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MASTER THESIS:

RADIO FREQUENCY IDENTIFICATION:
THE TECHNOLOGY AND SUPPLY CHAIN APPLICATION

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ABSTRACT

The Radio Frequency Identification (RFID) is quite a vast subject. It is used for so many different applications. The most developed area of research has first been to track animals. Nowadays, many pets have a chip hidden in their neck that permits to identify them very specifically as the information in the chip is unique.

Some researches have then been oriented on the supply chain area. Unfortunately, as the technology is quite new, a lot of issues have not been solved yet.

The purpose of this Master Thesis is to gather, to sort out and to clarify the more information on RFID technology as possible. Following this objective, the Master Thesis is articulated in three main parts.

First, data transmission is explained so that the basis of the technology would be understood and this would also clarify some problems encountered later in the report. Then, the technology itself is described. As you will read, the principle looks pretty simple at first sight but then when going deeper in the working of it, you will see that it is not. While presenting the variety of different systems that coexist on the market, the problem faced by the enterprises to chose the best suitable one would become obvious. The thesis helps clarifying all of that. Finally the application of the technology in the supply chain, with its advantages and limitations is presented.

I hope the knowledge put into this Master Thesis would clarify the world of the Radio Frequency Identification.

ACKNOWLEDGEMENTS

This master thesis is written on behalf of the Department of Design Sciences, the Division of Packaging Logistics at Lund Institute of Technology. The thesis is about the Radio Frequency Identification technology.

I would like to thank Robert Bjärnemo and Mats Johnsson for helping me finding a suitable thesis to my studies.

A special thank for my corridor mates who helped with my new Swedish way of life.

This thesis could not have been done without the help of the employees of Lund Institute of Technology. I would like to thank all my fellow students and especially Emilie Lecoq, Antoine Colcombet and Adriano Rossini as they helped me and encouraged me.

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1 INTRODUCTION

1 INTRODUCTION

The background and the basic conditions for the thesis are going to be explained in this introduction chapter. The problem statement, the objectives, the demarcations and the outline of the report are also presented.

1.1 Background

Possibilities to identify goods are various and multiple. The most common one consists in putting a label on it, on which there would be some information that could be more or less detailed. The information is collected at every step of a good's life. If mankind easily and directly interprets the information, it is still difficult to insert it in an automatic capture data. The barcodes have been developed for nearly twenty years in order to simplify and to facilitate this capture. The barcodes technology uses optical character recognition (OCR) and is very well adapted to today's normalization.

Barcodes is the most widely used technology nowadays for good's identification. The number of barcodes printed everyday is reaching seven milliards[1]. Nevertheless it has some inconvenient. The reading distance cannot exceed twelve meters and the information can be damaged. As the label is laying outside of the good, it can be destroyed and so can the information be. On the same way, the amount of information contained on one label is quite limited[2]. That is the reason why firms looked for a different and new technology.

Recently, a new technology has raised and is now challenging barcodes. The technology evolution permits to use a system based on hyper frequency (RFID: Radio Frequency Identification). The vast development in the Electronic industry helps with lowering prices on the electronic chips, base of this system. Though it is still much more expensive (but for how long?), the identification process is much more easy. The information stocked in the chip can be very big whereas the chip can be very small (the size of a rice grain). The information can be modified in some cases and the system works "out of sight" (with obstacles).

This kind of identification increases competitiveness and security in the supply chain[3] application area.

[1] Castagnier 2003
[2] Normes EAN 8 and EAN 13
[3] see chapter 5.1 for definition

1.2 The problem

What is hidden behind those four letters RFID? Radio Frequency Identification is starting to be known by a large number of people and used by many firms.

Radio frequency identification, how does it work? What are the different kinds of systems that exist on the market? Which criteria a firm has to take into account in order to chose the best appropriate system?

Many firms are using barcodes these days and they are content with it.

Is it worth for a company to use RFID technology instead of barcodes? What benefits will the company get? How should RFID tag be applied on packages?

As it is said in the name, RFID is transferring data through the air.

How data are coded? What happens to the data if there is an obstacle (absorption, reflection, refraction, diffraction, penetration into liquid, ...)? How many information can be transferred at the same time and how are they transferred? What are the different frequencies used, why those frequencies and does any standard exist?

1.3 Objectives

The first aim of the thesis is to understand how RFID works in a quite profound technical knowledge. The technical aspect is explained in a deep way but with simple explanations. This means that there are not a lot of difficult equations and that anyone would be able to understand it without any technological background.

The second goal of the thesis is to have an overall understanding on the utilization of RFID in the supply chain. With an example of the utilization of the RFID technology in the supply chain, it would be obvious how this can revolution the logistic in a firm. A benchmark about existing technology shows which RFID system suits with which kind of company.

1.4 Demarcations

The thesis focuses mainly on the supply chain application area. Only a little part of the report is about the other applications of RFID technology.

The report is only about existing RFID system, the aim is not to find out a new revolution technology. No creation is in the report, only description and clarification.

1.5 Disposition of the master thesis

Below, a brief description of the master thesis and its content are presented

Chapter 1 – Introduction

The background and the basic conditions for the thesis are going to be explained in this introduction chapter. The problem statement, the objectives, the demarcations and the outline of the report are also presented.

Chapter 2 – Methods

In this methods chapter, different types of method are described. From those descriptions, I explain which one I have chosen for the thesis and why I have opted for this particular one. At the end of the chapter there is the draft of how I have carried out my master thesis.

Chapter 3 – Theory on transmission RF

In this theory chapter, the basics of Radio Frequency transmission are explained. The way the data are coded and how they are transmitted is also clarified here.

Chapter 4 – The RFID technology

This chapter explain the basics of Radio Frequency Identification. The four main components of the RFID system are defined here (the reader/encoder, the tag, the antenna and the host computer).

Chapter 5 – Impact of the RFID on the supply chain

Now that the technology itself has been explained, it is time in this chapter to explain the role of the RFID in the supply chain.

Chapter 6 – Conclusion

As a conclusion, the results of the master thesis are reminded. The answers to the problem are also remembered.

2 METHODS

2 Methods

In this methods chapter, different types of method are described. From those descriptions, I explain which one I have chosen for the thesis and why I have opted for this particular one. At the end of the chapter there is the draft of how I have carried out my master thesis.

2.1 Why bother about methods in research?

Some people would say that they do know how to deal with research but do they really follow any method? Bothering about methods is very important while doing a master thesis in particular but also while doing any kind of research. At the beginning, it seems a waste of time but this time that is spent deciding which method to elect can permit a gain of a large amount of hours (or days, depending on the research). Indeed, following a method helps with keeping the aim of the research deeply in the mind.

You can never empirically or logically determine the best approach[4]. This means that no recipe exists. Maybe some people who have done many researches prefer one method to another but this doesn't mean that it will suit the next research they will have to do. From every new problem you have to start research from the beginning, that means define the best appropriate method.

2.2 Different kinds of research

2.2.1 Qualitative versus quantitative research

Most research can be categorized in two paradigms: the qualitative or the quantitative. The qualitative research concentrates on investigating subjective data, in particular, the perceptions of the people involved: meanings, attitudes and beliefs. The quantitative research concentrates on what can be measured. It involves collecting and analyzing objective (often numerical) data that can be organized into statistics.

The choice between qualitative or quantitative research depends on the aim of the study. Sometimes a combination of both can be interesting. Of course that would result in a much more complicated type of research but it can be benefit.

As my study has nothing to deal with attitudes, feelings nor beliefs, I chose to use a quantitative research. Only "hard data" and scientific experience are used.

[4] Methodology for creating business knowledge

2.2.2 Descriptive research

This method only describes the "who, what, when, where and how" of a situation, not what caused it (limitation of the method). Consequently, descriptive research is used when the objective is to endow with a systematic description that is as precise as possible. It provides the number of times something occurs, or frequency, lends itself to statistical calculations such as determining the average number of occurrences or central tendencies.

Typical methods used in descriptive research are:

- Statistical surveys
- Sampling
- Interviews

As the master thesis does not intend to invent anything, the descriptive method is of the techniques that I use. I gather all information from every case that I find from the RFID suppliers.

2.2.3 Experimental research

This type of research is useful for establishing a relationship between cause and effect[5]. It tests causal relationships by observing the behaviour of the subject under conditions where some variables are controlled and others manipulated.

Experimental research is identified by six characteristics[6] implied in their definition:

- Management of the predictor and criterion variables (see below) along with the conditions in which the investigation is conducted
- Use of a control group
- Attempting to control variance among the predictor and criterion variables
- Internal validity
- External validity
- Ability to manage multiple predictor, criterion, and extraneous variables

There are two primary types of variables in experimental research. The independent variable is manipulated, managed, or administered by the researcher. The result of the manipulation is the measured or observed change in the dependent variable. Predictor variables (traditional name for the dependant variable) must be carefully chosen or designed to maximize differences due to their effects. Reliable and valid criterion variables must be selected or designed to accurately measure change caused by the predictor variables.

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[5] Reading research *second edition*
[6] (Hadley & Mitchell, 1995)

2.2.4 Action research

Action-research is a form of problem solving based on increasing knowledge through observation and reflection, then following this with a deliberate intervention intended to improve practice.

Action research is deliberate, solution-oriented investigation that is group or personally owned and conducted. It is characterized by spiraling cycles of problem identification, systematic data collection, reflection, analysis, data-driven action taken, and, finally, problem redefinition. The linking of the terms "action" and "research" highlights the essential features of this method: trying out ideas in practice as a means of increasing knowledge about and/or improving curriculum, teaching, and learning[7].

Essentially, action-research consists of a number of phases:

- *Observing*
- *Reflecting on this observation*
- *Planning either a change of practice or a gathering of further data*
- *Acting (by making the change or gathering the data)*
- *Observing the effects of the change (or looking at the data)*
- *Reflecting on this observation (or analyzing the data)*
- *Planning a further change or data gathering process*
- *Acting to make the change or gather the data*
- *Observing the results*
- *Etc.*

This process is known as the 'action-research spiral' and is often depicted in diagrammatic form (diagram 2.2.4).

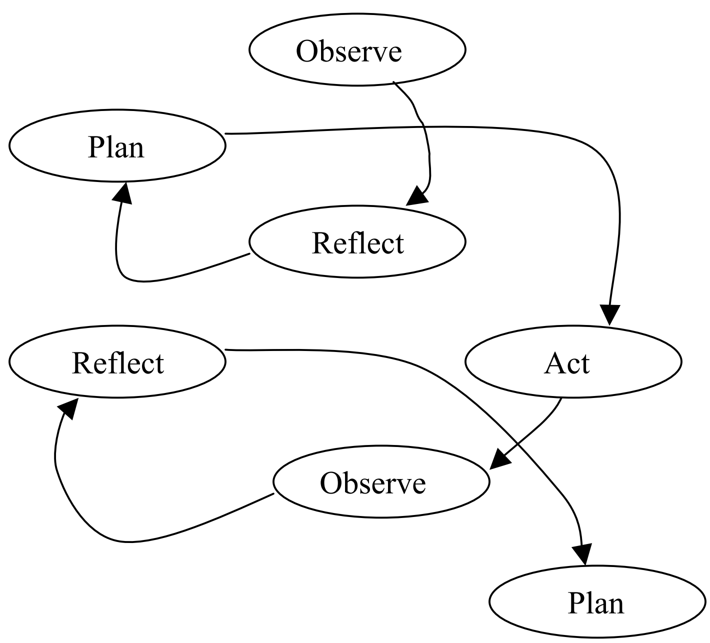


Figure 2.2.4 : The action-research spiral

[7] Kemmis & McTaggart, 1982

Action-research projects, then, are likely to be more 'messy,' in practice, than a straightforward description of the action-research spiral would suggest. However, describing each phase separately makes it easier to understand. My study is only descriptive, I am not acting in any different ways than gathering data and linking them. That is the reason why I do not use this method.

