ABSTRACT

The use of Ultra High Frequency (UHF) Radio Frequency Identification (RFID) in supply chain management (SCM) systems was a big source for optimism. However, the expected rapid industry adoption of RFID did not take place. This research explores some of the existing challenges and obstacles to RFID adoption, such as the lack of consistent UHF spectrum regulations for RFID or the absence of standards that promote integration with Automatic Identification and Data Capture (AIDC) media. As a conclusion, in this project we suggest some solutions to these challenges in the use of multi-frequency RFID tags that can be read at more that one frequency or novel migration strategies and standards that would help expand the industry.

1 TRACEABILITY

The International Organization for Standardization (ISO) defines traceability , in the International Vocabulary of Basic and General Terms in Metrology Like:

The ownership of the result of a measurement or the value of a standard where it can be related to specified references, usually national or international standards, through an unbroken chain of comparisons all with uncertainties specified.

According to the Food Safety Committee AECOC:

"Traceability is defined as all those self-established procedures and that provide insight into the history, location and path of a product or batch of products along the supply chain at any given time, through a specific tool."

1.1 Internal and External traceability

At the time of having to understand the traceability of a product moves through its supply chain and its logistics industry, the concept of traceability is divided into two distinct parts:

Internal Traceability, which is just the trace to obtain a product that leaves all the internal processes of a company, with their manipulations, their composition, equipment used, in turn, its temperature, batch, etc., all the evidence they do or can modify the product to the consumer.

External Traceability, which is more than externalize the internal trace data and add some more evidence if necessary, as a failure of the packaging, a change in the chain of temperature, etc.

As a result we see that to obtain traceability of a product, you have to go searching the evidence that leaves the product as it moves along the chain, either in the normal sense or in the opposite direction (such as reverse logistics). There are many ways of recording evidence, such as temperature sensors, humidity, etc., but there are few methods to pass on these signs in a standardized manner between different actors in the chain, among which the encoding GS1-128 and EPC .

1.2 Benefits of traceability

The new and stringent regulations of the United States and the European Union to require food-exporting countries have verifiable traceability systems. Required response times and volumes of information to manage, makes the incorporation of information technology in an investment that ensures the arrival of the products to market more demanding buyers.

When it comes to traceability for export, one of the obstacles to overcome is the cultural, due to the lack of agreement about what it means and what the scope of the concept. Many companies believe they have traced products when in fact it is not, and only discovered the mistake in the event of a problem on arrival. Depending on the severity of the incident, the practice shows the recall of all the merchandise associated with the lot with problems. However, if the tracking information does not apply at the level of each box, instead of removing the item in dispute, the company should withdraw all of its shipments to all destinations. The economic consequences are enormous, but this adds to the negative impact on business image and credibility of both the company and country. Even though only rarely these events have an impact on consumer health.

1.3 Applications

Traceability is applied for reasons related to business improvement that justifies their presence: more efficient production processes, lower costs fail, better customer service, etc. In this area include sectors such as automotive, aerospace, distribution, logistics, consumer electronics, ETC.

This practice is possible certification, for example in quality management systems, environmental management and control systems known as chain of custody.

A new application is in the construction industry. Currently, construction companies and end users, require a good tracking of its products for use in the work. In which case, tracking begins when the product reaches the work, quality certification, referrals purchase and supplier data, and immediately afterwards, laboratory tests are recorded, shipping dates, enabled, casting and performance charts.

For example: in a structural element as a concrete column, the trace elements would be the steel and concrete basically. For steel, quality certificates are identified, the number of

bound metal, weight, number of pieces of evidence destruction and enabled dates. For concrete would have to register: Provider, Endurance, age, warranty, aggregate size, slump, cement type, dose and additional additives, if any used. Once registered these data usually are obtained from the note accompanying the concrete supplier, are registered concrete testing and performance charts for that particular item. If any, is included in the record, more specific laboratory studies such as, concrete coring, magnetic resonance studies and others to verify the physical and actual composition of the item.

Under this scheme, we can create the history of earthworks, civil engineering, metal, rolling, and finished up a building.

Thus, the purpose and outcome of traceability would be necessary if structural elements fail. Why did it fail?, what were the materials? On what date was it built? Who were the suppliers?, are answers to be found in the appropriate record and detailed for each and every one of the elements of a building.

1.3.1 Measurement

The term measurement traceability is used to refer to an unbroken chain of comparisons relating an instrument's measurements to a known standard. Calibration to a traceable standard can be used to determine an instrument's bias, precision, and accuracy.

In many countries, national standards for weights and measures are maintained by a National Measurement Institute (NMI) which provides the highest level of standards for the calibration / measurement traceability infrastructure in that country. Examples of government agencies include the National Physical Laboratory, UK (NPL) the National Institute of Standards and Technology in the USA, and Physikalisch-Technische Bundesanstalt (PTB) in Germany. As defined by NIST, "Traceability of measurement requires the establishment of an unbroken chain of comparisons to stated references each with a stated uncertainty."

1.3.2 Logistics

In logistics, traceability refers to the capability for tracing goods along the distribution chain on a batch number or series number basis. Traceability is an important aspect for

example in the automotive industry, where it makes recalls possible, or in the food industry where it contributes to food safety.

The international standards organization EPCglobal under GS1 has ratified the EPCglobal Network standards (esp. the EPC Information Services EPCIS standard) that codify the syntax and semantics for supply chain events and the secure method for selectively sharing supply chain events with trading partners. Theses standards for traceability have been used in successful deployments in many industries and there are now wide ranges of products that are certified as being compatible with these standards.

1.3.3 Materials

In materials, traceability refers to the capability to associate a finished part with destructive test results performed on material from the same ingot with the same heat treatment, or to associate a finished part with results of a test performed on a sample from the same melt identified by the unique lot number of the material. Destructive tests typically include chemical composition and mechanical strength tests. A heat number is usually marked on the part or raw material that identifies the ingot it came from, and a lot number may identify the group of parts that experienced the same heat treatment. (i.e. were in the same oven at the same time.) Material traceability is important to the aerospace, nuclear, and process industry because they frequently make use of high strength materials that look identical to commercial low strength versions. In these industries, a part made of the wrong material is called "counterfeit," even if the substitution was accidental.

1.3.4 Supply Chain

In the Supply chain, traceability is more of an ethical or environmental issue. Environmentally friendly retailers may choose to make information regarding their supply chain freely available to customers, illustrating the fact that the products they sell are manufactured in factories with safe working conditions, by workers that earn a fair wage, using methods that do not damage the environment.

1.3.5 Software

In software development, the term traceability (or Requirements Traceability) refers to the ability to link product documentation requirements back to stakeholders' rationales and forward to corresponding design artefacts, code, and test cases. Traceability supports

numerous software engineering activities such as change impact analysis, compliance verification or traceback of code, regression test selection, and requirements validation. It is usually accomplished in the form of a matrix created for the verification and validation of the project. Unfortunately the practice of constructing and maintaining a requirements trace matrix (RTM) can be very arduous and over time the traces tend to erode into an inaccurate state unless date/time stamped. Alternate automated approaches for generating traces using information retrieval methods have been developed.

1.3.6 Blood

In blood transfusion practice, the term traceability relates to the requirement for a continuous audit trail accounting for the whereabouts of a blood product and its current status in terms of processing, testing, storage, etc. at all points from initial collection from a donor right through to either transfusion to a recipient or disposal. This is particularly important with regards to prevention of transfusion-transmitted infection, and is a legal requirement in many countries including all member states of the European Union.

In transaction processing software, traceability implies use of a unique piece of data (e.g., order date/time or a serialized sequence number) that can be traced through the entire software flow of all relevant application programs. Messages and files at any point in the system can then be audited for correctness and completeness, using the traceability key to find the particular transaction. This is also sometimes referred to as the transaction footprint.

1.3.7 Food processing

In food processing (meat processing, fresh produce processing), the term traceability refers to the recording through means of barcodes or RFID tags & other tracking media, all movement of product and steps within the production process. One of the key reasons this is such a critical point is in instances where an issue of contamination arises, and a recall is required. Where traceability has been closely adhered to, it is possible to identify, by precise date/time & exact location which goods must be recalled, and which are safe, potentially saving millions of dollars in the recall process. Traceability within the food processing industry is also utilised to identify key high production & quality areas of a business, versus those of low return, and where points in the production process may be improved.

In food processing software, traceability systems imply the use of a unique piece of data (e.g., order date/time or a serialized sequence number, generally through the use of a barcode / RFID) which can be traced through the entire production flow, linking all sections of the business, including suppliers & future sales through the supply chain. Messages and files at any point in the system can then be audited for correctness and completeness, using the traceability software to find the particular transaction and/or product within the supply chain.

The European Union's General Food Law came into force in 2002, making traceability compulsory for food and feed operators and requiring those businesses to implement traceability systems. The EU introduced its Trade Control and Expert System, or TRACES, in April 2004. The system provides a central database to track movement of animals within the EU and from third countries. Australia has its National Livestock Identification System to keep track of livestock from birth to slaughterhouse.

India has started taking initiatives for setting up traceability systems at Government and Corporate levels. Grapenet, an initiative by Agriculture and Processed Food Products Export Development Authority (APEDA), Ministry of Commerce, Government of India is an example in this direction. GrapeNet is an internet based traceability software system, for monitoring fresh grapes exported from India to the European Union. GrapeNet is a first of its kind initiative in India that has put in place an end-to-end system for monitoring pesticide residue, achieve product standardization and facilitate tracing back from pallets to the farm of the Indian grower, through the various stages of sampling, testing, certification and packing. Grapenet won the National Award (Gold), in the winners announced for the best e-Governance initiatives undertaken in India in 2007. Grapenet was designed and developed by Logicsoft, award winning traceability solutions company, based in New Delhi, India.

1.4 Traceability and RFID

Following the development of new technologies, RFID today plays an important role in getting the product traceability along the supply chain. Today, barcodes are scanned manually million times each day to enter data into computers and can record the evidence you need traceability. Today, the supply chain is extremely dynamic, in which goods and

transactions flowing in both directions, where what is sought is to provide customers what they want, when you want to be and where he wants.

RFID streamlines the supply chain to get delivered faster, customizing orders, reducing stock and ready to reverse chain. Today, the RFID responds to the challenges in a global economy, complying with existing traceability legislation.

2 DIFFERENT IDENTIFICATION SYSTEMS

Different automatic identification systems exist. In this family we can find systems like barcode, intelligent labels, RFID or in another field voice recognisor systems or fingerprint. We can observe that the schedule of these different systems in the figure 3.1.

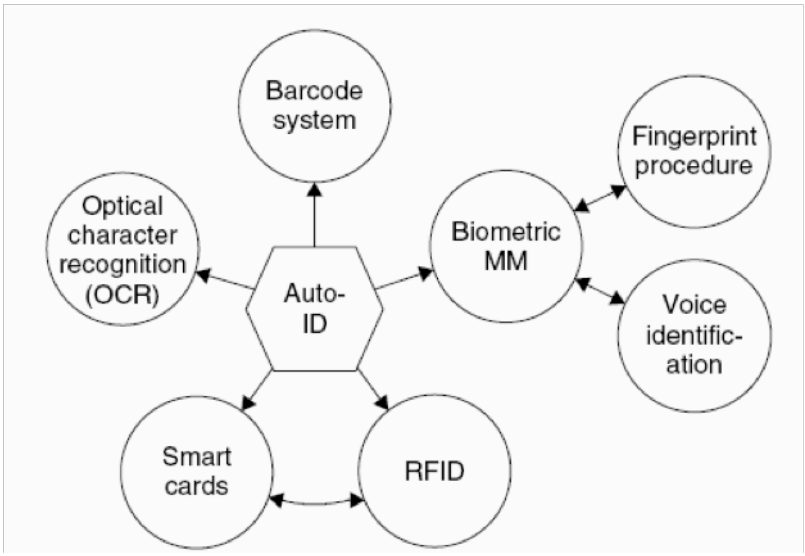


Figure 3.1- Most important communication systems.

2.1 Barcodes

It is the most used identification system. The barcode is a binary code made for some parallel bars and spaces. These fields design represents a data related with an element. The sequence can be interpreted like a numeric or alphanumeric form. This sequence is reed for a laser optical scanner, which is based in the different reflection that the laser light suffers in the black and white bars. We can see a classic barcode in the Figure 3.2.

Figure 3.2- Barcode with the product ISBN.

