of metal and fluid on UHF RFID tags especially, the new technology (Plasmonic structure) was studied.

6.2 Future work.

This work has studied the effects of metallic surfaces and liquids on the read range of UHF tag, and the study only concentrated on what is the effects of placing metallic surfaces close to UHF tag on the read range of the tag, and it did not explain what changed could be happened to the other parameters for the tag antenna such as the antenna efficiency, directivity and power transmission coefficient because of some circumstances. So it would be interesting to conduct a set of experiments to examine the effects of these materials on these parameters.

I also suggest examining the effects of placing different types of isolators such as plastic, wood, glass.etc between the metallic surface and the tag on the read range.

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