2.3 Collecting data

There are so many information on RFID that it is difficult to know where to start. First of all I checked on the Internet to know what RFID is about but none of the websites I looked at were well explained. After two or three days of investigation, I had seen a lot of things that was relevant to my problem. Hopefully I did my researches in a good way. I marked every web site I have read and summarized is very quickly. I also wrote down the way I used to find those pages. This is very useful. Writing down “RFID” in google or yahoo’s web browser, drives to approximately 150 000 responses. The investigation should be more specific as for example: “RFID + technology” for something technique or “RFID + applications” to know more about what RFID are used for.

Once that I have many data I have to be very careful of the provenance of the information. What this means is that the source can be influenced a lot. For example, if the font comes from a seller his RFID technology would always be the best. The important thing to do is to find some information that corroborate with each other and being objective is also essential in the Thesis.

This is the method that I use in my thesis: matching subjective data from seller with scientific information from my education in order to obtain the more objective point of view about RFID as possible.

3 THEORY ON TRANSMISSION

3 THEORY ON TRANSMISSION

In this theory chapter, the basics of Radio Frequency transmission are explained. The way the data are coded and how they are transmitted is also clarified here.

3.1 System principle of a data transmission system

Numerical data transmission, even if it looks simple at first sight, needs some precautions to be taken in order to obtain acceptable performances. The synoptic schema of such a transmission is represented in the next figure (see figure 3.1a):

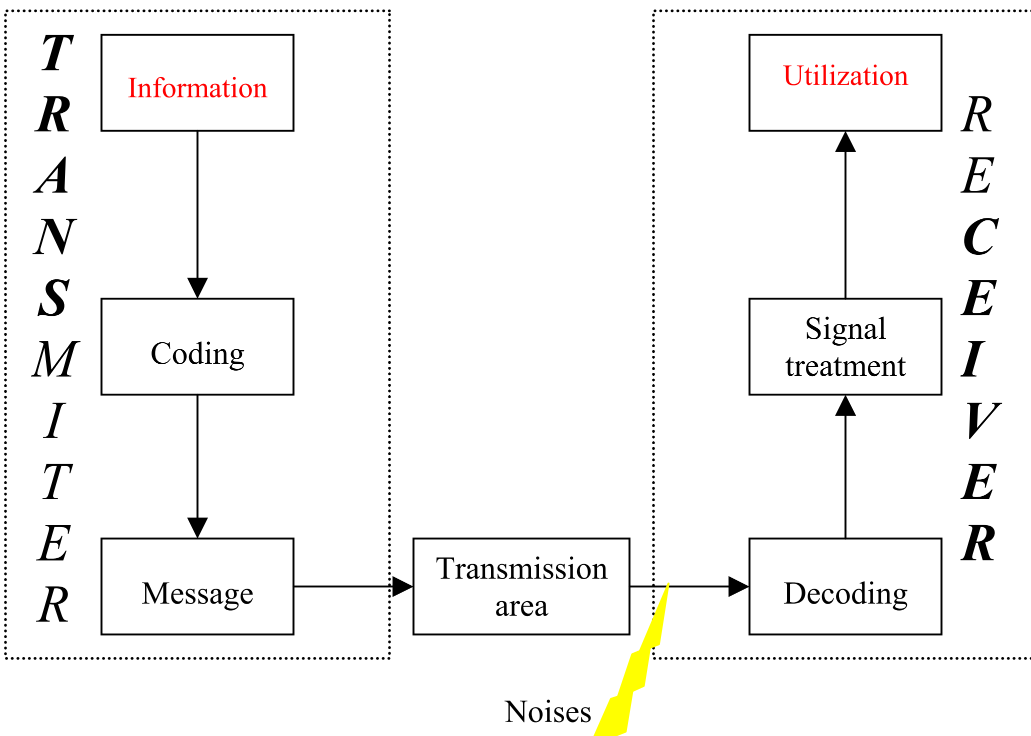


Figure 3.1a: Schema of a data transmission system

In the traditional point to point communication model, the information or the message that we want to transmit from a source to a distant user goes through a channel or a transmission medium, such as a twisted-pair of wire, a coaxial cable, a fiber-optic link, the air etc. However, no channel is perfect and the transmitted signal usually attenuates to extremely low levels of power and is corrupted by natural and man-made noises and interference signals. Thus, it is necessary to move the information to a frequency[8] range (a continuous spectrum of frequencies that extends from one limiting frequency to

[8] see definition chapter 3.2.1

another[9]) that will reduce the amount of attenuation of the transmitted signal and it is easier to combat various degradations. The process of translating the information from one band (a set of frequencies authorized for use in a geographical area defined for common carriers for purposes of communications system management[10]) to another is known as Modulation[11].

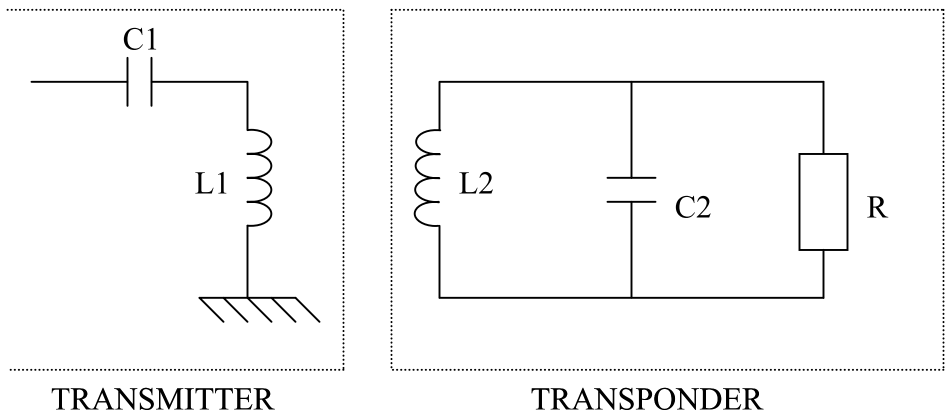


Figure 3.1b:Ttransmitter and transponder architecture

The above figure (figure 3.1b) shows the basics of the architecture of the reader and the tag. It is based on the same model as the one used in the figure 3.1a. Both the transmitter and the transponder are tuned on a resonance frequency e.g. f=125kHz or f=13,56MHz. Tuning is adjusting the parameters and components of a circuit so that it resonates at a particular frequency or so that the current or voltage is either maximized or minimized at a specific point in the circuit[12]. All inductively coupled, passive RFID tagging systems need good coupling and maximum energy transfer from transmitter to transponder. For these reasons, the reader is working in series resonance and has an electric coil L1 and a capacitor C1 whereas the transponder is working with a parallel resonance circuit and has a electric coil L2 and a capacitor C2. The resistance R represents the consumption of the tag. Indeed, to generate the maximum H field from the reader, the design should achieve maximum coil current at the resonance frequency. As the impedance is zero at resonance in a series LC circuit, this kind of circuit is chosen for the reader. Conversely, the voltage gain at resonance in the tag should be maximized. As the impedance goes to infinity at resonance in a parallel LC circuit, this kind of circuit is chosen for the tag. Tuning is achieving for both circuits by:

$$f = \frac{1}{2\pi\sqrt{LC}} \qquad (1)$$

[9] Internet, http://www.atis.org
[10] Internet, http://www.atis.org
[11] see explanation chapter 3.4
[12] Internet, http://www.atis.org

3.2 Propagation of Electromagnetic waves

A wave is an undulation or a vibration, a form of movement by which all radiant energy of the electromagnetic spectrum is estimated to travel. An Electromagnetic wave is produced by the interaction of time-varying electric and magnetic fields. A radio wave is an electromagnetic wave of a frequency arbitrarily lower than 3000 GHz.

In order to study the Electromagnetic waves propagation phenomena, the hypothesis that the waves are plan and uniform are usually made. This signifies that the electric field ***ε*** and the magnetic field ***H*** are only dependent on one of the spatial coordinate (e.g. z) and the time t.

3.2.1 Overview on Electromagnetic waves

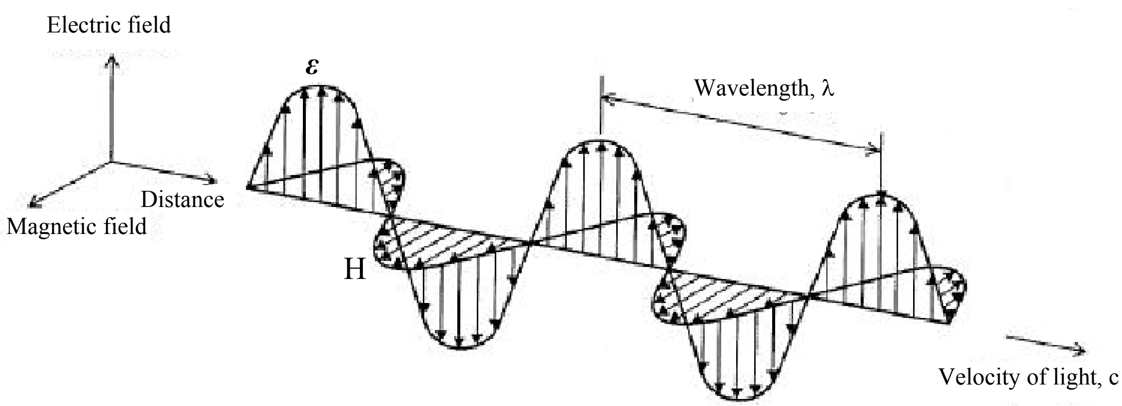


Figure 3.2.1a: Electromagnetic wave

The **wavelength** λ is the distance between identical points in the adjacent cycles of a waveform. The size of the wavelength varies depending on the frequency of the signal. Generally speaking, the higher the frequency is the smaller the wavelength is. The **frequency f** is the number of complete cycles per second in alternating current direction. The standard unit of frequency is in hertz (Hz). If a current completes one cycle per second, then the frequency is 1 Hz. The values are calculating thanks to the relation:

$$\lambda = \frac{c}{f} \tag{2}$$

λ : wavelength (m)
c : speed of light (3.10^8 m/s)
f : frequency (Hz)

The other basic properties that define the Electromagnetic radiation are the amplitude and the polarization. The **amplitude** ε_0 of the oscillation defines directly the amount of energy (and entropy) carried by Electromagnetic radiation. The energy carried is proportional to $|\varepsilon_0|^2$. The **polarization** of radiation defines the "sense" of the oscillation, it does not affect the energy varied but it can affect the way radiation interacts with matters.

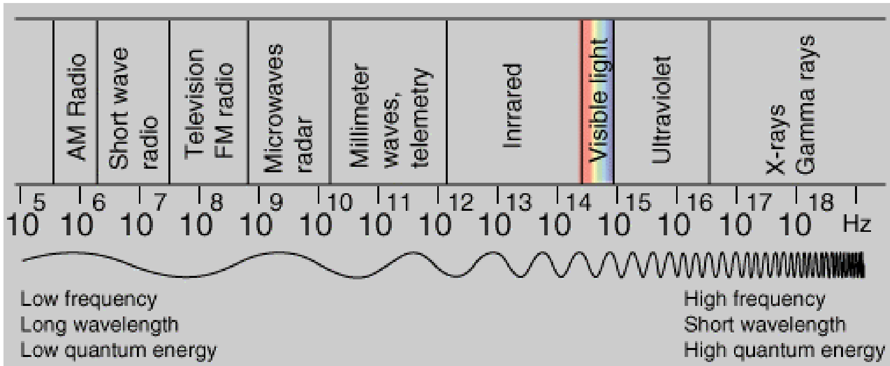


Figure 3.2.1b: The frequency spectrum[13]

The resolution of Maxwell equations indicates that the fields ***ε*** and ***H*** are perpendicular and linked by the relation (in the space):

$$\frac{\varepsilon_x}{H_y} = z_{m_0} = \sqrt{\frac{\mu_0}{\varepsilon_0}} \cong 376{,}7\,ohms \qquad (3)$$

where z_{m0} is the characteristic impedance of the space.