The most popular of these barcodes is the EAN (European Article Number) code, which was specially designed for the alimentation section. This code is an US UPC (Universal Product Code) evolution, which was introduced in the EEUU before 1973. Nowadays these two codes are totally compatibles. The EAN code is form for 13 digits: the country identifier, the enterprise identifier, the manufacturing number and the check digit. Other barcodes systems exists in other industrial fields like the Codabar code, in the medical section, the 2/5 code in the automobile industry, ships containers, heavy industry or the 39 code, used in industry process, logistics or bookstores. We can see the barcode structure with EAN code in the figure 3.3.

<table>
<tr><td colspan="2">Country identifier</td><td colspan="5">Company identifier</td><td colspan="5">Manufacturer's item number</td><td>CD</td></tr>
<tr><td>4</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>0</td><td>8</td><td>1</td><td>5</td><td>0</td><td>9</td></tr>
<tr><td colspan="2">FRG</td><td colspan="5">Company Name
1 Road Name
80001 Munich</td><td colspan="5">Chocolate Rabbit
100 g</td><td></td></tr>
</table>

Figure 3.3- EAN Barcode structure.

Another kind of optical system exist named OCR (Optical Character Recognition) that was first used in the sixties. These systems have an advantage for their huge information density. Nowadays they are used in production, service and administrative fields and in some banks for the check ticket register. The problems of these systems are their high price and the readers complexity comparing with other identification systems.

Nowadays is being discussed the possibility that the RFID systems replace the barcodes, for that reason we can compare the two technologies:

The barcode was invented 25 years ago and, during this time, it has been the more used technology for the commerce to identify the products. Nevertheless, the barcode has some limitations:

- Line of sight. In other words, the barcode must be visible for the reader to identify the product.

- The barcode identifies one type of product, not a unit of this product. The X barcode can identify bottles of water, but can not difference a specific bottle. This is not an inherent technology limitation but usually the barcode systems are not used as unique identifiers.
- A barcode is easily damaged or injured, because usually is attached to the product surface and is not a part of it, and if is broken can not be read.

The RFID technology beats these limitations. We are talking of radial technology (in other words, is not necessary that the tag and the reader became face to face, it works in a determined action range), can identify unique products and not only the product itself and, finally, the dispositive is very resistant and usually it is part of the product or is placed in a protected surface.

It also remarkable that even the tag's fabrication cost is low it would never be lower than the barcode system price, but in a long term the RFID installation can result more economic than optical system due to the inherent advantages.

2.2 Biometric procedures

They are people identifier systems through individual features comparison and matching it with an individual physical characteristic and it does not admit mistakes. We can talk of fingerprint identification systems, voice identification and retina identification.

2.3 Smart cards

A smart card is a system of electronic data storage, with an additional capacity to process such data (microprocessor card). For convenience it is embedded in a plastic card that is sized like a credit card. The first smart cards were launched in 1984 as telephone cards. Contact with reader provides power and a clock pulse. The data transfer between and the card reader may use a bidirectional serial interface (port I / O). One of the main advantages of smart cards is the ease of storage information and protection that has potential unwanted access. Are safe and inexpensive.

Its disadvantage is vulnerability to contact with clothing, corrosion and dirt. Readers that are used often are very expensive to maintain due to malfunction.

It is possible to distinguish two types of smart card for its internal operations: Memory card and microprocessor card. In the memory card, usually an EEPROM is accessed using a logical sequence state machine. Has a simple security algorithms and functionality specific to each application. These cards are very limited as far as functionality is concerned, but supplemented with minimal cost.

The microprocessors are connected to segments memory (ROM, RAM and EEPROM). Those who have built a system ROM microprocessor operating inserted during manufacturing. It cannot be subsequently modified. RAM, an area where the microprocessor works with temporary memory, the stored data is deleted when you disconnect the power. The EEPROM contains application data and programs manage the application. Are changed while operating it. Cards are very flexible, which can perform more than one application.

System parameters	Barcode	OCR	Voice recog.	Biometry	Smart card	RFID systems
Typical data quantity (bytes)	1–100	1–100	—	—	16–64 k	16–64 k
Data density	Low	Low	High	High	Very high	Very high
Machine readability	Good	Good	Expensive	Expensive	Good	Good
Readability by people	Limited	Simple	Simple	Difficult	Impossible	Impossible
Influence of dirt/damp	Very high	Very high	—	—	Possible (contacts)	No influence
Influence of (opt.) covering	Total failure	Total failure	—	Possible	—	No influence
Influence of direction and position	Low	Low	—	—	Unidirectional	No influence
Degradation/wear	Limited	Limited	—	—	Contacts	No influence
Purchase cost/reading electronics	Very low	Medium	Very high	Very high	Low	Medium
Operating costs (e.g. printer)	Low	Low	None	None	Medium (contacts)	None
Unauthorised copying/modification	Slight	Slight	Possible* (audio tape)	Impossible	Impossible	Impossible
Reading speed (including handling of data carrier)	Low ~4 s	Low ~3 s	Very low >5 s	Very low >5–10 s	Low ~4 s	Very fast ~0.5 s
Maximum distance between data carrier and reader	0–50 cm	<1 cm Scanner	0–50 cm	Direct contact**	Direct contact	0–5-m, microwave

Table 3.1- Comparison of the different systems.

3 RFID SYSTEMS

3.1 What is a RFID system?

A RFID (Radio Frequency IDentification) system is a wireless technology that allows the communication between a reader and a label. Those systems can store information in the labels using radio frequency waves. The range of this information can be from a Bit to Kbytes, depending of the store capacity of the label.

The RFID systems are not new at all, it appears in the 80's in identification systems, but is now when many industries fields are looking this technology, that thing is the cause of all the advances of this technology. Is for that reason that continuous standards, application and innovations are appearing.

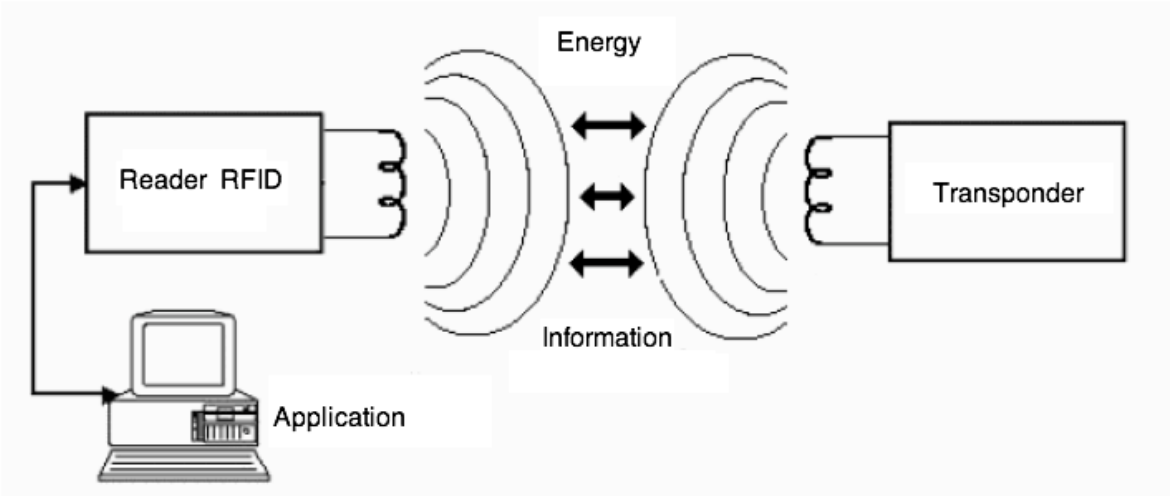


Figure 4.1- RFID working system.

A tag, transponder or smart label has a microchip and an antenna, which can adders to any product. Even now there are some tags under development that are made with so small size that cannot be seen in some objects. The microchip stores an identification number – a kind of unique registration of that product-. There are some kinds of proposed methods for that numbers, for example the Electronic Product Code (EPC), designed by Auto-ID Center. We can say that every object will has a unique code that will difference and identify not only in other kinds of products but equal products.

The working of the system is so simple, as we can see in the Figure 4.1; the reader sends some radiofrequency waves to the tag, that its micro antenna captures them. Those waves active the chip, then, using the micro antenna and through radiofrequency waves, transmits to the reader the memory information. Finally the reader receives the tag's information and then is send to database which has a previously registration of that products or can be processed depending on the application.

The communication within the reader and the tag is realized through radiofrequency signals in a specific frequency that reader antennas and tags generate, this frequencies can be the same or harmonics. The communication within them has specific range, velocity and security characteristics depending on the frequency range, the used antennas, kind of tag and some others parameters that can be configured for specific uses.

In RFID systems we can find anti-collision systems that lead reed different cards at the same time. In case of various tags are in the same reach range of the reader and two or more would like to transmit at the same time, a collision is produced. The reader detects the collision and order to stop the tag transmission during a short period of time. Later the tags will answer one by one using a complex algorithm. Obviously with a more capacited tag and reader, the algorithms will be more effectives.

The RFID works with a range from 50KHz to 2.5GHz. The units that work at Low Frequency (50 KHz – 14 MHz) are of low cost, low range and noise resistance. The license is not required to operate in this range of frequency. The units that works in the highest frequencies (14 MHz – 2.5 GHz), are expensive and with a more complex technology. The electromagnetic radiation of a RFID reader is less than a fifth part of the produced by a mobile phone, that means that five activate antennas located near a person generate less radiation than a mobile phone; in the real live, is very difficult that one person becomes near of one or more activated antennas at the same time, so RFID electromagnetic radiation is not dangerous for the health.

The label is containing information that can be read or lead the writing, depending on the kind memory that the tag belongs. More of the systems have EEPROM (Electrically Erasable Programmable Read-Only Memory). In some the information came written from the enterprises and in other cases the user can write it. The user receives the information in a portable reader with an alphanumeric display or can link it directly in a computer that processes the obtained data.

For the RFID system creation you must consider different design things as reach range where the communication can be done, the information capacity of the transponder, the data flux velocity obtained between the reader and the tag, the physical characteristics of the tag, the multi-tag capacity of the reader or the strength of the communication to noises between the reader and the tag. You must consider the emission level to do not exceed the country regulations, if a supplementary battery exists to communicate a tag with a reader.

The RFID systems have an advantage of the not seen functionality between the tag and the antenna. In this point is where the barcode and other optical systems has been upgraded. But due to the costs, which have been reduced progressive instead of being always more expensive than barcodes, It has not been yet implemented in the daily applications where the barcode is still being the most used technique. But is in the applications where the barcode and the optical technology is limited and is not effective, where the growing RFID technology is becoming important.

RFID systems have a lot of applications. They can be used as identification cards with no contact, for example we can see that method in the Spanish toll payment system "Via-T", that leads the vehicle pass without stopping. Another used application is the vehicle immobilizer, they consist in a interrogator system located in the safety vehicle and a key identification. They are used to identify letters and packages in a post agency, animal identifications, aerial luggage identifications, supermarket management, automatic inventory, automatic distribution, etc… Now a days its been talk to use that RFID technology in the probation people or people who may be considered dangerous for the society identification. There are also some projects in progress that include medical history chips and in legal banknotes to avoid steels and localize the money all the time.

It is sure that these applications can bring a lot of advantages. For example, to know the medical history of an unconscious person with no lose of time with the doctor's reader, can reduce the action time and save his life. Nevertheless a lot of people and institutions are against this implementations because of a privacy violation. The use of RFID identifier in the banknotes could cause that someone with a RFID knows instantly how much money brings a person or has in house.

They try to apply this system in all of the industry processes, having more conscience in the logistics, making in that way the traceability concept. In that way we can know like a user, in the final step of a sale or in another step, all the belonged history of that product, and all

the belonged factory processes. Airports like Barcelona, uses this technology in the luggage identification. That was a breakthrough in this field.

3.2 RFID systems evolution.

RFID systems have revolutionized the remote identification in early XXI century. But the study of these systems it is remounted at XX mid-century.

The first existence assumptions of a magnetic field are so far away in the natural magnets studies in the Chinese culture in I century a.C. It was at the early XIX century when electromagnetic concept was really understood. People like Maxwell, Hertz, Marconi, etc. contributed with their discovers and inventions. Later at the beginning of XX Century the generation, the radio wave transmission and the radar invention, based in radio waves that bounce on a localized object are the bases of the system identification concept by radiofrequency or RFID.