The hypothesis that the waves are plane is correct when situated in a quite long distance from the source. The attenuation in the space is inversely proportional of the square of the distance ***D*** from the source:

$$P_d = \frac{P_t}{4\pi . D^2} \qquad (4)$$

$\boldsymbol{P_t}$ is the spread power by the source, $\boldsymbol{P_d}$ the power at the distance ***D***.

Since power density ($\boldsymbol{P_d}$) and electric field (***ε***) are related by impedance, it is possible to determine the electric field strength as a function of distance given that the impedance of free space is taken to be approximately 377 Ω (as defined in the precedent equation).

$$\varepsilon = \sqrt{z_{m_0} P_d} = 5{,}48 \frac{\sqrt{P_t}}{D} \qquad (5)$$

where ***ε*** is the electric field strength in volt per meter.

[13] Internet, http://www.fiber-optics.info/default.htm

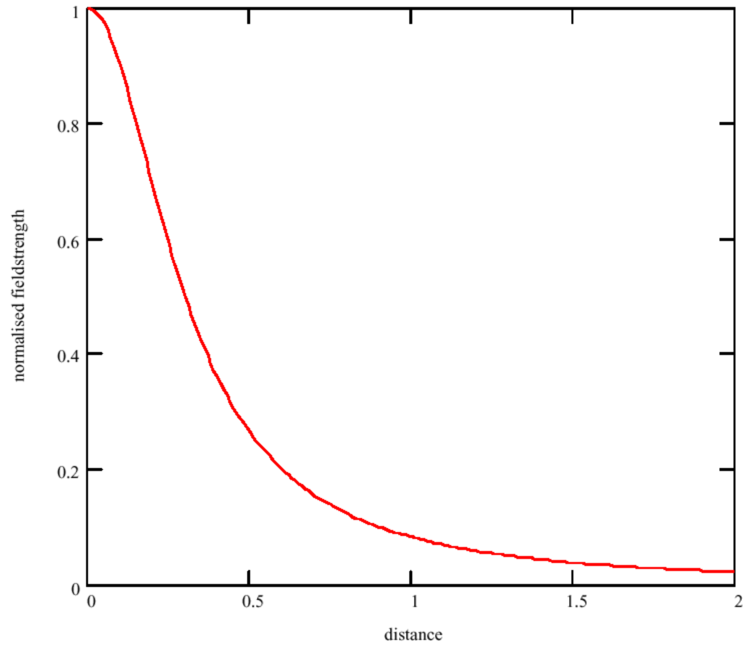


Figure 3.2.1c: Typical behaviour of the magnetic field strength versus distance[14]

As we can see on the above figure (figure 3.2.1c), the magnetic field strength drops while the distance increases. It is approximately 50% of its strength at the source when reaching 0,40m and only 10% at 1m. This example is for a typical system, from varying some data, this model can change and the distance can be increased.

[14] Internet, http://www.aim.com

3.2.2 Equations of Shannon and Nyquist

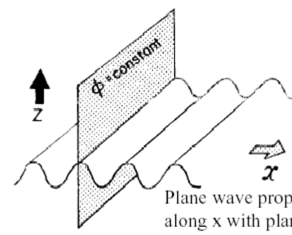
After those terms definitions, it is now time to make some mathematical definition of the electromagnetic radiation.
The plane wave form is expressed as:

$$\varepsilon(x,t) = \varepsilon_0 \cos(x - ct) = \cos(kx - \omega t) \qquad (6)$$

$$k = wavenumber(1/\lambda)$$

$$\omega = kc = angular \quad frequency$$

$$\varphi = k(x - ct) = (kx - \omega t) = phase$$

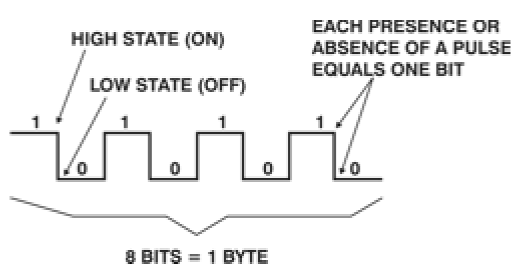


Plane wave propagation along x with plane of constant phase highlighted

The energy carried by the wave, related to $|\varepsilon(x,t)|^2 \rightarrow |\varepsilon_0|^2$, does not get altered by the simple act of propagation (must interact with matter for the energy to be altered.

Bandwidth has a general meaning of how much information can be carried in a given time period (usually a second) over a wired or wireless communications link. More technically, bandwidth is the width of the range of frequencies that an electronic signal occupies on a given transmission medium. Any digital or analog signal has a bandwidth.

An other important value that is needed is the amount of data that a wave can carry. A data transfer rate (or often just *data rate*) is the amount of digital data that is moved from one place to another in a given time, usually in a second's time. The data transfer rate can be viewed as the speed of travel of a given amount of data from one place to another. In general, the greater the bandwidth of a given path, the higher the data transfer rate.
Transmission of digital information is brought about by frequent signal changes (see modulation). The number of signal changes per second with which a channel can cope is called the Baud rate [15]of the channel. If each signal change represents one bit of data then the Baud rate is the same as the data transfer rate. A bit is the smallest unit of information upon which digital communications are based; also an electrical or optical pulse that carries this information.



[15] The measure was named after a French engineer, Jean-Maurice-Emile Baudot. It was first used to measure the speed of telegraph transmissions.

The maximum data rate D (in bps) of a communication channel (Channel Capacity) with bandwidth B where there is K levels in the signal is $D = 2B\log_2(K)$. If the K levels are encoded using m bits we obtain the channel capacity $D = 2B\log_2(2^m) = 2mB$. For example, a noiseless 13,56MHz channel cannot transmit two levels (i.e. one signal change per bit) information at a rate exceeding 27 120 000 bps. This theorem is good when applied to e noiseless channel. Unfortunately, many channels are subject to thermal noise. This noise is measured by the ratio of the signal power to the noise power, called the signal noise ratio and denoted by S/N. This ratio is more normally quoted in decibels (dB) where $SNR = 10\log_{10}\left(\frac{S}{N}\right)$ (where S and N are signal and noise power respectively). Claude Shannon extended Nyquist's theorem to include the case where the channel is subject to noise. Shannon's law states that $D = B\log_2\left(1 + \frac{S}{N}\right)$.

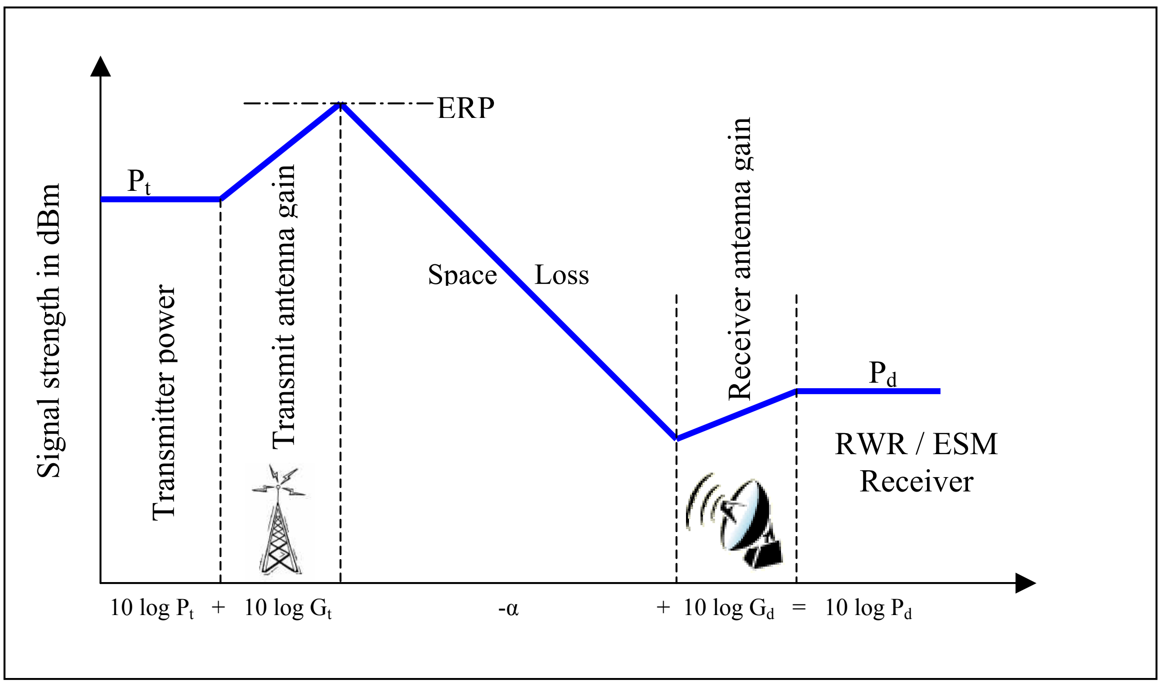


Figure 3.2.2: Signal position in space

On the above figure (figure 3.2.2), we can observe the signal strength in dBm from the source to the receptor. The amount of space loss is quite big (depending on the distance) and the gains of the antennas help for a better reception.

3.3 Problems encountered by radio waves

The waves are reflected, refracted and diffracted when the environment is not homogeneous. Those phenomena are linked to the nature of the encountered materials and to the wavelength of the emitted signals.

3.3.1 Reflection

When a wave encounters an obstacle, part or the entire wave is reflected (see figure 3.3.1) with a loss of power. The reflection is like the incident angle equals the reflected angle. From the definition, a radio wave can propagate in many directions. After multiple reflections, a signal can attend a point using different paths (multipath).

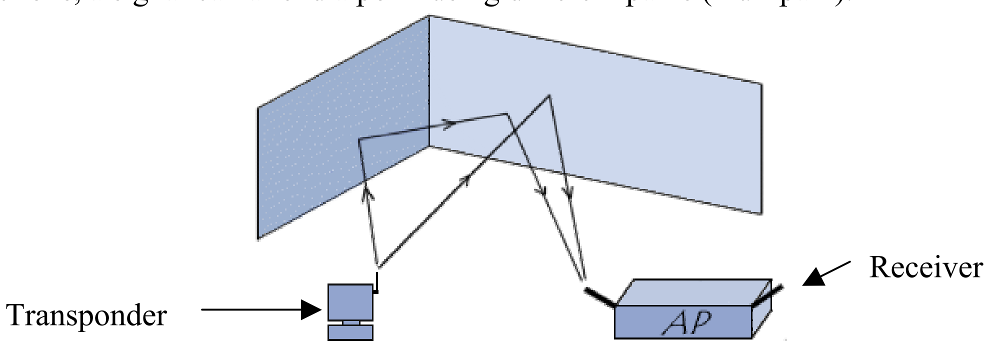


Figure 3.3.1 : Reflection of a wave

The propagation delay between two signals that had used different paths can induce interferences in the receiver as the data are redundant. Those interferences become more and more important as the transmission speed increases as the time between the data are shorter. Different methods are used to avoid those kinds of problems (see modulation), the use of multiple antenna can also reduce the effect of this problem.