The RFID technology has a confused past. There is no remarked discoverer, it has been developed with a high number of contributions and collaborations. At the beginning one of the most prominent investigators, but not the first one, Harry Stockman, said that all the difficulties for the communication using bound radio waves on objects were passed, with all the applications that could bring. It could not be until thirty years after when the Stockman work was studied again. Transistors, microprocessors and advanced communication nets were not yet developed, also a change of the RFID business vision was needed to make it a feasible thing.

It was in the fifties when the RFID technology followed a similar development process like the radio and radar in the previous years. Different sections of the RFID technology where started, including the long range transponders systems, specially those knew like "identification friend or foe" (IFF) used in the aeronautic industry. Works like those created for F.L. Vernon "Application of microwave homodyne" and for D.B. Harris "Radio transmission systems with mouldable passive responder" were determinate to change the RFID technology from an idea to a solution.

The sixties can be considered like the next years explosion prelude. A high number of articles were written, and the commercial activity in this field started to exist. The first used system was the EAS (Electronic Article Surveillance) to detect stores robberies. The system

was very easy with an only one-bit information, to detect the tag or not, in the reader action range and ring an acoustic alarm in case of the one disarmed tag pass-through near the reader. The most common case is two readers one in front of the other which makes that the customer must walk through them to get out of the establishment. Nevertheless of its limitations, it was cheap and effective. Its used started to extend quickly.

In the seventies some notable advances were produced like those ones contributed by the institutions like “Los Alamos Scientific Laboratory”, “Northwestern University” and the “Swedish Microwave Institute Foundation”. At the beginning of this decade a lot of applications were tried in the logistic and supply chain fields, like those used in the New York and New Jersey ports, automobile trace applications. The logistic fields applications are not yet ready for a complete insertion in the market. In this decade there was a big system technique development, mostly focused to cattle trace applications, vehicles and industrial automation. Based on microwaves in the EEUU and on inductive systems in Europe. The new RFID enterprise creation experimented a continuous growth, it was a positive potential sign of RFID systems.

The eighties arrived, and with it a lot of study implementations and developments of the previous years. In EEUU were interested in the supply chain and access applications and with less interest in animals. In Europe countries like France, Spain, Portugal and Italy were focused in industry applications and short range systems to control animals.

In the first years of the nineties the electronic control toll was started in EEUU, highways of Houston and Oklahoma incorporated a system that managed the vehicles flow trough the control facilities. In Europe this field was also investigated and microwaves and inductive systems were used for the access control and electronic tickets. A new improvement in the automobile world came with the RFID technology thanks to Texas Instruments (TI), a automobile start up control system. A Philips system also appeared in where the start up management, combustible control and vehicle access were permitted. Highways and electronic tickets applications were extending in Asia, Africa, South America and Australia. From this point RFID technology success in these fields made that other economical segments used this technology. Dallas was the first place where only one tag was used for Highway, university campus and parking access. The knowledge improvement of this technology in this decade was fast due to technological developments in other fields that let

produce smaller and cheaper equipment with more memory and range every time. With the new improvements some discarded uses were accepted again.

The RFID future seems to be encouraging, in a world based in the information power and more wireless every time, the action range of this technology seems to be huge. Te virtual commerce interest seems to have in this technology its more appreciated helper to manage all the things correctly. For that reason the FCC (Federal Communications Commission) chose the spectrum allocated in the 5,9 GHz for new transport intelligent systems and for new necessary applications. But for these new applications it is necessary a big development of technology. The RFID future seems to be encouraging, nut like all the technologies needs other technology fields to improve.

We can resume the RFID technology advance in the Table 4.1.

Decade	**Technology improvements**
1940-1950	Radar is redesigned for military used with a big importance in the IInd World War. RFID appears in 1948.
1950-1960	First RFID experiments in laboratories.
1960-1970	RFID technology development, first assays in some technological fields.
1970-1980	Technology explosion. More tests are done. First applications
1980-1990	More technologic applications.
1990-2000	RFID appears in the daily world. The standards appeared.

Table 4.1- RFID technology evolution.

3.3 RFID system elements

A RFID system is composed basically of two elements: a reader and a transponder.

3.3.1 Transponder

The transponder word comes from TRANSmitter/responDER, that explains its working. We can distinguee the basic components of a transponder in the Figure 4.2 and are:

- Non volatile memory where data is stored.
- ROM memory where basic working instructions are stored like temporizers, data flux controllers, etc.
- It can also contain RAM memory to store data during the communication with the reader.
- The antenna that detects the reader field and take the necessary energy for itself.
- Electronic components to process the antenna signal and data process like buffers, filters, etc…

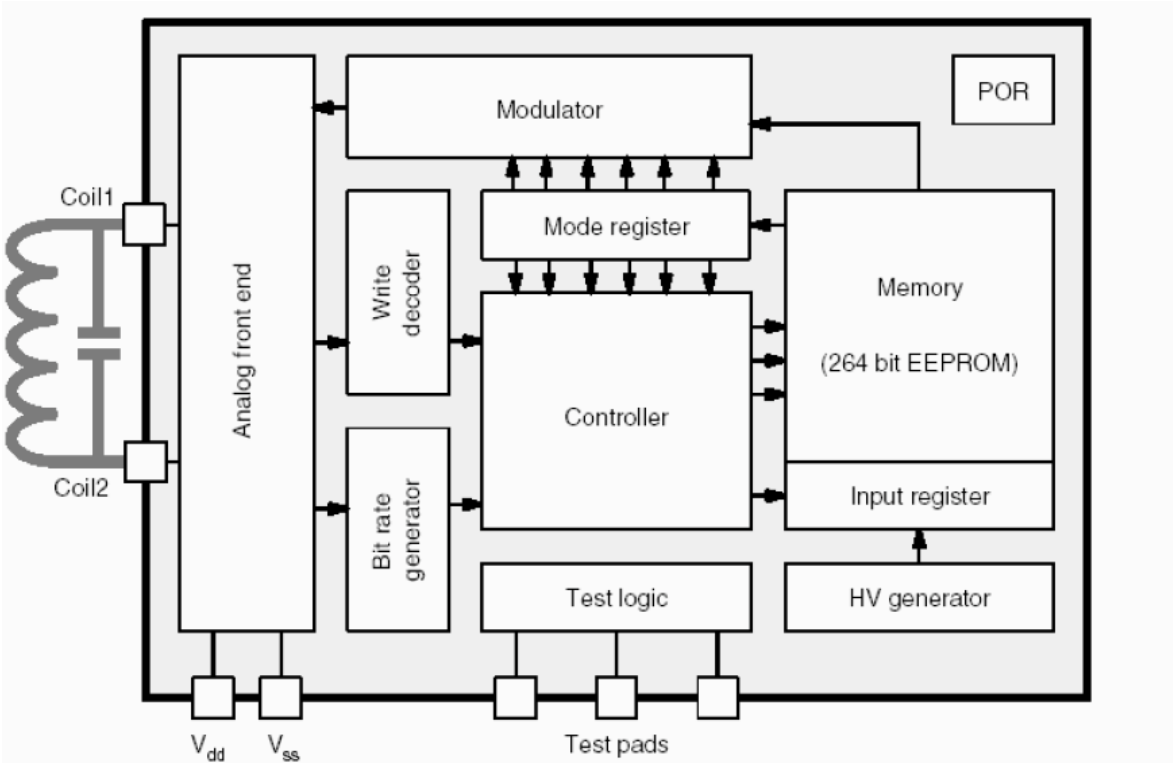


Figure 4.2- Transponder's basic components

Alimentation

The transponders need few alimentation, of the order of mW. We can differentiate three kinds of tags depending on the used energy in the communication:

- Active labels: transponders the need support of an additional battery because they do not have enough energy with the energy that the reader gives. That kind of tag has the advantage of having a bigger communication range and also do not need that the reader starts the communication. Also it permits lecture and rewriting processes sending previously instructions to the reader and the utilization of bigger memories (there exist tags with more than 1 Mb of memory). Nevertheless they offer limited work life (less than 10 years), depending on which kind of battery and the operating temperatures. Also the elevated cost is a remarkable thing, their price use to be 5 times more expensive than passive tags. That makes appear new applications for the RFID systems thanks to this alimented battery tags.
- Passive labels: are transponders with no additional battery, because they only feed the energy from the reader field. For the passives tags, the necessary energy to transmit the stored information, it comes from the reader signal. These tags uses the supplied energy from the reader to generate their own signal that it is recognized again for the reader.
- Semi-active labels:contains an internal power source, which could be a battery, and a specific electronic according to the task. The battery is limited to power the circuitry and the chip, since the energy to generate the communication is collecting radio waves of the reader (and liabilities). Therefore, for communication to occur is that the reader has to start. The main advantages of the tags semi-activos/semi-pasivos meet the liabilities is that by not using energy from the reader to operate the circuitry can be read at greater distances, are faster to read and you do not need to keep the reader long signal circuits to power the tag and if the object moves at high speeds can be read.

	Memory (Bytes)	Write/read distance	Power consumption	Frequency	Application
ASIC#1	6	15 cm	10 μA	120 kHz	Animal ID
ASIC#2	32	13 cm	600 μA	120 kHz	Goods flow, access check
ASIC#3	256	2 cm	6 μA	128 kHz	Public transport
ASIC#4	256	0.5 cm	<1 mA	4 MHz*	Goods flow, public transport
ASIC#5	256	<2 cm	~1 mA	4/13.56 MHz	Goods flow
ASIC#6	256	100 cm	500 μA	125 kHz	Access check
ASIC#7	2048	0.3 cm	<10 mA	4.91 MHz*	Contactless chip cards
ASIC#8	1024	10 cm	~1 mA	13.56 MHz	Public transport
ASIC#9	8	100 cm	<1 mA	125 kHz	Goods flow
ASIC#10	128	100 cm	<1 mA	125 kHz	Access check

*Close coupling system.

Table 4.2- Power consumption of different RFID Systems (Amtel 1996).

Transmission frequency and velocity

The tags can be classified in order to the operational frequency range, in other words, in which frequency the reader will communicate.

- LF (Low Frequency) in the range of 120 KHz – 134 KHz.
- HF (High Frequency) in the range of 13,56 MHz.
- UHF (Ultra High Frequency) in the range of 868 MHz – 956 MHz.
- Microwave in the range of 2,45 GHz, knowed as ISM (Industrial Scientific and Medical) band.

A higher frequency means a higher speed data transmission, although this makes the system prices higher. Choosing the frequency range is one of the most important design parameters, and should be adequate to the designed application.

Programming options

Depending on the transponder memory, can makes only the lecture, programmable ones and multiple lectures or reading/writing. The tags that let only lectures used to be programmed in factory, generally with an identification number. The user can program both types.

Shapes and sizes

The tags have different shapes and sizes, all depending on the designated applications. Now a days some reduced tags exist, Hitachi announced that they have enough technology to incorporate an imperceptible RFID to legal bank notes. In other industrial applications were size is not an important factor they are using 120x100x50 mm size tags, for example pales or containers. Tags used in the cattle control and localization is less than 10mm size. Different producers also affirm that they could include transponders in some products that the customer could not see it, that news caused polemic for the association consumers opposition.

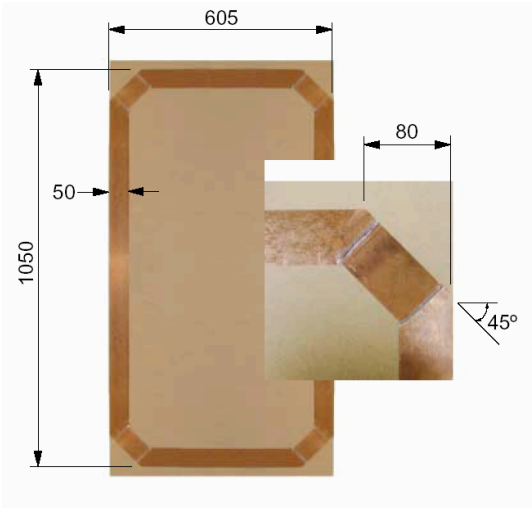


Figure 4.3- Tag size.

Costs

The tag's prices have been decreasing while the technology advanced. It is a fact that with more capacity and more complex electronics the prices will be increased. We have to know that the tag's encapsulated can make it more expensive because it can work in mines or metallurgic factories where the tags receive extreme conditions of humidity and temperature. Is for that reason that the encapsulated must be strong what usually increase the prices.

The active Tags are usually more expensive, the same happen with tags which operate at higher frequencies.

3.3.2 Readers

The other principal element of a RFID system is the reader or interrogator.

The readers are who send an RF signal to detect the possible tags in a determinate action range. In its production it is usually to separate them in two kinds:

- Simple coil systems, the coil it is used to transmit the energy and the data. They are cheaper and simple but with less range.
- Two coil systems interrogators, one to transmit the energy and the other one to transmit the data. They are expensive but with more benefits.

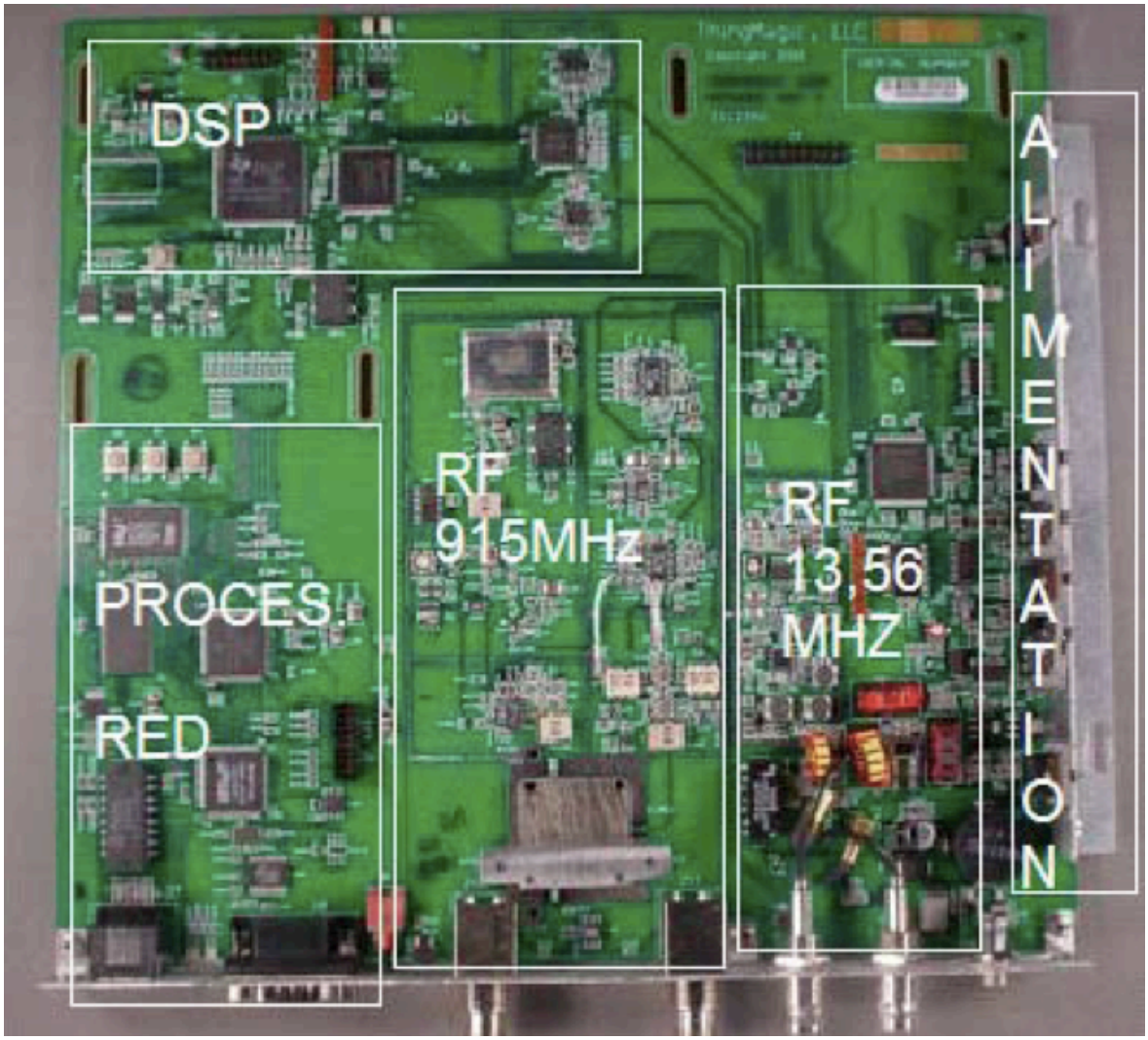


Figure 4.4- RFID Reader.

The readers are more complex depending on the tag, if they are sophisticated, the interrogator components must arrange the signal, detect errors and fix them. Additionally they can work in more than one frequency.

Once all the information has been received by the reader, exists some algorithms used for difference the actual transmission of a new one, ordering to the tag to stop transmitting. It is usually used to check some tags with a short time period. Another algorithm used for the reader is calling all the tags for its identification number, saying that way the transmission time. They are mechanisms to prevent the information collision.

In the next Figure we can see two kinds of RFID readers.

Figure 4.5- Two kinds of RFID readers fixed and mobile.

3.4 Basic operating principles

A RFID communication system is based in the bidirectional communication between a reader and transponder suing radiofrequency waves.

The information transmission system changes depending of the working frequency, so the RFID systems can be classified in electromagnetic attachment or inductive and the based in the electromagnetic waves propagation.

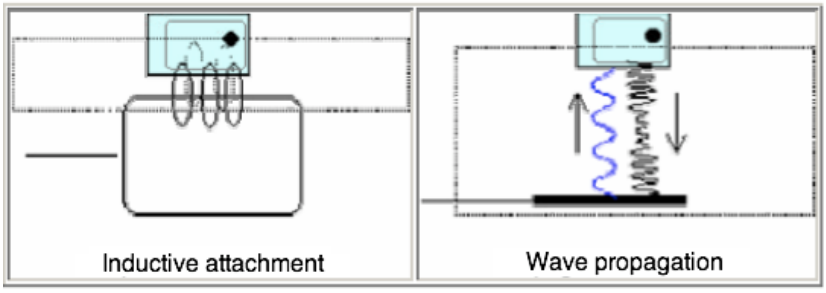


Figure 4.6- Basic operating principles

We have to know that the communication can happen in industrial zones with metals, what with the communication noise, interference and distortion features complicate the bits reception correctly. Furthermore this is an asynchrony communication, what affects in a high-grade parameters like the way that the data is communicated end the bits organization. All this things brings the study of the canal codification to improve the information reception.

In every communication via radio its needed between the two components a variable sinusoidal field or portable wave. The communication it is done applying a variation in that field, in amplitude, phase or frequency, depending on the transmitting data. That process is known as modulation. In RFID its usually applied the ASK (Amplitude Shift Keying), FSK (Frequency Shift Keying) and PSK (Phase Shift Keying) modulations.

The different propagation methods are used in different frequencies. Thereby the inductive attachment works in lower frequencies and the waves propagation system with higher frequencies. Also exists another propagation method used in short distances (1cm), it can theoretically works with low frequencies (30MHz), those are the “close coupling” systems.

Those systems use magnetic and electric fields to communicate. The communication between the reader and the tag is not an excessive waste of energy, so in this systems it can be used microchips that have elevated energy consumption. Those systems are usually used in applications with a minimal range but with strict security systems. It is used in applications like electronic lock doors or contactless smart card systems. Those systems are becoming less important in the RFID market.

By the other hand exist the “remote coupling” systems based in the inductive attachment between the reader and the tag. Is for that reason that those systems are also known as

inductive radio systems. The capacitive attachment systems are practically not used in the industry, by the other way the inductive ones cover the 80% of the RFID systems. This communication system between the reader and the tag works in a frequency range from 135 KHz to 13,56 MHz. Although in some applications it can work in elevated frequency. Its range is about 1m. Those systems always use passive transponders.

3.4.1 Inductive attachment

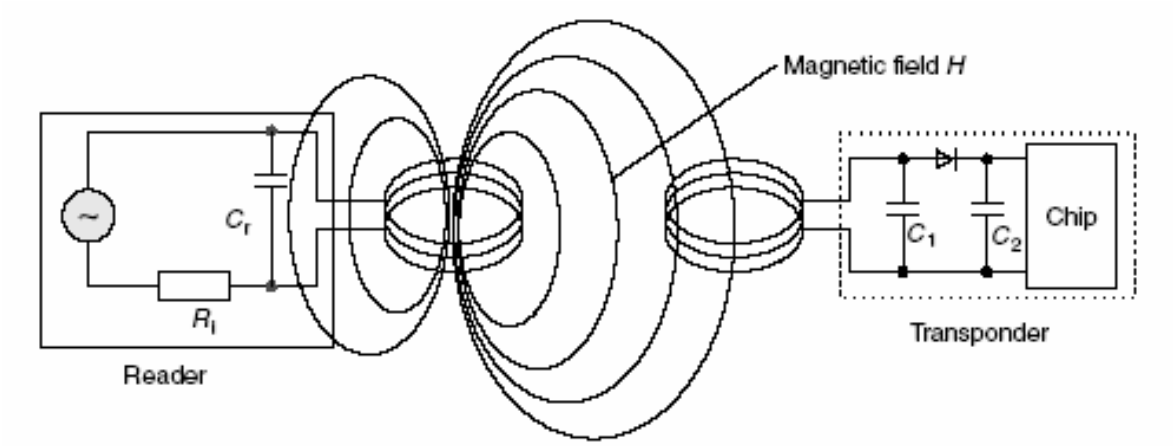


Figure 4.7- Inductive attachment sketch.

In the inductive attachment is based on same work process like the transformers. In the Figure 4.7 we can see inductive attachment resume sketch. In those frequencies the reader antenna's field is the energy that the transponder uses for its communications. This field is near of the reader's antenna; this allows reaching a near distance of the antenna diameter. In large distances the necessary power is very high. The reader coil creates a strong electromagnetic field, that is inserted in the transponder antenna section and near zones.

Those systems antennas are big sized coils, in the reader and the tag, due to the circumstance that the wavelength (λ) (as the frequency reverse) is high. We are talking of 2400m for frequencies lower than 135KHz, and of 22,4m in a frequency of 13,56 MHz. As this wavelength is higher than the distance between the reader and the tag, the electromagnetic field can be treated like a simple alternant magnetic field considering the distance between the tag and the reader.

A small part of the emitted field penetrates in the transponder coil. A tension in the antenna (coil) is generated by induction. This voltage is rectified and is useful as alimentation for

the transponder microchip that stores the information. We can see in the Figure 4.7 that a capacitor is connected in parallel with the reader antenna, this capacitor value is chose due to the antenna inductance that generates parallel resonance circuit with a resonance frequency that must be the same with the reader transmission frequency. In the reader antenna high intensities are generated due to the parallel circuit resonance, this allows to create intensive fields needed for the communication between the reader and the tag.

The transponder antenna (coil) and the parallel capacitor make the resonant circuit in the same frequency as the reader emits. The voltage generated by the transponder is the highest due to transponder circuit resonance.

The efficiency of the transmitted energy between the reader's antennas and tag's antennas is proportional to the operation frequency, the relation between the number of coil's turns (in the tag knew as factor n), The encapsulated area for the transponder antenna, the angle formed for the coils and the distance between two coils. When the frequency is incremented the required inductance in the transponder and the number of turns is decreased. For example, we can say that a frequency of 135KHz, the value of the factor n is between 100 and 1000, and for a frequency of 13,56MHz the value of the factor n is between 3 and 10.

This is due to the induced voltage in the transponder because is proportional to the resonance frequency, nevertheless the number of coil's turns does not affect significantly to the transmitted energy efficiency in high frequencies.

Data transference between reader and tag

We have three different inductive attachments systems to work with:

- Load modulation
- Load modulation with subcarrier
- Sub-harmonics.

1. Load modulation

It is based in the transformer work, being the primary coil the reader's one and the secondary the tag's one. This is true if the distance between the coils is not higher than 0,16λ, and the tag and the reader have to be near. If a transponder is in resonance and is inside a reader's magnetic field, takes the energy from this magnetic field.

The transponder feedback result in the reader antenna can be represented like impedance (Z_T). Connecting and disconnecting the charge resistance of the transponder antenna you can change the value of the Z_T. The voltage of the reader's antenna also changes. This has an effect on the reader's voltage wide modulation caused for the remote transponder. The time that you disconnect and connect the charge resistance is controlled by the data; this is what is used to send the reader transponder data.

2. Load modulation with subcarrier.

Due to the weak attachment that is made by the reader and the tag, the fluctuations produced in the reader's antenna voltage (the information) is less in magnitude than the owns reader voltage. For example, in a system of 13,56MHz, there is a resonance voltage of 100V in the antenna; the transponder's received signal is about 10mV.