3.3.2 Refraction

When a wave goes trough a material, it sustain losses by absorption (see figure 3.3.2) that are proportional to the thickness and the nature of the material. Passing from e medium to another induces a change in the direction of the wave. The angle between the incident wave and the normal is called the angle of incidence. As the wave passes through the boundary, it is bent either toward or away from the normal. The angle between the normal and the path of the wave through the second medium is the angle of refraction.

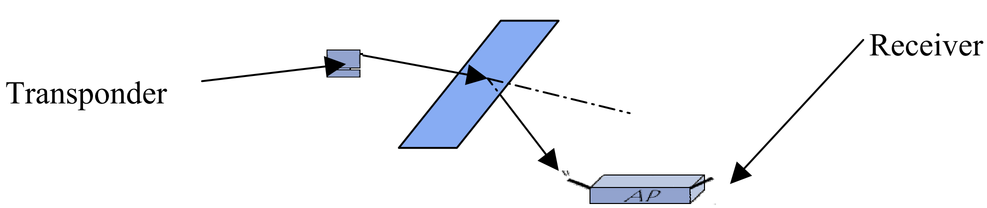


Figure 3.3.2 : Refraction of a wave

3.3.3 Diffraction

Diffraction occurs when the radio path between the transmitter and receiver is obstructed by a surface that has sharp irregularities (edges). The secondary waves resulting from the obstructing surface are present throughout the space and even behind the obstacle, giving rise to a bending of waves around the obstacle (see figure 3.3.3), even when a line-of-sight path does not exist between transmitter and receiver. At high frequencies, diffraction, like reflection, depends on the geometry of the object, as well as the amplitude, phase (period of time during which a specified function occurs in a sequential list of functions), and polarization (confinement of the E-field vector or H-field vector to a given plane) of the incident wave at the point of diffraction.

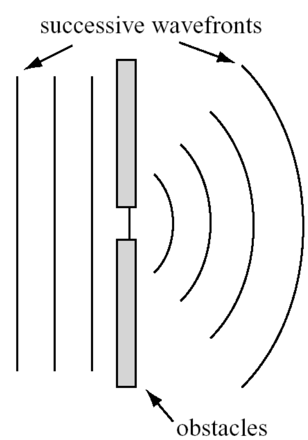


Figure 3.3.3 : Diffraction of a wave

3.4 Modulation

3.4.1 Modulation principle

An analog signal is represented by a sinusoidal of the type:

$$y(t) = A\sin(2\pi ft + \varphi) \qquad (8)$$

A: amplitude maximal
φ: phase
f: frequency (period ω=2πf)

To modulate (see figure 3.4.1a) is the process, or result of the process, of varying a characteristic of a carrier (the sinusoidal component of a modulated wave whose frequency is independent of the modulating wave), in accordance with an information-bearing signal. Graphically it is represented as:

Figure 3.4.1a: Analog signal

To modulate is to adjust or adapt in some proportion or to adapt in some manner. The aim of the modulation is to transform one signal in a signal adapted to the support (atmosphere). The modulation allows a better protection from the noise.
The carrier wave can be represented as:

$$p(t) = A_p \cos(2\pi f_p t + \varphi_p) \qquad (9)$$

A_p: amplitude maximal of the carrier
φ_p: carrier's phase
f_p: carrier's frequency (period $\omega_p=2\pi f_p$)

The carrier transports the signals in the pass band (the portion of spectrum, between limiting frequencies that is transmitted with minimum relative loss or maximum relative gain). It doesn't carry the information itself, only its modulation (see figure 3.4.1b) has a signification.

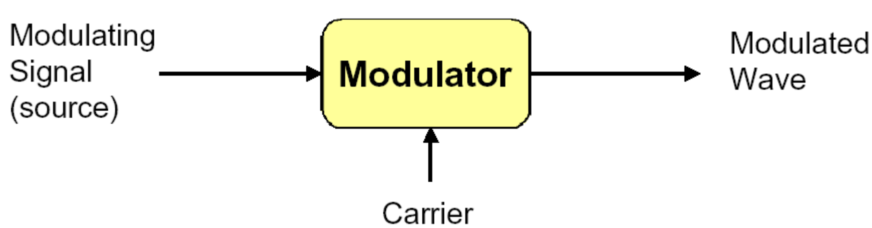


Figure 3.4.1b: Schema of a modulation system

There are three ways in which the bandwidth of the channel carrier may be altered simply. It is worth emphasising that these methods are chosen because they are practically simple, not because they are theoretically desirable. These are the altering of the amplitude, frequency and phase of the carrier sine wave. These techniques give rise to **amplitude-shift-keying (ASK)**, **frequency-shift-keying (FSK)** and **phase-shift-keying (PSK)**, respectively

3.4.2 Amplitude Shift Keying

ASK describes the technique the carrier wave is multiplied by the digital signal (1-m). Different amplitude levels represent the digital source bits (see figure 3.4.2). Mathematically, the modulated carrier signal p(t) is:

$$p(t) = A_p(1-m)\cos(2\pi f_p t + \varphi_p) \qquad (10)$$

φ_p and f_p are constants

When m=1 the amplitude waves from 0 to $2A_p$.This a particular case which is called OOK (On-Off Keying). This particular case is much more suitable for wireless transmission than the normal ASK as it is less disturb by noises. Indeed the amplitude in a wireless environment is much more prone to impairments than the frequency or the phase of the signal. The amplitude in a wireless environment is much more prone to impairments than the frequency or the phase of the signal.

$$p(t) = \begin{cases} A_p \cos(2\pi f_p t + \varphi_p) \rightarrow symbol \quad 1 \\ 0 \rightarrow symbol \quad 0 \end{cases} \quad \text{in the case of OOK} \qquad (11)$$

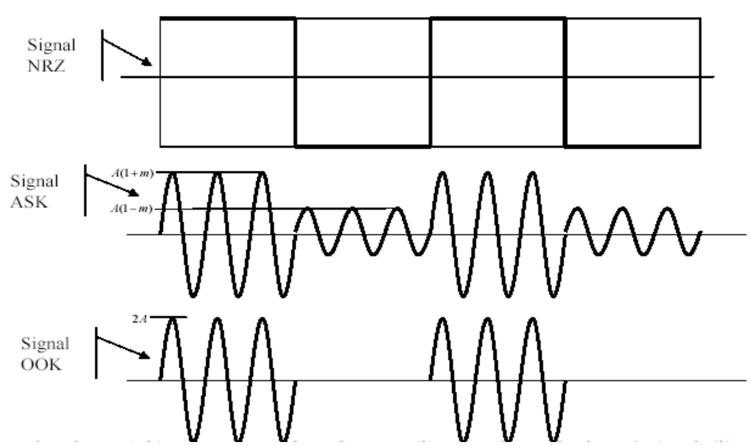


Figure 3.4.2: Amplitude Shift Keying

The advantage of this modulation is that the bandwidth of the signal remains unchanged.

3.4.3 Frequency Shift Keying

In FSK, two carrier signals are used instead of one. In the example (see figure 3.4.3), the second carrier frequency has been chosen has to be twice the first carrier frequency. The second carrier frequency will occur when a symbol 0 occurs. Mathematically, the modulated carrier signal p(t) is:

$$p(t)=\begin{cases} A_p \cos(2\pi f_p t+\varphi_p) \rightarrow symbol \quad 1 \\ A_p \cos(2\pi n f_p t+\varphi_p) \rightarrow symbol \quad 0 \end{cases} \tag{12}$$

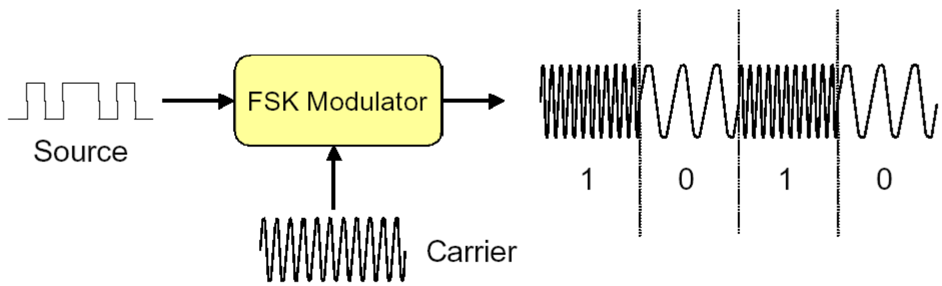


Figure 3.4.3: Frequency Shift Keying

From the equation, we can see that in order to detect the logic level, we would need to be able to detect the two different frequencies. The problem of this method is that it needs a larger bandwidth.

3.4.4 Phase Shift Keying

The phase of the carrier is switched depending on whether the source data is “one” or “zero” (see figure 3.4.4). Mathematically, the modulated carrier signal p(t) is:

$$p(t)=\begin{cases} A_p \cos(2\pi f_p t+\varphi_p) \rightarrow symbol \quad 1 \\ A_p \cos(2\pi f_p t+\varphi_p+\pi) \rightarrow symbol \quad 0 \end{cases} \tag{13}$$

These equations are valid for a binary signal as the variation of the phase is π. It is also possible to have a variation of π/2 in order to create 4 different values. Etc…. This type of modulation is more complex but more robust against interferences.

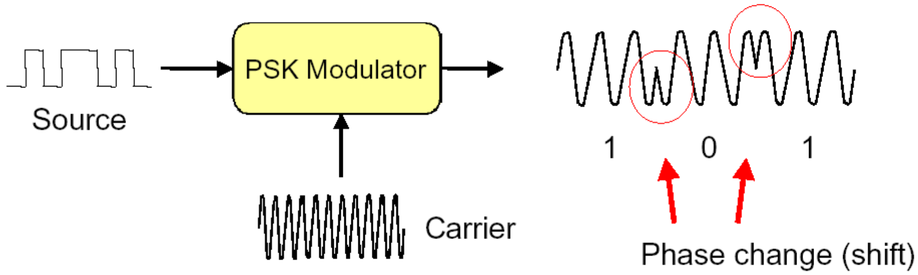


Figure 3.4.4: Phase Shift Keying

Each of the three different schemes has their own advantages. Selection of the modulation technique to use depends on the nature of the application. Digital modulation is not limited to only two logic levels. It can be easily extended to more than M-ary logic. This is called M-ary ASK, PSK or FSK.

The performances of these systems are measured by their respective Bit Error Rates (BER). This can be found out by doing a careful analysis of the noise and nature of the channel over which the signal is to be transmitted over. The bit error rate (BER) is the percentage of bits that have errors relative to the total number of bits received in a transmission, usually expressed as ten to a negative power. For example, a transmission might have a BER of 10 to the minus 6, meaning that, out of 1,000,000 bits transmitted, one bit was in error. The BER is an indication of how often a packet or other data unit has to be retransmitted because of an error. Too high a BER may indicate that a slower data rate would actually improve overall transmission time for a given amount of transmitted data since the BER might be reduced, lowering the number of packets that had to be resent.

One way to lower the spectral noise density is to reduce the bandwidth, but we are limited by the bandwidth required to transmit the desired bit rate (Nyquist criteria). We can also increase the energy per bit by using higher power transmission, but interference with other systems can limit that option. A lower bit rate increases the energy per bit, but we lose capacity. Ultimately, optimizing Eb/No is a balancing act among these factors.