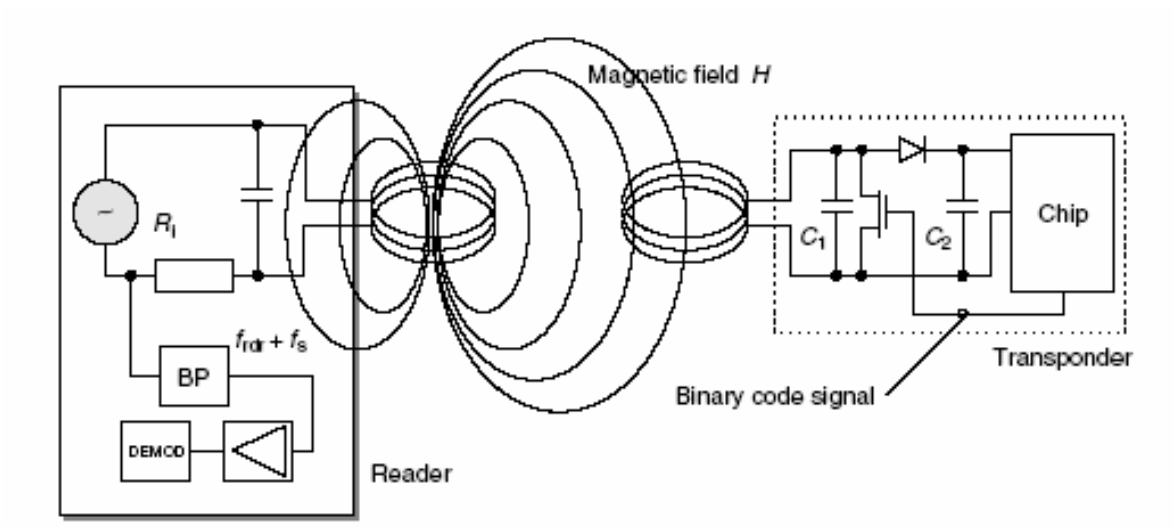


Figure 4.8- Generation of the load modulation connecting and disconnecting the drain-source resistance of the chip FET. The reader has circuit able to detect de subcarrier.

Detecting this fluctuation requires a complicated circuit, a solution is to use contiguous bands to the created modulation. For this a new transponder charge resistance is

incorporated and is connected and disconnected in a high frequency fs, then to spectral lines are created in a distance fs of the resonance frequency between the reader and the tag. One of the possible methods is to use the FET transistor and the transponder like we see in the figure 4.8.

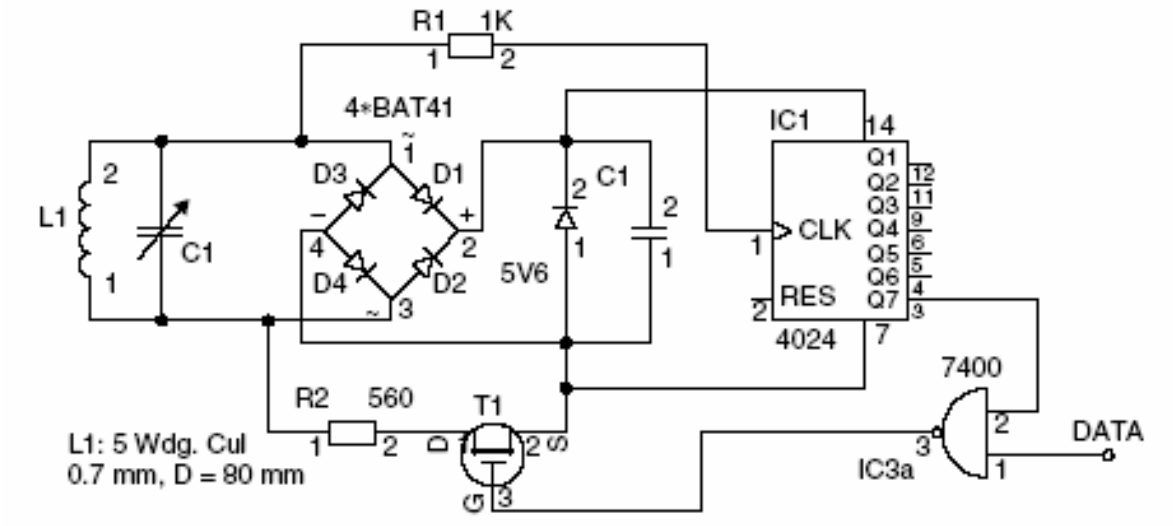


Figure 4.9- Detailed example of a charge modulation generator with a subcarrier in a inductive attachment system.

In those frequencies known as subcarriers, is easier to detect the voltage variations. The information can be modulated in ASK, FSK or PSK with the data flux. This means an amplitude modulation in the subcarrier. Last a bandpass filter is required to isolate one of the two subcarriers. Due to the broadband that those filters require, this process is only used in the ISM band in the frequencies 6,78MHz, 13,56MHz and 27,125MHz.

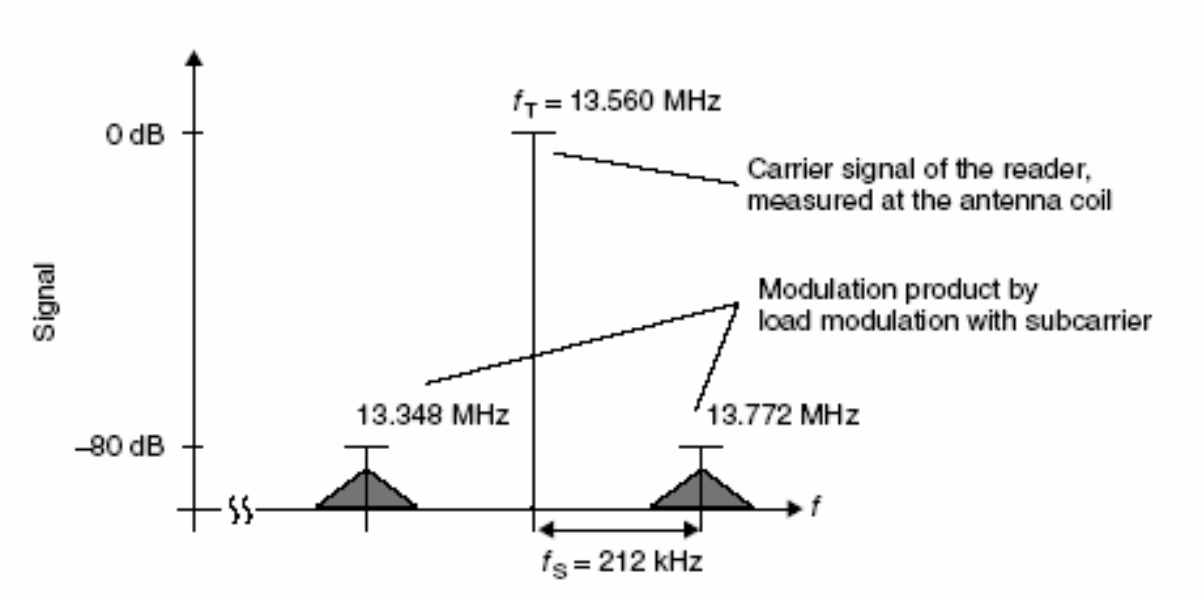


Figure 4.10- Load modulation creates two subcarriers in a frequency fs of the reader transmission frequency. The information is in the lateral bands of the two subcarriers.

3. Subharmonics.

Based in the utilization of subharmonics of a frequency f_A, ergo, $f_1=f_A/2$, $f_2=f_A/3$, etc. It is usually used the first subhamonic (half frequency of the reader transmission). The after divisor's signal is modulated for the data flux and is sent to the transponder. This will be the frequency that the transponder will answer. The transponder needs a frequency binary divisor to do this operation. The most popular operation frequency for these subharmonic systems is 128KHz and the transponder's answer frequency is 64KHz.F

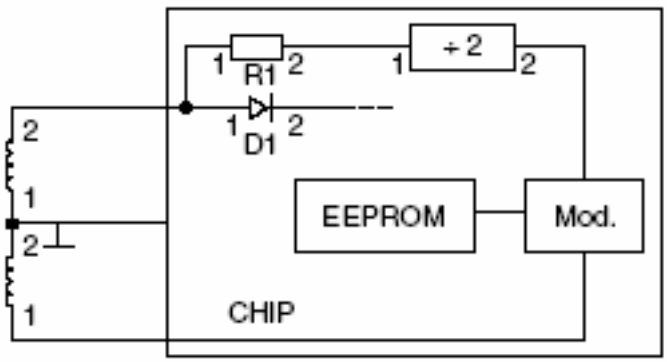


Figure 4.11- Transponder design using subharmonics.

Backscatter attachment

Other information transference systems are the long-range systems, that their range is more than 1m. These systems are based in the uses of the electromagnetic waves in the range of UHF or microwaves. Most part of these systems are known like backscatters due to their principal operation. Other large-range systems exist and they use surface's acoustic waves in the microwave range.

All these long-range systems work in the UHF range, 868MHz (Europe), 915MHz (USA) and 956MHz (Japan) and in the microwave range of 2,5GHz and 5,8GHz. The principal advantage of working with these frequencies is having a short wave longitude, so that allows the construction of little size and high efficiency antennas. The systems that use the backscatter have typical ranges of 3m in passive transponders (without batteries) and about 15m in active transponders. The active transponders battery do not give the necessary energy for the communication between the reader and the tag, they only feed the microchip in its store process and the memory consulting. The power for the transmission between the tag and the reader is only extracted of the generated electromagnetic field for the reader when it communicates with the transponder.

Basically the tag modulates the received information from the reader changing the antenna impedance, this is done changing the charge resistance value R_L. We can see in the Figure 4.12 the same as the inductive attachment example; the transponder's impedance is modulated for the chip's FET transistor.

The reader has a directional coupler to separate the transmitted signal of the weakest received signal. The reader detects the transmitted data for the card as a signal perturbation. The reader receives signal from the label is about -60db under the sensor's carrier transmission.

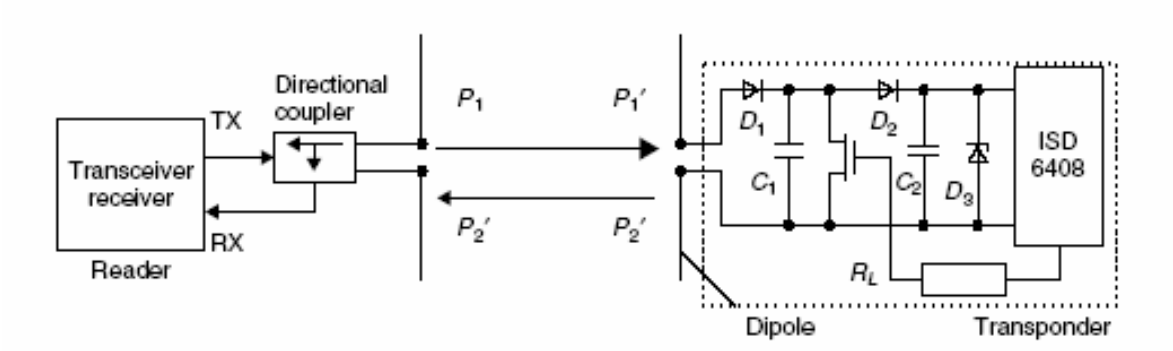


Figure 4.12 backscatter working system sketch

In reference to the necessary energy for the information transmission in these frequencies, a calculation of free spaces loses has to be done previously in relation with the distance r between the reader and the tag, we can see the equation 1.1. In this case we will have like variables the two antennas gain and the system operation frequency. The unit frequency it is expressed in Hz and the distance in m.

$$a_F=-147{,}6 + 20\log(r) + 20\log(f) - 10\log(G_T) - 10\log(G_R) \qquad (1.1)$$

The loses in free spaces are the relation between the reader's emitted power and the tag received power, all this in a determinate frequency.

Using the low intensity semiconductors technology the transponder chips can operate with no more than 5µW. Systems with additional batteries in the transponder also exist, that means a increasing in the reach range, this systems allows the optimization of this batteries, when the tag is not in the reader reach range, the batteries remain in a disconnection status until the reader starts to work. In this standby state the consume is of few µA. The chip is not reactivated until strong signal is received in the reader reach range to return to the normal status.

In the Table 4.2 we can see the lose of free space in different frequencies, we see how we expected that at more frequency and more distance, more losses.

Distance *r*	868 MHz	915 MHz	2.45 GHz
0.3 m	18.6 dB	19.0 dB	27.6 dB
1 m	29.0 dB	29.5 dB	38.0 dB
3 m	38.6 dB	39.0 dB	47.6 dB
10 m	49.0 dB	49.5 dB	58.0 dB

Table 4.2 Loses in the free space considering the tag's gain like 1.64 (dipole), and the gain of the reader antenna like 1 (isotropic emitter).

The principal difference with the inductive systems is where does the energy that the tag uses come from, while the high frequency systems use the electromagnetic waves, getting this way a higher reach range, the inductive systems use the energy that the antenna creates.

Data transfer between reader and tag

Thanks to the radar technology we know that the electromagnetic waves are reflected in objects bigger than that the half of the wave longitude. The efficiency that this objects are reflecting the waves is described for the term known as reflection cross-section. A little part of the reader antenna emitted power is absorbed for the transponder antenna, goes through the tag antenna like HF voltage and then is rectified for the diodes. The voltage must be strong enough to feet small ranges. A proportion of the absorbed power is reflected for the antenna and returned.

The reflection features can be influenced for the alterations in the antenna charge. To transmit from the tag to the reader, the tag charge resistance connected in parallel with the antenna, is connected and disconnected depending on the data flux. This reflected wave amplitude from the tag is what is modulated, for this is called backscatter modulation. This reflected power is radiated in the free space, small part of this power is took for the reader antenna. That power is taken by the reader through a directional coupler, rejecting the power emitted by itself which is higher.

Close coupling

The close coupling systems are designed for reach range between 0,1cm and 1cm. When the transponder is communicating usually is in the middle of a ring that is the reader coil, or, in the middle of a “u” shaped coil. The tag’s coil and reader work is the same than a transformer. The reader represents the primary turns and the tag the secondaries of the transformer. We can see it in the Figure 4.13.

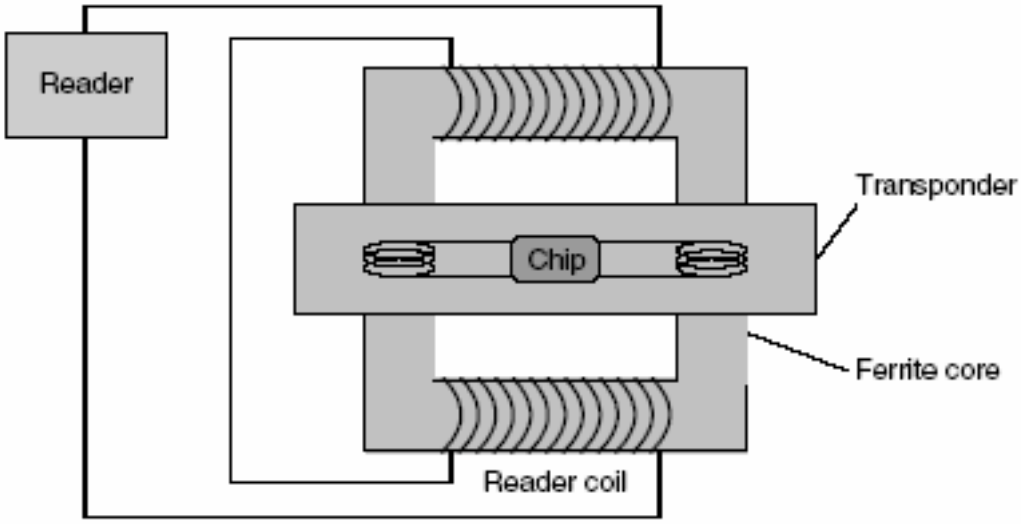


Figure 4.13 In the close coupling systems the tag must be inserted in the reader to let the magnetic attachment between coils be produced.

A high frequency alternate intensity in the primary turns can generate a high frequency magnetic field that is transmitted for the tag's coil. This energy is rectified and feeds the tag's chip. Due to that the induced tension is proportional to the entrant intensity frequency, the selected frequency must be the highest. In practice they are using ranges between 1 to 10MHz. To keep the lost in the tag nucleus this coils are produced with ferrite, a material that optimize the loses in these frequencies.

Differing from the inductive coupling systems and microwaves, the efficiency of the transmitted energy from the reader to the tag is excellent, for that reason they usually use systems that need powered chips uses, that waste a lot of energy, like for example the microprocessors.

3.5 Frequency ranges

The fact that the RFID systems generate and radiate electromagnetic waves implicates that these are classified as radio systems.

Other radio systems work does not have to be interrupted or damaged, in any case, for the emitted waves through a radio frequency identification system.

It is important to be shire that the RFID systems do not interfere with the television and radio, the mobile radio services (police, security and industry), the aeronautic and sea

communications and the mobile phones. The necessity to accommodate other radio services decreases significantly the working available frequency variety at the time to implement RFID system. For this reason, normally it is only possible to use frequency ranges that are specific reserved for industry, scientific or medic applications. These are the frequencies classified in all the world like ISM (Industrial-Scientific-Medical) ranges or SRD and can be also used for the identification applications through radiofrequency.

In the Figure 4.14 we can see all the RFID ranges used in the world.

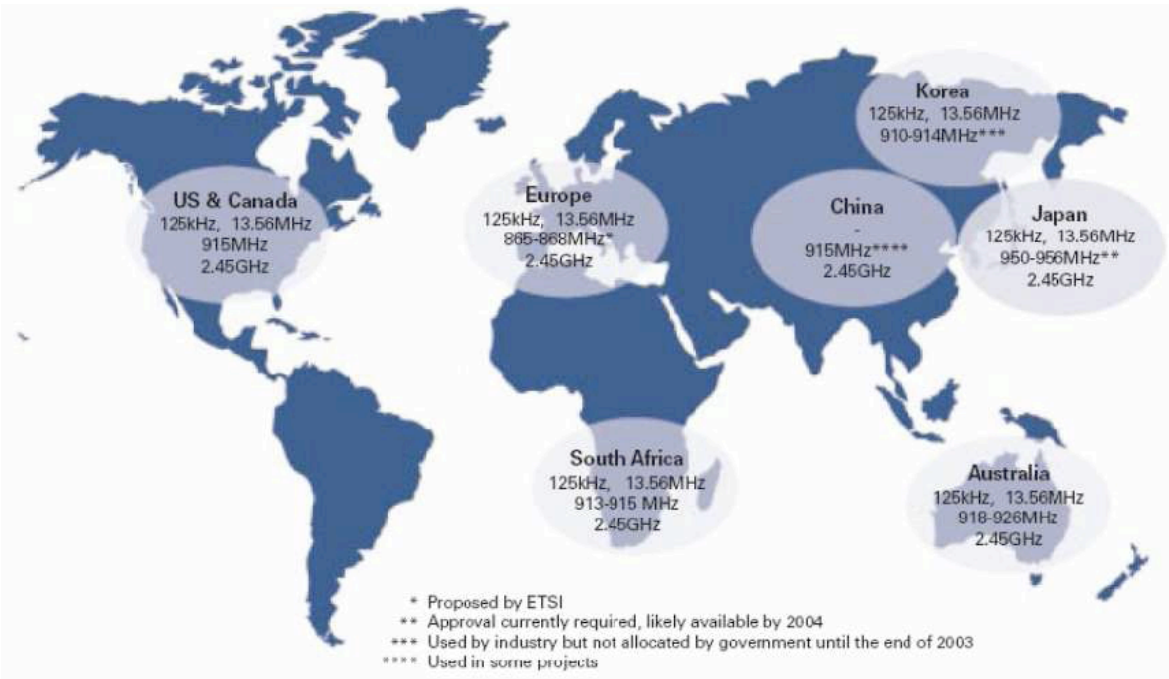


FIGURE 4.14- RFID spectrum in the world.

As we can see in the Figure 4.15 the ISM band group a wide range of frequencies that can be used in RFID systems.

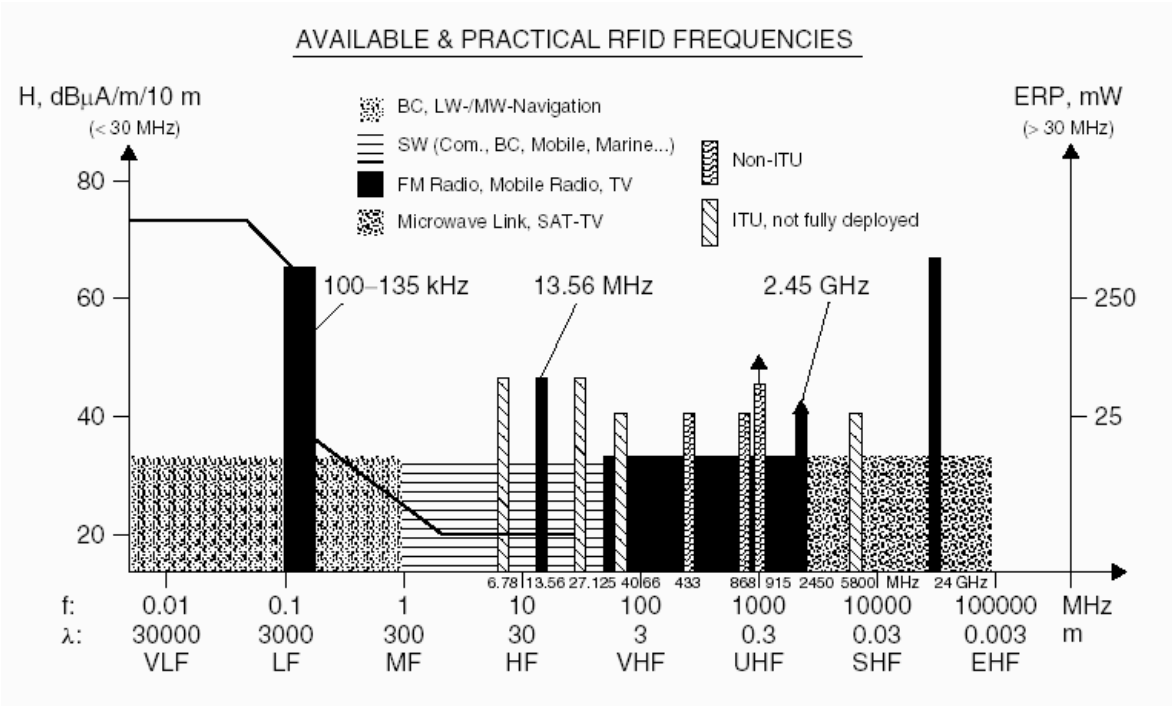


Figure 4.15- Representation of ISM band.

3.6 Anti-collision systems.

On numerous occasions in the reader's area range can be found multiple RFID tags. In this type of situation can distinguish between two types communication.

The first is used to transmit data from the reader to the tag (Figure 4.16). All tags receive the data stream sent by the reader simultaneously. This type of communication is what is known as broadcast.

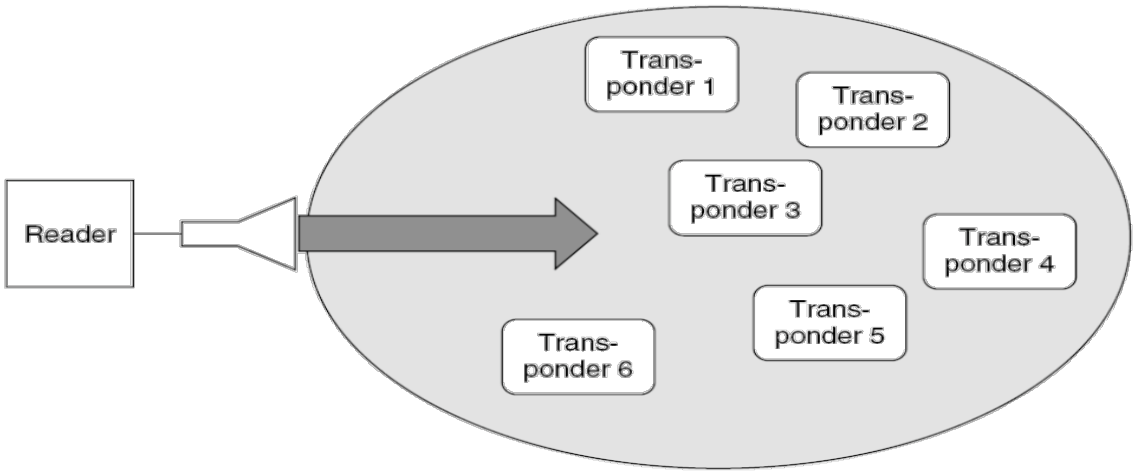


Figure 4.16- Broadcast mode: all tags found in the interrogation zone receive simultaneously the flow of data transmitted by the reader.