Reliability the data transaction, i.e. obtaining an error-free data exchange between tag and reader, can be designed into the ID system to the extent required for system performance. To prevent erroneous readings, a number of extra bits of information are programmed in the tag to check or correct the accuracy if the main "message" bits, according to algorithms well known in data transmission theory. Increasing he number of error checking/correcting bits defines the reliability of the system; however, the number of extra bits in the tag also complicates the tag design, increases the tag chip size and increases the data transaction time. Therefore, the reliability algorithm should be chosen to utilize the minimum "reliability" bits consistent with the needs of the system.

4 THE RADIO FREQUENCY IDENTIFICATION TECHNOLOGY

4 THE RADIO FREQUENCY IDENTIFICATION TECHNOLOGY

This theory chapter explains the basics of Radio Frequency Identification. The four main components of the RFID system are defined here (the reader/encoder, the tag, the antenna and the host computer).

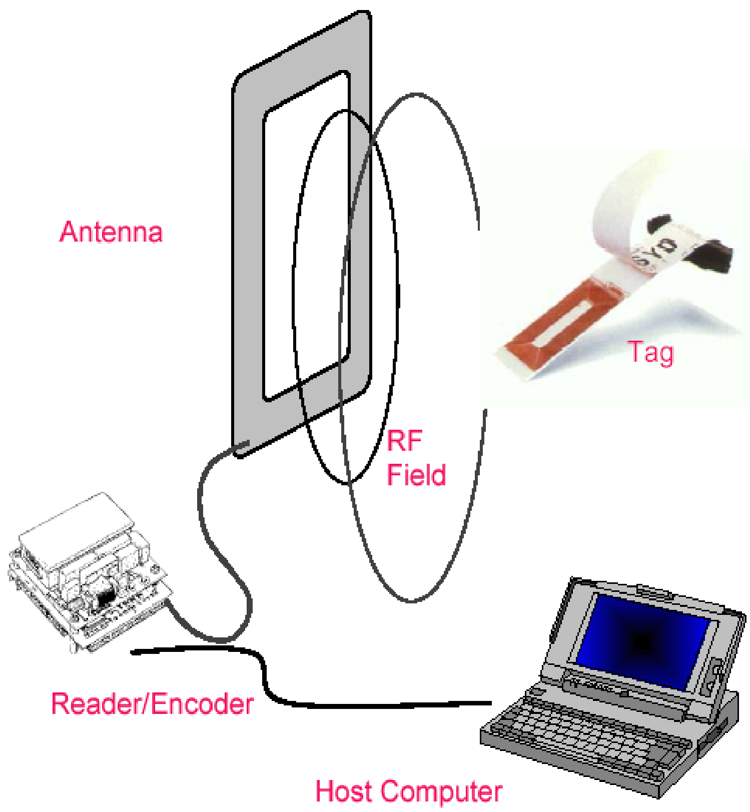


Figure 4.1: Operation of a typical magnetic coupled RFID system[16]

RFID is a complete system solution that operates in the electromagnetic spectrum to transmit data without contact or line of sight. It is an automatic identification and data collection technology utilizing "electronic" programmable tags for tracking, tracing and identification of objects[17]. It works as explained in the figure 4.1:

- Tag enters RF field
- Tag transmits ID, plus data
- Reader captures data
- Reader sends data to computer
- Computer determines action
- Computer instructs reader
- Reader transmits data to tag

[16] Internet, http://www.vericodesys.com/Documents/RFID.pdf
[17] Internet, http://www.vericodesys.com/Documents/RFID.pdf

4.1 The Radio Frequency Identification system

The most common way used for data transmission is the, magnetic coupled communication system. Two methods categorize and distinguish RFID systems, one based upon close proximity electromagnetic or inductive (transfer of energy from one circuit to another by virtue of the mutual inductance between the circuits) coupling (see figure 4.1.1b) and one based upon propagating electromagnetic waves[18] (see figure 4.1.1a).

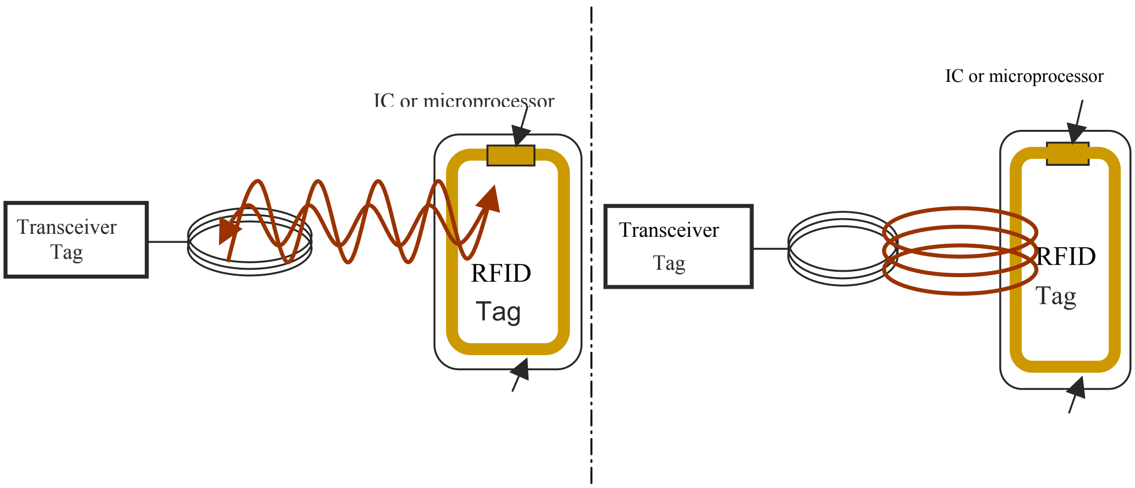


Figure 4.1.1a: Propagation coupling *Figure 4.1.1b: Inductive coupling*

The magnetic field (see figure 4.1.1b) drops off very quickly and it is difficult to propagate sufficient energy to power a transponder at a distance. The electric field (see figure 4.1.1a) travels forever. Even out in space a detector would be able to pick up the field if desired. The decision of using either technology is governed by practical restraints of antenna size and the very high speed at which light and radio waves travel. To simplify the problem, below 100MHz operating frequency, designers wanting efficient energy transfer would use the magnetic properties, while electric would be favored above this frequency[19] as the antenna structure for electric field coupling starts to become practical for tagging above this frequency.

Data transmission is possible thanks to the antennas placed in the reader (transceiver) and in the tag. By modulating the magnetic field, the reader can transmit (write) data to the transponder. The transponder will power up and return its on-chip data to the reader.

[18] Internet, http://www.cs.unc.edu/~sparkst
[19] Internet, http://www.transpondernews.com

4.1.1 Reader/Encoder

This component can be very different (size and shape) due to the wide type of applications. The transmitter RF is the radio waves' source transmitted in order to reach the passive tag and make it react. The transmitter RF can be either in the same box as the reader or separate from it. The transmitter control and modulate the radio frequencies that the antenna is going to emit and receive. It also amplifies the signal that comes from the passive[20] tag.

The frequencies used do not interfere with any other electronic systems wire or wireless that can be working nearby at the same time (cell phones, computers, …).

As usual, the utilisation of RF is subdued to the approbation of different governments. Power output of a reader's magnetic field generator may vary by orders of magnitude from the smallest hand held systems to large fixed-point installations. The requirements for constructing large and powerful magnetic field generators for proposed fisheries projects demand very efficient, low-distortion electronics and resonant electromagnetic networks. The power output of field generators sufficient to meet reading requirements for the largest systems may exceed regulatory agency specifications for RF emissions. In this case, electromagnetic shielding may be necessary to reduce RF emissions outside the reading volume to acceptable levels.

The transmitter RF is asked by the reader to emit a signal and to receive an appropriate answer. The reader can identify the tags and can transmit the other data received from the tag to the host computer.

The RFID technology permits a reader to identify around 100 for read, 32 for read/write[21] tags per second, this is forty times faster than the barcodes. In many applications it is desirable to communicate with a tag when other similar tags are simultaneously visible to the reader. In the case of tagging pigs, it is unlikely two pigs will need to be in the read space at the same time. In the case of library books an important design feature is the ability to read and "check-out" multiple books as the same time. For systems in which multiple tags within the reading volume must all be recognized and read, an "anti-collision" algorithm must be employed. The most common anti-collision methods use a method to cause multiple tags active in the field to transmit their information in such a way that only one tag at a time is interacting with the reader. The transaction time for the group of tags in the reading volume must then be assumed to be at least the transaction time of a single tag times the number of tags in the reading volume

The user can change or customize the reader's operations to suit a specific requirement by issuing command through the host computer or a local terminal[22]. Advance capabilities to utilize the reader's processor to provide some logic in the unit can make the difference between success and failure. There are multiple connectivity options and one must make sure they allow for the support needed in the enterprise solution.

[20] See chapter 4.1.3
[21] Internet, http://www.copytag.com/barcode.htm
[22] Intermec Technology Corporation

4.1.2 Tag

Usually called transponder (TRANSmitter/resPONDER)[23], the tag has response or emission functions. It answers the inquiry transmitted by the reader/encoder concerning its own data that are contained in a small integrated circuit (silicon chip). The data identify the object.

Tags can have a very large variety of size (see figure 4.1.2a), memory capacity, temperature survivability and ranges. Nearly all RFID Tags are encapsulated for durability against shock, chemicals, moisture, and dirt.

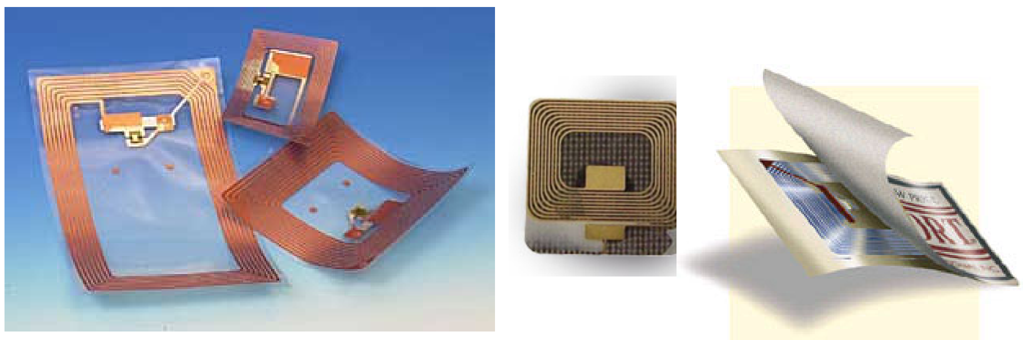


Figure 4.1.2a: Different types of RFID tags[24]

Tags exist in different versions, read only or read/write (the content can be modified approximately a hundred of thousand times[25]). Each version can either be passive or active. The main thing is that active tags have an internal battery where as passive tags don't have any and so are powered by a separate source, typically the interrogator.

Active systems are generally used in the cases where the tag is read/write type. Indeed this system needs more energy to be modified or recoded many times. However, even if the data storage capacity of those tags is bigger than in the passive model, a great number of disadvantages prevents this system to equal the market of passive structure. In fact, the fabrication costs and the lifetime of the internal battery are the only things that help the success of this system. The optimal output of the tag is considered only for ten years of utilization in normal conditions.

Passive systems are operational without any help from any external energetic source. The reader directly supplies the energy needed for the good working of the tag. Tags are lighter, cheaper and their lifetime is almost unlimited. This system can be find either in read only or read/write types. Passive RFID operations requires very strong signal from the reader, and the signal strength returned from the tag is constrained to very low levels by the limited energy.

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[23] See related figure 3.1a

[24] Internet, http://www.cs.unc.edu/~sparkst

[25] Adctech data

		ACTIVE RFID	PASSIVE RFID
Technical aspects	Tag power source	Internal to tag	Energy transferred from the reader via RF
	Tag battery	Yes	No
	Availability of tag power	Continuous	Only within field of reader
	Required signal strength from the reader to to the tag	Very low	Very high (must power the tag
	Available signal strength from the tag to the reader	High	Very low
Functional capabilities	Communication range	Long range (100m or more)	Short or very short range (3m or less)
	Multi-Tag collection	• Collects 1000's of tags over a 7 acre region from a single reader • Collects 20 tags moving at more than 100 mph	• Collects up to a few hundred tags within 3 meters from a single reader • Collects 20 tags moving at 3 mph or slower
	Sensor capability	Ability to continuously monitor and record sensor input; data/time stamps for sensor events	Ability to read and transfer sensor values only when tag is powered by reader; no data/time stamps
	Data storage	Large read/write data storage (128kB) with sophisticated data search and access capabilities available	Small read/write data storage (e.g. 128 bytes)

Table 4.1.2b:Active versus passive RFID[26]

This table (table 4.1.2b) is the complement of the thing written on the page before about passive and active technology.

The required amount of data space (For example, the size of a population of objects to be tagged) determines the number of unique codes needed during the use of the ID system. Since the code space (number of unique codes possible for a system) determines both the ID tag memory length and the speed of transmitting the data transaction, the code space should be as small as possible while sufficiently serving the needs of the system over the expected product life.

[26] Internet, http://www.rfidusa.com/rfid_choices.html

A new generation of low-cost radio frequency identity tags costing less than $1 each means that RFID tags can be disposable and economically used in billions, and this is opening up new markets not available to conventional RFID[27].

All forms of chipless tag can be developed to support predetermined digital data readable by electronic devices anywhere in the world that work to agreed rules. This is the main opportunity, covering perhaps 95% of potential demand. The lowest cost tags, whether chip or chipless, work at no more than 2.5 -25cm range and they are usually read only, although some are remotely cancelable. Chipless tags are more rugged and physically flexible than chip tags, they work over a wider temperature range and some are less susceptible to electrical interference. And unlike chip tags, if buried in thin packaging and labeling, they do not create a telltale bump to alert the counterfeiter to their presence. Some types are only 20 microns thick and some can be printed directly on a product, using a special ink.

However, chipless tags remain primitive in data-handling terms. They usually have limited memory (64 bits or less and most of them 24 bits/6 digits or less) and no encryption[28]. At present, only chips can do remote rewriting without line of sight, though most chipless tags can be made in a form that is rewriteable or partly rewriteable by contact if that is what is required. Chipless tags are more economic where batches with a given ID are required. Chipless tags' most compelling benefit is low cost combined with thinness and ruggedness. This means that they will usually be the winners in brand protection and highest volume logistics. As the barcode is replaced across the world in the next 50 years it will be the chipless RFID tag that is mainly responsible. From being just 2,5% of the RFID market today, chipless devices have the potential to grow to 30% of the market by 2010[29].

4.1.3 Antenna

The antenna emits signals in order to activate the tag and read or write data to it. Each system contains at least one antenna, sometimes two. Indeed one antenna transmits and one antenna receives the signal, in some systems, one antenna can do both those two applications.

Depending on the application, the quantity and type of antenna that are used differ. It can de found in different sizes and shapes, some can fit in very tiny spaces (e.g. used for animals) and some are very large so that they can emit in long distance.

With other components of the link budget determined, antennas can be selected (and possibly make up for any shortfall in link budget). Antenna selection is usually guided by antenna size and cost, followed by desired coverage area and gain. For example, it is

[27] Internet, http://www.idtechex.com
[28] Internet, http://www.idtechex.com
[29] Internet, http://www.frontlinetoday.com

impractical to use large antennas on handheld devices or to use directional antennas at central locations with remotes spread over 360° areas.

In indoor applications, directional antennas can provide better performance than omnidirectional antennas. This is not due to the gain increase typically associated with directional antennas, but rather to backside and off-axis rejection that can reduce multipath cancellation. Not all directional antennas (e.g., Yagi antennas) have much backside rejection.

Antenna gain results from focusing transmitted energy into a smaller cross-sectional area. Ideal radiators, called isotropic radiators, radiate energy in all directions from a point source at equal intensity. Limiting the radiated energy to a portion of this ideal sphere increases signal intensity in the focal area. This is referred to as the EIRP. Therefore, the smaller the coverage area, the higher the antennas gain. The more narrowly focused the coverage area, the more difficult it is to properly aim antennas over long ranges.

The orientation of the tag antenna with respect to the reader antenna will impact on the range. Linear polarization is normal with a simple antenna, such as a dipole or yagi. With linear polarization, the tag's antenna must be in the same orientation as the reader antenna to be able to receive maximum energy. It is possible and highly undesirable, for the polarization of reader and tag antennas to occur at right angles, with a resultant signal null occurring. If non-linear polarization of the reader antenna is used then it is not important which way the tag is oriented Circular polarization of the reader antenna, easy achievable at 900 MHz, allows any tag antenna orientation[30].

4.1.4 Host computer

Now this is a real broad category. The host application tells the reader when to read RFID tags and then do something with the data that it receives. The principal aim of the host computer is to support the software that will enable the reading of the data. It will help with the parity control, error detection and correction.

[30] Internet, http://www.aimglobal.org/technologies/rfid/what_is_rfid.htm

4.2 *How to chose a frequency*

RFID applications are just one of the many radio applications that exists all over the world. These include private, public and mobile telecommunications, radio frequency data capture, security alerts-even garage door opener. The diversity of those devices is exploding into a cloud of differing and exclusionary claims to radio spectrum. The applicants are heard and their claims adjudicated by a network of overlapping but harmonized authorities that allocate spectrum for different radio services under the overall aegis of the International Telecommunication Union (ITU). The electromagnetic spread spectrum is roughly like shown on the diagram (figure 4.2) below:

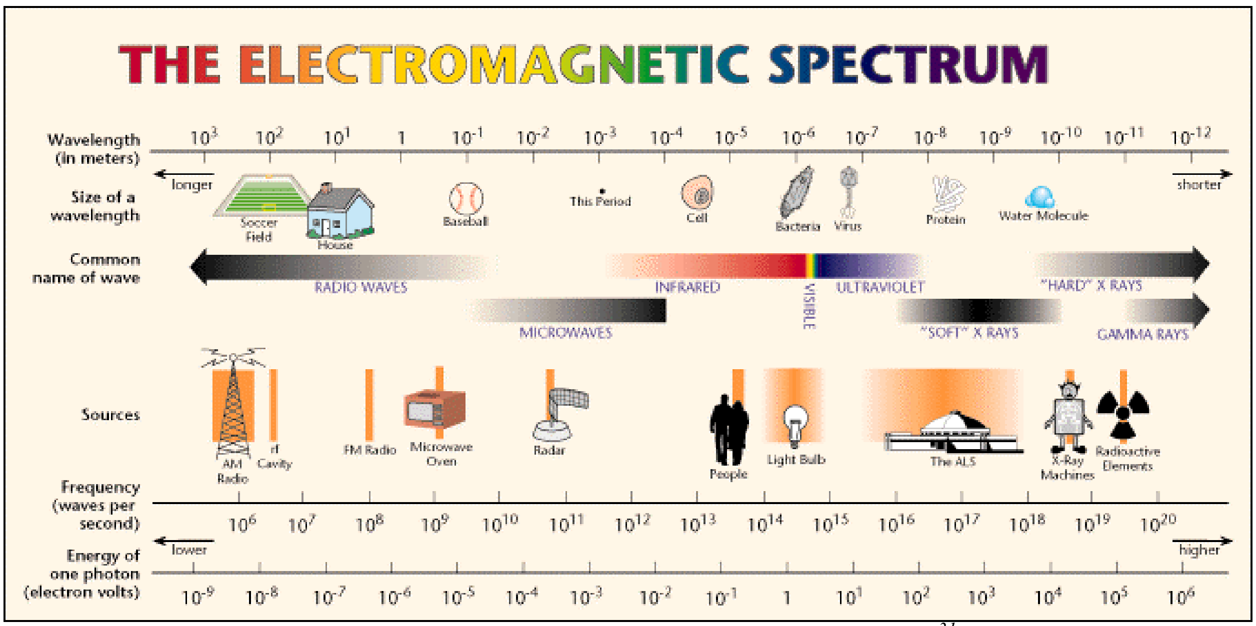


Figure 4.2: The electromagnetic spectrum and its applications[31]

4.2.1 The three regions

If the flexibility that RFID procures is good news, the proliferation of incompatible RFID standards is a big issue. Every vendors offer proprietary system, with the result that various applications and industries have standardized on different vendor's competing frequencies and protocols.

Nowadays, standardization is trying to be held in the three geographical regions (see figure 4.2.1) as defined by the ITU: Europe and Africa (Region 1), North and South America (Region 2) and the Far East and Australia (Region 3). The shaded areas are the Tropical Zones as defined in the regulation.

[31] Internet, http://www.lbl.gov/MicroWorlds/ALSTool/EMSpec/EMSpec2.html

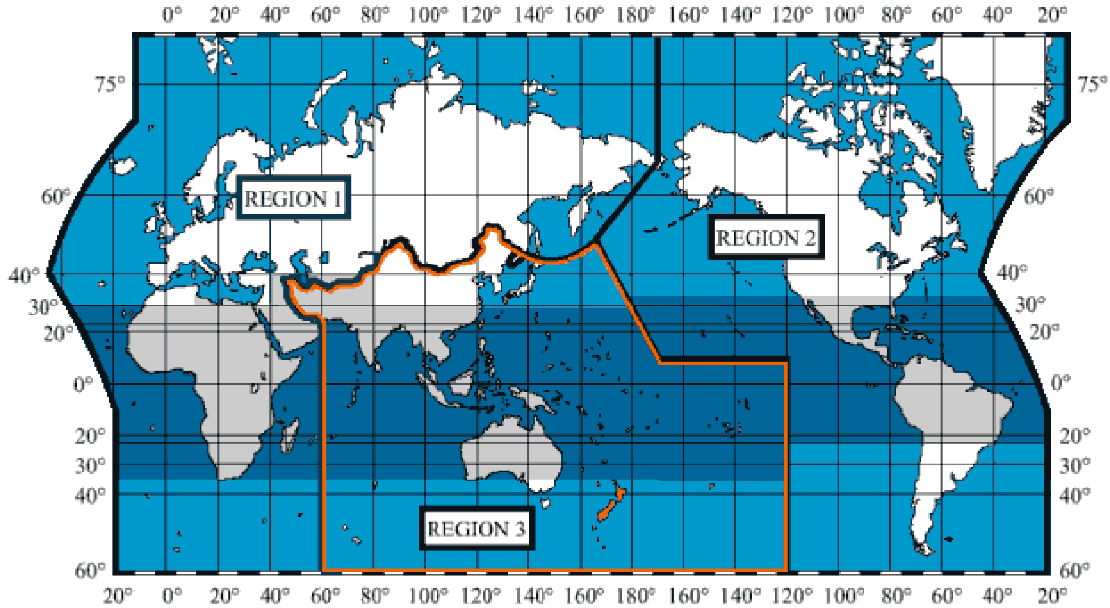


Figure 4.2.1: The three regions as defined by the ITU[32]

Every country takes care of its own frequency attribution while conceding to the rules in its region. Unfortunately those regions showed little cohesion in the past and the radio frequency spectrum is a finite resource. That is the reason why the amount of available frequencies saved for this technology is very small. This also hinders international easy-of-use. Hopefully, this would gradually changed as the countries have to obtain a certain standardisation before the year 2010. As RFID is quite a new technology, this problem is quite usual and should be fixed sooner. The success of RFID highly depends on such agreements between countries. These standards initiatives attempt to lower the cost of the raw material of RFID, and to enhance widespread adoption and use. International standardisation would mean the elimination of duplicate efforts and conflicting systems in market that will clearly be connected as the world becomes increasingly connected trough travel and mobile technology.