The second form of communication involves the transmission of data from many tags, which are in the interrogation zone, to the reader. This form of is called multi-access communication.

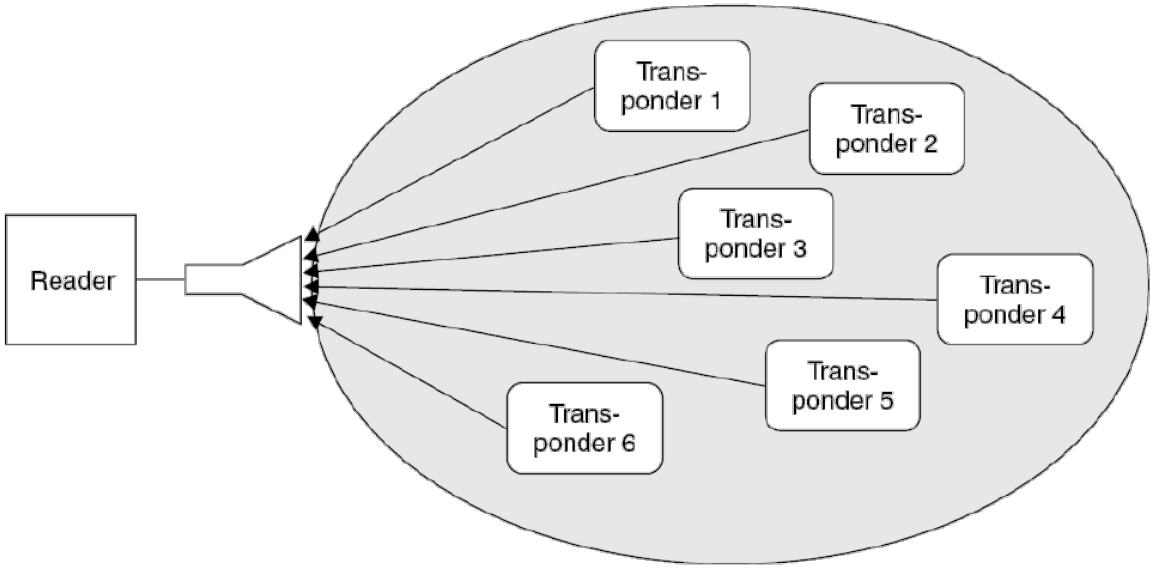


Figure 4.17- Multi-access mode: multiple tags communicate at the same time with the reader.

Each communication channel has defined the channel capacity, which is determined by the maximum rate of transfer of the communication channel and time available.

Available channel capacity must be divided between each label and the result is the amount that each tag can transmit to the reader without suffering interference because of the other (collision).

The multi-access problem has existed for a long time in technology radio. As an example we can look at the satellite or wireless networks where a large number of participants try to access the same satellite or station base.

For this reason, many methods have been developed with the aim of separating signal from each individual participant of any other. In particular, there four different methods:

- Space Division Multiple Access
- Frequency Domain Multiple Access
- Time Domain Multiple Access
- Code Division Multiple Access or Spread Spectrum

On the other hand, the cloud of an RFID system is characterized by periods of activity
On the other hand, the cloud of RFID system is characterized by periods of activity, interspersed with periods of inactivity of varying lengths. Channel capacity is only active during the time just enough to establish an exchange of data.

In the context of RFID systems, the technical process (protocol access) facilitates multiple access management, thus avoiding interference is called Anti-Collision Systems.

For competitive reasons, system manufacturers do not offer the public the collision avoidance systems they use. Here we describe the multi-access methods that are often used to help understand avoidance methods.

3.6.1 Space Division Multiple Access (SDMA)

The space division multiple access term refers to techniques that use some resource (channel capacity) in separate spatial areas.

One option is to reduce significantly the reading area of a single reader, but to compensate it, then have to be positioned a large number of readers and antennas in array so as to cover the entire area previously covered by the reader when it has more scope.

Another option is to use an electrically addressable antenna on the reader. Thus the tags can be targeted directly (SDMA adaptive). In this way several labels can be distinguished by its angular position in the reader interrogation zone (if the angle between two transponders is greater than the width of the used directional antenna beam, one channel can be used multiple times).

This is a group of dipole forming the antenna, for this SDMA adaptive only can be used in RFID applications at frequencies above 850MHz. If it is used frequencies smaller, the size of the dipoles would be excessively large. Each of the dipoles is arranged to has a separate phase of the other dipoles.

The radiation pattern of the antenna is located overlapping the different radiation patterns of dipoles located in different directions. To set the direction, the dipoles are fed by a high frequency signal phase variable, controlled by phases controllers.

With the intention to cover all the space, you must scan the reader's area using the directional antenna until a label is found inside the focus search reader.

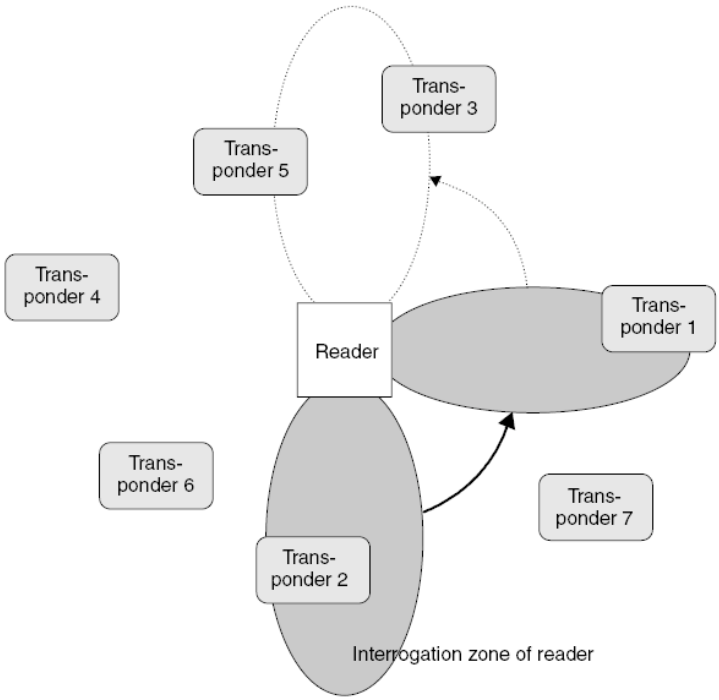


Figure 4.18- electrically addressable antenna on the reader. The range is addressed to different tags; one after the other.

A drawback of SDMA is the relatively high cost of implementation due to complicated antenna system. The use of this technique is restricted this way to a few specialized applications.

3.6.2 Frequency Domain Multiple Access

The term frequency domain multiple access refers to techniques in which several transmission channels with multiple carrier frequencies are available to participants in the communication (Figure 4.19).

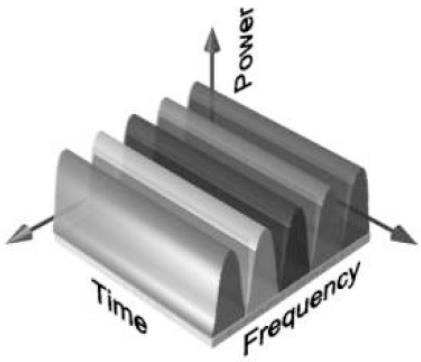


Figure 4.19- In FDMA we have various frequency channels in the same time.

In RFID systems can be achieved a transmission rate not harmonica and freely adjustable. Several channels can be used within the ranges defined frequency specifications for transmitting. This can achieved using several different frequency subcarriers (Figure 4.20).

One of the drawbacks of the FDMA systems is the relatively high cost due to the readers as from a dedicated receiver has be possible reception for each channel.

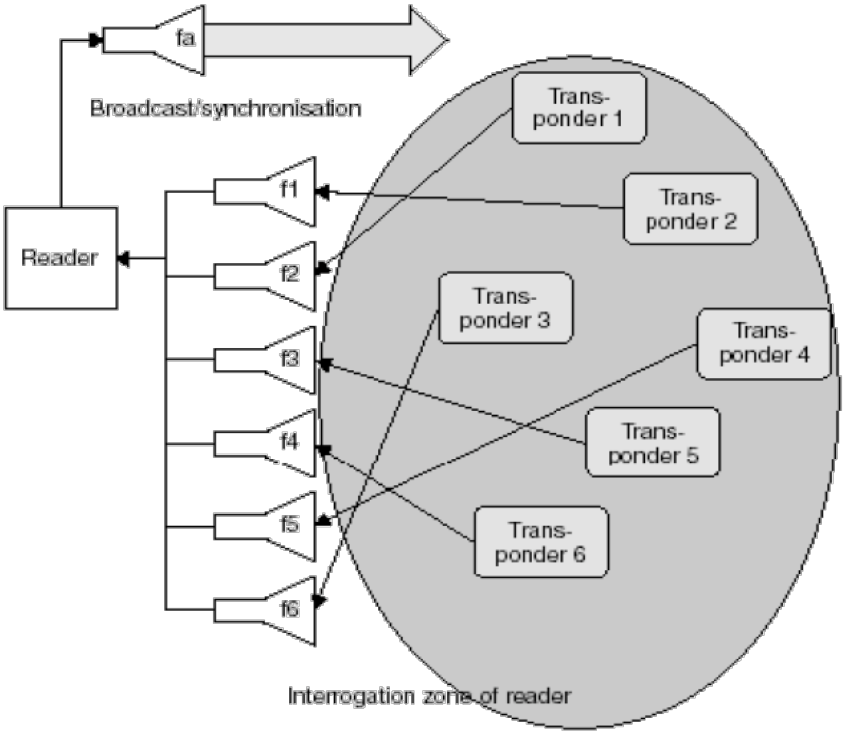


Figure 4.20- In the FDMA systems various frequency channels exists for the data transmission from the tags to the reader.

3.6.3 Time Domain Multiple Access

The term time domain multiple access refers to techniques multi-access in which an available channel is divided chronologically between all participants of the communication (Figure 4.21). The use of TDMA is particularly widespread in the field of digital mobile radio communications systems.

In RFID systems, TDMA is the most used anti-collision technique.

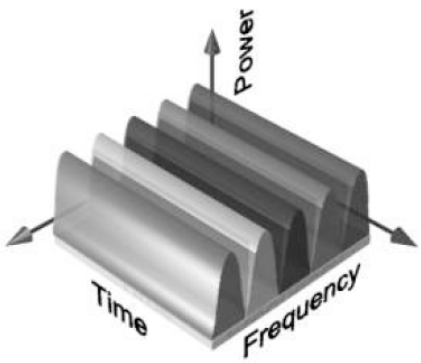


Figure 4.21- TDMA uses all the available band range, distributing with all the users chronologically.

The used tags procedures are asynchronous, so there is no transfer data control from the reader. This is the case, for example, of the ALOHA procedure.

These procedures that control the label are of course very slow and inflexible. Most applications use processes that are controlled by the reader, taking it the role of 'master'. These methods can be considered synchronous, since all tags are checked and verified simultaneously by the reader.

First of all a single tag is selected from a large group of labels on the reader's interrogation zone using a specific algorithm and then communication occurs between the selected tag and reader. Once the communication is over the reader selects another tag. Only a single communication can be initiated at a time, but transponders works in quick succession and it seems that everything happens at the same instant of time. This is the purpose of TDMA methods.

Procedures controlled by the reader (synchronous) can be subdivided into polling and binary search. All these methods are based on the principle that all tags are identified by a unique serial number.

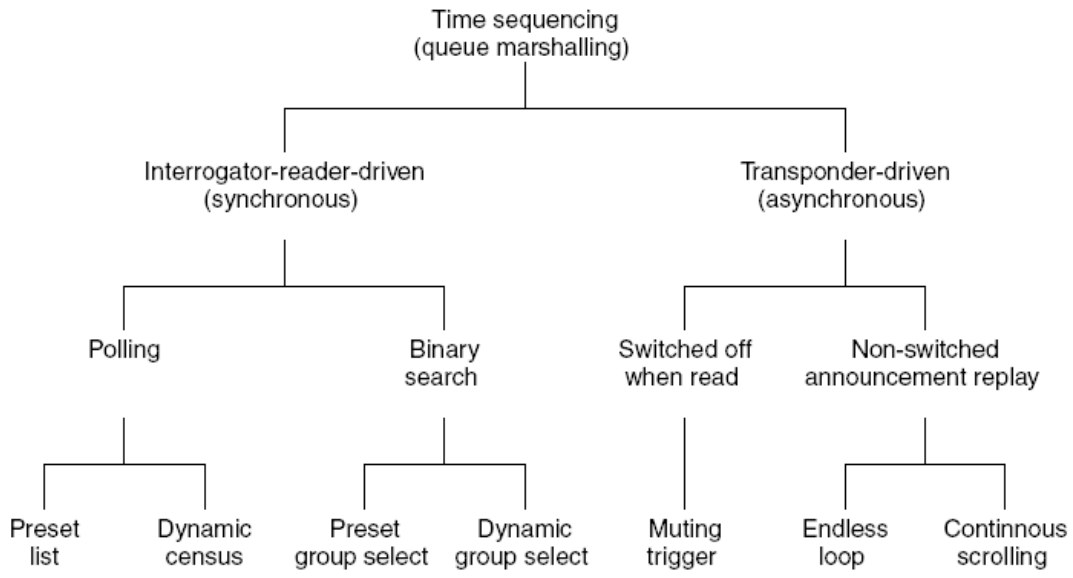


Figure 4.22- TDMA anti-collision methods classification for Hawkes (1997).