However, a number of organisations, both in Europe and in the United States of America, have been working to address some commonalty among competing RFID systems. ISO has already adopted international RFID standards for animal tracking, ISO 11 784 and 11 785.

The three main carrier frequencies that had quickly emerged are 125 kHz, 13,57 MHz and 2,45GHz for respectively the low frequencies, medium frequencies and high frequencies. Eight frequencies bandwidth are nevertheless used in the world of RFID. The applications of those bandwidths are detailed in the table (KLJDH). Not every country has access to those bandwidths as in certain countries they were already attributed to different uses. Every country and every bandwidth has their own prescriptions that determine the frequency uses. Those prescriptions could be on the energy levels and the perturbations as well as on the tolerance of the frequency.

[32] ITU source

4.2.2 Rules on applications

FREQUENCY RANGE	APPLICATIONS AND COMMENTS
Less than 135 kHz	A wide range of products available to suit range of applications, including animal tagging, access control and track and traceability. Transponder systems which operate in this band do not need to be licensed in many countries
6,78/8,1/13,56 MHz	Electronic article surveillance (EAS) and RFID systems and ISM (Industrial, Scientific and Medical)
27,12 MHz	ISM applications and RFID
433/459 MHz	ISM and RFID applications specifically in Region 1
868-870 MHz	RFID in CEPT countries
902-916 MHz	ISM and RFID applications in Region 2. In the USA, this band is well organised with many different levels of priorities. This includes Railcar and Toll road applications.
918-926 MHz	RFID in Australia
2400-2500 MHz	RFID and World-wide ISM band. IEEE 802.11 recognizes this band as acceptable for RF communications and both spread spectrum and narrow band systems are in use.
5400-6800 MHz	Band allocated for future use (including for RFID)

Table 4.2.2: Frequency range applications[33]

The table 4.2.2 shows that depending on the application, the frequency range allocated differs. To help this, some standards have been developed for the enterprise.

Industry Specific Standards[34]:

- Title 21- California Department of Transportation Title 21, compatibility specifications for automatic vehicle identification equipment.
- AAR- Association of American Railroads S-918 mandated standard for automatic equipment identification.
- UIC- Union Internationale des Chemins de Fer standard for European rail transport equipment.
- ANSI- American National Standards Institute MH5.1.9 standard for identification of freight containers.

[33] ITU source
[34] Internet, http://www.aim.com

- ISO- International Organization for Standardization 10374.2 standard for intermodal freight containers.
- ATA- American Trucking Associations standard for automatic equipment identification.
- CEN- Comité Européen de Normalisation EN 10374 for automatic container identification.
- IATA-- International Air Transport Association Recommended Practice #1620.
- IATA- International Air Transport Association Recommended Practice #1740c. DRAFT/4-Feb 97. Radio Frequency (RF) Specifications for interline baggage.

4.2.3 The environment

Apart from the regulation aspects, it is also primordial to take care about the effect of RF on the environment (see figure 4.2.3).

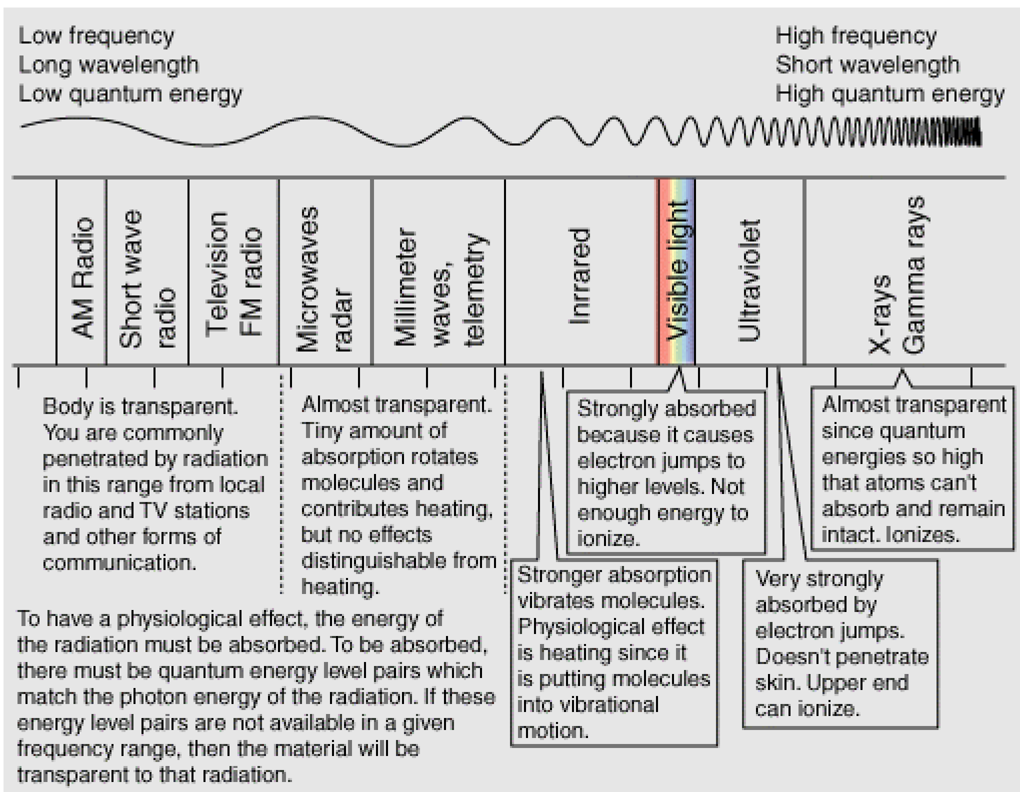


Figure 4.2.3: Impact of the frequencies on the environment[35]

[35] Internet, http://www.fiber-optics.info/default.htm

5 IMPACT OF THE RFID ON THE SUPPLY CHAIN

5 IMPACT OF THE RFID ON THE SUPPLY CHAIN

Now that the technology itself has been explained, it is time in this chapter to explain the role of the RFID in the supply chain.

5.1 Definition of the supply chain

The supply chain is the full range of activities from the earliest level of input, through processes along the chain, to delivery of the final product to the consumer. It includes producers (their input suppliers such as stock feed companies), abattoirs and meat processors, transporters, packers, wholesalers, marketers, retailers, and export/import distributors. One definition of supply chain management is "The network of retailers, distributors, transporters, storage facilities and suppliers that participate in the sale, delivery and production of a particular product"[36].

The partnership (or vertical alliance) of organisations within a specific supply chain should add value to their activities and products. Adding value includes benefits in addition to price; i.e., product meeting specification, flexibility in service, continuity of supply etc, all of which allow this chain to perform better than its competitors.

Competitive advantage arises from a supply chain creating value for the customer and this value is dependent on the activities of all firms in the chain. To be long lasting and successful the partnership must benefit the organisations to a greater extent than their operating independently. Also the partnership is a move from a short-term, opportunistic, transaction based relationship between buyer and seller (based just on price for the product), to a longer-term cooperative relationship.

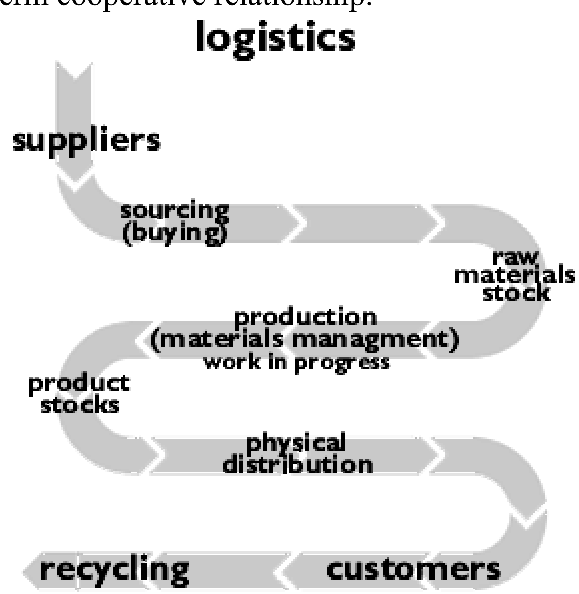


Figure 5.1: The supply chain diagram[37]

[36] Larousse definition
[37] The Institute of Logistics and Transports

What is meant by logistics is the management of business operations, such as the acquisition, storage, transportation and delivery of goods along the supply chain.
Once that all the definitions are given, an example is always good to show. In the two next pages the example of the automation of the supply chain for the milk is given.

5.2Application of the RFID in the Supply chain

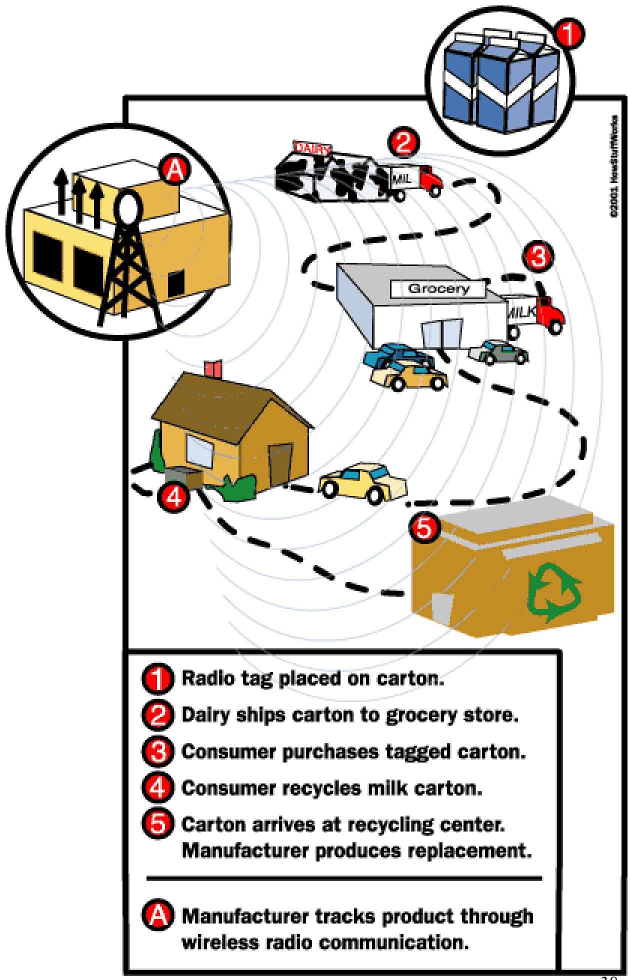


Figure 5.2a: The RFID tag all along the supply chain[38]

1) The milk company adds a Radio Frequency Identification tag to every milk carton. From the concept of Auto-Id center, each tag is cheap and contains a unique Electronic Product Code (EPC). These tags will allow the milk carton to be identified, counted and tracked in a completely cost-effective fashion.
The cartons are packed into cases, which have their own RFID tags, and loaded on tagged palettes.

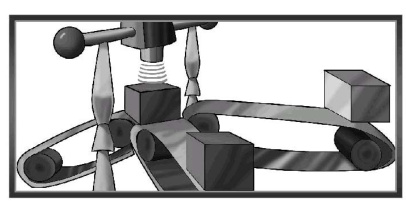
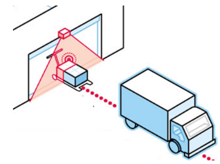


Figure 5.2b: Example of a tag's reading[39]

[38] Internet, http://www.cs.unc.edu/~sparkst

2) As the palettes leave the manufacturer, an RFID reader positioned above the loading dock door for example hits the smart tags with radio waves powering them. The tag "wake up" and start broadcasting its individual EPCs. Only one tag is allowed to talk at a time. It rapidly switches them on and off in sequence, until it has read them all. The reader is wired into a computer system, it sends the EPCs it has collected. The system sends a query over the Internet to en Object Name Service (ONS) database, which acts like a reverse telephone directory: it receives a number and produces an address. Because it knows the location of the reader which sent the query, the system knows which plant produced the milk carton. If an incident involving a defect or tampering arose, this information would make easy to track the source of the problem. The palettes arrive in the shipping service's distribution center. Thanks to RFID reader in the unloading area, there's no need to open packages and examine their contents. The system provides a description of the cargo, and the milk cartons are quickly routed to the appropriate truck. The delivery arrives at the grocery store, which has been tracking the shipments thanks to its own system connection. The grocery store also has loading dock readers. As soon as the milk carton arrives, the grocery store's retail systems are automatically updated to include every milk carton that arrived. In this manner, it can locate its entire milk carton inventory automatically, accurately and without incurring cost.



3) The grocery store's retail shelves also feature integrated readers. When milk cartons are stocked, the shelves "understand" what is being put in them. Now, when a consumer grabs of a milk carton, the diminished shelf will route a message to the grocery store's automated replenishment systems. With such a system, the need to maintain costly "safety volumes" of milk cartons in remote warehouse is eliminated. Tags make customer's life easier too. Rather than wait in line for a cashier, the customer simply walks into a gate with its purchases. A reader built into the door recognizes the items in the cart by their individual EPCs. A swipe of the debit or credit card and the customer is on its way home. At home, the refrigerator updates its records to reflect the influx of milk carton. As the milk is depleted, the fridge will add the beverage to its automated grocery list.

4) When the milk cartons hit the recycling center, RFID readers will automate the process of sorting them into the appropriate recyclable category (eliminating expensive manual sorting).

5) The cartons can even be routed to their manufacturer for reuse at the plant.

[39] Internet, http://www.rfidusa.com/pdf/manuf_dist.pdf

5.3 Analysis of the RFID in the supply chain

From interpreting this example, it is now possible to enumerate all the advantages that a company could get by using the RFID and not the barcodes. The limitations of this technology are also going to be listed in this chapter.

5.3.1 Advantages

Unlike barcodes, the memory available in the tag can be modified, extended or reduced all along the chain by authorized users in order to update the historic of the product. Tags can be incorporated in the equipment used for handling (pallet) or in the original packaging. If the content or the destination of one product is changed during the transportation, a new label had to be printed and pasted on the product whereas now the data has just to be reprogrammed.

To allow bar code labels to be read automatically, standardization committees, such as EAN International and the UCC, have defined rules for positioning labels on trade items and logistic units. RFID labels, however, are not subject to the same restrictions of visibility. All that is required to detect an RFID label is that it must be within the field of the reader[40]. This means that a lot of time can be won as the items do not have to be very well positioned when read (The data transfer is performed in fractions of a second resulting in higher processing speeds and faster logistic processes). The person that used to do that job with barcodes is not needed anymore. Whereas the barcodes had to be visible, the RFID tags are ultra thin and can be read when concealed within a folder or item. Moreover, a reader, using an anti-collision algorithm, can read numerous tags that are in the field of the reader at the same time. Data is recovered from one tag at a time. Therefore the time to read all tags in the field will increase with the number of tags to be read in the field[41].

The transportation of goods becomes more secure as tags can be hidden to provide enhanced security. Data can be fragmented in different part with different password so that authorized persons only can have access to it. Some RFID proponents believe that RFID will eventually replace EAS tags as a way of preventing theft. A source at Tyco says the company's view is that its customers will likely want EAS, or RFID or a combination of the two and that the company is well placed to provide whatever technology customers need.

Today, companies produce goods in the hope that consumers will buy them. In the future, RFID will help to better match supply and demand, so we are not producing huge amounts of product that no one really wants. More efficient use of resources is critical to preserving the environment.

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[40] EAN international
[41] EAN international

A survey made by the Ifop for Agro Market International tells that the first thing that can reassure the customers is to know the origin, the composition and the production's mode of the product (44%). 72% are ready to pay more for the same thing just if it has precise information on it. "Traceability has a cost and it is accepted, it is a real revolution" said Jean-Jacques Mennillo[42].

The concept of traceability was born in the middle of the eighties but it was only the answer of logistic issue: it guaranteed the control of the good's flux within a supply chain permitting to save up. This is not the reason why many companies, from all over the world, whereas nothing was compelling them to do it, have decided to equip their firms with complete traceability system. Nowadays, the responsibility in case of a crisis is no more on only one boss' shoulders.

The recent Coca-cola's case just proved it: whereas the firm of Atlanta and her subsidiaries in Europe had a traceability system, both the Belgium and the French government forbade the selling of its goods because many wholesaler clients couldn't trace the trade exchanges.

Traceability is defined as the aptitude to find the historic, the utilization or the localization of an article or an activity, or articles or similar activities, by means of a registered identification[43]. This permits to follow and to find a good from his creation (production) to his destruction (consumption). The mean of it is to collect and to treat traceability information so that at every step of the chain, it would be to enrich and to strengthen it in database in order to let the information accessible to concerned people.

The first objective of traceability is to identify a product or a batch of goods so that it could be taken away from the chain very quick with maximum security in case of non-conformity, danger. It also permits to intervene at the origin of the production (raw materials) that enables a diminution of quality costs which usually intervened at the end (final product). Fluxes are much more identified and many statistics can be brought out of it, which can be useful for the "after selling service" and the marketing service. Traceability improves the quality and the global efficiency of a firm.

And, of course, RFID will also help the environment by making it possible to identify goods that can be recycled (not to mention hazardous materials that need to be disposed of according to special procedures).

As to clarify this part of the report, the table in next page (table 5.3.1) will help the comprehension.

[42] President of Agro Marches Internationaux
[43] ISO 8402 definition

Coverage Area	How it works	Benefits	Results
1. RECEIVING	• Reads pallet-level and case-level tags as product is moved off the truck and into the receiving area • Verifies match between pallet ID tag and cases on pallet, and source of product and purchase order confirms receipt	• Eliminates manual steps to enable faster and more accurate receiving process	➢ Less labor ➢ Better information accuracy ➢ Improved throughput ➢ Higher asset utilization ➢ Reduces returns/claims ➢ Improves customer service levels
2. FORKLIFT/ ORDER PICKER	• Reads case tags as product is taken from location and placed on a pallet or belt (case picking) • Integrates with WMS to validate product and picking quantities, updates inventory	• Eliminates manual steps to count and record picks • Eliminates time spent correcting error • Improves order line fill rate	
3. CONVEYOR	• Reads case tags as product passes reader on belt • Integrates with WMS and conveyor control to divert product and record transaction	• Does not require line of sight • Eliminates time spent correcting no reads	
4. SHIPPING	• Reads pallet-level and case-level tags as product is onto the truck moved • Integrate with the WMS to confirm product, customer, truck, load sequence	• Eliminates manual steps to enable faster and more accurate loading • Enables direct loading from pick	

Table 5.3.1: Advantages of the RFID in the supply chain[44]

[44] Internet, http://www.autoidcenter.com

5.3.2 Limitations

A system cannot have only advantages, it has to have some limitations. Some of them are going to be defined in this chapter.

The radio waves will not go through metal or any conductive material such as a liquid. A human body can block the radio waves (as it is 90% water) as can metal shelving or a concrete wall containing rebar. The presence of metal can affect RFID system performance causing shielding or reflections or introduce frequency shift keying in the system. However, Tagsys, in conjunction with Philips, has already tackled the problem, with demonstration of a system that reads through shampoo bottles. Signal detection is helped by the use of spread spectrum technology but can be significantly degraded by the presence of nearby conducting objects. Special tags are needed for metal containers or containers with conducting liquids.

With passive ID tags the retransmitted energy level is very small. Returned signal detection can be lost due to interference from other devices operating on the same wavelength (RF barcode scanners, cell phones, wireless LANs to name but a few). This is a real problem than can cause damages especially in places like hospitals or airports.

The receiver can only detect a limited number of tags within its antenna's range (typically 10 to 50). In a very simple system only the closest tag will be detected. By using various schemes, such as randomly varying the retransmit delay time from the tag, most systems can read a limited number of tags at the same time. RFID triggers tremendous amounts of data, with thousands of tags being read every second by multiple readers within range of the tagged objects. It’s technology to the rescue in this case: The Savant framework with the Oat Systems applications riding on it. The system uses business rules to ignore most repetitive data but links certain new events to alerts and actions. In a demonstration, Gillette’s chairman had his picture taken at a simulated shelf when he took more than two Mach 3 Razor Blade packs.

These are now required by regulations in Japan, Europe, and North America. ThingMagic has developed an agile reader that can handle multiple frequencies. It is in use at several pilots, and global giant Tyco/Sensormatic.s agreement to manufacture the reader provides viability

RFID technology seems to have a large number of limitations but fortunately many companies are working on this and some of the problems are on the way to be solved.

In order to illustrate all that has been said and the different chapters of this master thesis, the table (figure 5.3.2) recapitulates which technology is best suitable for which application.

Application → / Technology ↓		Logistics - Pallets, Freight, vehicles	Logistics –cartons, baggage	Logistics – item level	Transactions/tolling	Positioning/locating	Anti-counterfeiting	Secure Access including car keys	Ticketing/magstripe replacement
Passive Chipless Tags	Electromagnetic			●			●	●	
	Magnetostrictive			●			●		
	LC arrays		●			●			
Passive Chip tags	Electric beam (high freq)	●	●	●	●	●	●	●	
	Inductive (low freq)	●	●		●		●	●	●
Semi-active tags (chip)		●			●	●			
Active tags (chip)		●				●			

Table 5.3.2: Which application for which technology[45]

[45] Internet, http://www.idtechex.com

6 Conclusion

6 Conclusion

The RFID is finally a quite recent technology that is in full expansion. It has been and is still under a lot of conception, evolution and normalization phases. It started with an active battery technology with a limited lifetime and has nowadays tipped over passive technology. The situation is quite identical as the one that chip cards had undergone in the years 1980. The enthusiasm of the market and the means deployed let augur a much higher development speed.

As said in the master thesis, a lot of different technologies are on the market, but no single technology will win, because the required size and price of the tag varies by many magnitudes as does the range and other parameters. Functionality varies also widely between applications.

Some people would think that this technology is a danger for privacy as the movement of the goods would be done all over the surface of the globe. Indeed, every single thing is about to be tagged and tracked (shirts, shoes, mobile phones….), but some firms are now developing some tags that would be “auto destroyed” when bought by a consumer. As it is explained all along this master thesis, the RFID is only used to improve the supply chain efficiency and to progress in security efficiency.

The RFID technology, despite its new appearance on the market is becoming very useful and quite irreplaceable. As it is also quite a simple technology and as it is becoming cheaper and cheaper, it is for sure that you would use it in your everyday life quite soon. So get prepared to first experience it and then use it.

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7 REFERENCES

7.1 Table of figures

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