The polling method requires a list of all the default labels that can be found at all times inside the application reading. The reader interrogates all the tag codes one by one until one of the asked tags answer. This process can be slow depending on the number of tags that may appear in the application; is for that reason that this system can only be used in systems which the number of tags to identify is small.

The binary search method is more flexible and is one of the most common procedures. Is when the reader causes intentionally a collision with any label, randomly chosed. If the process is successful, the reader will be able to detect which precise position of all bits collision has happened.

3.6.4 Code Division Multiple Access

The term code division multiple access refers to multi-access techniques which all the frequency spectrums shared, but to separate communications are used different code sequences (Figure 4.23).

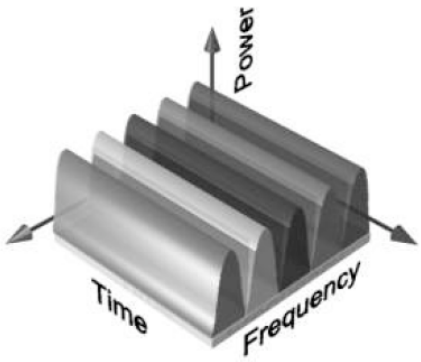


Figure 4.23- CDMA uses the entire channel band with, using different code sequences.

CDMA anti-collision method is used in many applications where used in combination with digital modulations, although RFID applications has not applied, assuming that the manufacturers do not offer the public the systems used and this would be an expensive and slow method.

4 CHALLENGES TO RFID ADOPTION

4.1 Present realities

Although the promising applications of RFID in SCM, some challenges have hampered the adoption of RFID. Almost all the questions can be broken down into technology challenges, standard challenges, patent challenges, cost challenges, infrastructure challenges, return on investment (ROI) challenges, and barcode to RFID migration challenges.

4.2 Technology challenges

4.2.1 Material effects on antenna power pattern

A passive RFID tag has no power source of its own. The power source is based on its antenna to receive the reader emitted radio waves and converts these radio waves into electrical power. The data stored in the chip can be transmitted back to the reader via the tag antenna. Consequently, the antenna plays an important role in the radio communication between the tag and the reader. Radio waves will be reflected and refracted differently depending on the material to which the tag is attached. If UHF radio waves pass through a liquid, a large portion of the radio energy will become refracted into the liquid. If UHF radio waves propagate toward metal, a large portion of the radio energy will become reflected into this metal. In both cases, there will be signal strength degradation and interference in the reception quality of the tag. Products with a high percentage of water like shampoo or juice, and canned goods with metal cases refract and reflect RF waves. Radio waves reflected from multiple objects can cause multi-path interference to the receiving antenna.

4.2.2 Tag antenna orientation affects radio wave reception

RFID technology allows non-line-of-sight, non-contact, and multiple-tag simultaneous-reading capabilities and this is more efficient than scanning barcodes for product tracking. Nevertheless, RFID readability can be affected because of the relative position and orientation of the tag antenna and the reader antenna. This is explained just because the antenna orientation affects the power pattern. So, if a tag antenna is perpendicular to a reader antenna, the former cannot receive the latter's radio signal. As well, if there are

obstacles between two antennas, the radio signal strength will be attenuated and consequently the reading range will also be reduced. In real world the RFID tags attached on variety products, have random antenna orientations. This will cause unreadable tags because they travel through the portal with just one uni-directional reader antenna.

4.2.3 Collision caused by simultaneous radio transmission

If an RFID system is designed with tags able to be read one by one by a reader, the chances of successful reading are high. Though, a time-consuming exists, especially with a large number of tags. In UHF RFID applications, hundreds of tags can respond simultaneously to a reader's signal. Simultaneous transmitted radio signals cause collision interference to the receiver. To let a reader communicate with multiple tags, some techniques of collision-resolution protocol must be employed.

There are three major anti-collision procedures to achieve multiple tag reading. Because anticollision procedures require additional Communications sessions, the reading speed is delayed. An alternate method (binary search) can prevent tag signal collisions.

When a large number of tags are being read simultaneously, it is difficult to identify those tags which have failed to be read. It is a problem in any Trucking system if 100% accuracy cannot be achieved.

4.3 Standard challenges

There are three major advantages of developing International standards for RFID systems. The first advantage is that a common RFID standard ensures interoperability among tags and readers manufactured by different vendors and can allow for seamless interoperation across national boundaries. The second one is that due to compatibility and exchangeability, the demand for RFID components and equipment is very high and this can bring the cost down. And the last advantage is that an internationally accepted RFID standard facilitates the growth of the worldwide RFID market.

4.3.1 Lack of a unified RFID standard

At present, there are two major organizations working to develop international standards for RFID technologies in the UHF spectrum. These two organizations are: EPCglobal and International Standards Organization (ISO). EPCglobal released its EPC class 1 G2 protocol for the UHF band at the end of 2004, and the ISO released its 18000-6 in August

of 2004. In both cases standards are still evolving and are not completely compatible with each other. A unified, globally interoperable RFID standard is the best way to realize the full benefits of RFID applications. The lack of a complete and unified RFID standard has caused many companies to doubt in adopting the RFID systems; these companies were afraid of making a commitment that might render their entire RFID system investment worthless in the future.

4.3.2 Lack of consistent UHF spectrum allocation for RFID

Regulations on radio spectrum allocation for RFID use are not unified in all the nations. A large portion of the UHF spectrum has already been auctioned to cellular phone service providers for high license fees by a few countries. It is almost impossible to buy that portion of spectrum back for RFID use. This adds complexity to the adoption of RFID for global supply chain management applications where tagged goods must often travel across borders. In countries where different spectrum bands are allocated for RFID use, RFID tags which respond only to a specific UHF frequency range, cannot be read.

The United States and Canada can allocate the frequency band from 902 to 928MHz for UHF RFID systems because their GSM bandwidths are not located within this band. But outside North America the frequency band around 915MHz is almost exclusively used for wireless communications services like GSM, PHS, GPRS or 3G. The European Telecommunications Standards Institute (ETSI) has released a 2MHz band ranging from 865.6 to 867.6MHz for Europe's UHF RFID use in July 2004. Japan has allocated a 2MHz UHF band ranging from 953 to 954MHz for RFID use in May 2005. The diversity in national spectrum allocation for RFID adds the growth of RFID systems in the world market.

In addition to the unavailability of common spectrum bandwidths for RFID systems, power regulations and certification procedures are incompatible from country to country.

4.4 Patent challenges

The purpose of developing international standards is to control existing intellectual properties (IPs) and technologies from all vendors in the industry. Under EPCglobal's IP policy companies holding IPs that adhere to EPC standards must declare their IPs and indicate if they will make the IPs available to other vendors on a royalty-free basis or a RAND (reasonable and non-discriminatory) royalty-bearing basis. Even though the EPC

G2 standard has been released, the royalty payments for IPs involved in this standard are still not clear.

A clear example of confusion could be as now is explained: in June 2004, Intermac filed a patent-infringement lawsuit against Matrics.

4.4.1 Manufacturing costs

In November of 2001, Sanjay Sarma of the Auto ID Center published a White Paper titled ‘‘Towards the Five-Cent Tag’’ . This report contemplates a chip-based, passive, packaged 64-bit read-only RF tag that would be cheap enough to enable usage on a mass scale, all the way down to the individual item level. In the present, prices for passive tags currently range from $0.15 to $1.10, depending on the volume of tags produced and the complexity of tag functions.

Based on industry marketing reports, tag cost structure can be broken down as follows:

1. Chip: In the range of $0.25–$0.35 a piece in quantities of roughly 1–10 M.

2. Inlay/Substate with antenna: From $0.02 to $0.10 and beyond, depending on the size and the material used.

3. Assembly: Typically from $0.02 to $0.04.

4. Licensing: Referencing Intermec’s licensing plan, 5–7.5% of the hardware value.

Two major cost elements constitute the tag cost; the chip cost and the assembly cost. Chip cost is related to the die size and fabrication yield. For example, one six-inch wafer can produce more than 15–20 thousand chips, but the wafer, mask, and chip preparation costs are shared among only the good chips. An RFID chip consists of analogy logic, digital logic, and memory circuitry; in this way it is a challenge to keep error rates low in the chip fabrication process. The chip cost decreases if the chip order volume becomes large.

RFID chips are very small in size (0.4–1.0mm2), and the antenna inlay material is very soft so it is a challenge to perform RFID chip assembly at a very high throughput with a high accuracy.

Consequently, the goal of a five-cent tag will require efforts from every participant in the value chain before it can be realized. Unless customers have an urgent need that can be

solved by RFID, they tend to wait until RFID tag prices drop and standards are sorted out before making any investments.

4.4.2 Customization costs

A UHF RFID system collects data from thousands of belongings simultaneously. It can generate a large throughput of data, and requires computing power and system integration to collect and process all the data. In spite of this, many users and system integrators (SI) presuppose that installing an RFID system is a simple task and all tags will be accurately read by readers. The presence of objects in the vicinity of the tags and readers can interfere with radio signal propagation. Accordingly, the RFID system's greatest challenge is to assure that all tags are read successfully.

For a specific working environment an RFID system must be customized. For example: multiple readers must be installed at proper locations with serious consideration of the tags' and readers' antenna orientation, the RFID system's operations environment, and the client's mission and performance expectations of the RFID application. Ergo, the successful operation of an RFID system will have to incur considerable system design, customization and configuration costs.

4.5 Infrastructure challenges

Multiple companies will benefit for the adoption of a UHF RFID system along an entire supply chain. Industry supply chains can be long and often cross international borders. For example, an industry supply chain may begin with a manufacturer who assembles goods from parts imported from around the world. The finished goods may be sent to a warehouse for distribution, then to an airport or seaport for international transport, after that to an overseas distributor's warehouse, and finally again to individual retail stores by trucks. If it is possible RFID readers will track the flow of goods, thereby increasing the management efficiency in the entire chain.

But to achieve this goal, an entire RFID infrastructure must first be established. This will allow for the collection of real-time tag information from anywhere in the supply chain, including the manufacturer's factory, local logistic/warehouse, air cargo, foreign logistic/warehouse and the retailer or department stores.

The sending of goods involves multiple manufacturing companies, multiple transportation companies, and multiple sea ports and airport authorities; but the entire RFID infrastructure available to track every tagged item from the beginning to the end of the supply chain is really a challenge.

4.6 ROI challenges

ROI is an important consideration in evaluating RFID investments. Expectations of RFID benefits can be broken down into two parts: cost reduction (e.g. labor cost reduction, inventory cost reduction, process automation, and efficiency improvements, etc.), and value creation (e.g. increase in revenue, increase in customer satisfaction due to responsiveness, and anticounterfeiting, etc.). No comprehensive RFID infrastructure exists as yet. It is difficult to calculate the true returns based on limited benefit information from pilot projects in segmented RFID system installations.

4.7 Barcode to RFID migration challenges

RFID technology is still developing, standards are still converging, and costs are still being brought down to attach tags to individual consumer products. Nevertheless, the barcode system is deeply entrenched and will not be replaced any time soon. With that we can say that both barcodes and RFID systems have to coexist in parallel for a long time to come. The migration from barcodes to the RFID system will not only increase demands on system capabilities and compatibilities but also increase costs on maintenance and operation of both systems.

4.8 Future development directions

As with many other emerging new technologies, RFID will simply take time for reality to meet ends with the ideals. As more efforts are put in for RFID research and development, more pilots will be run and more data will be collected; these can be used to solve problems that stand in the way of widespread adoption. This is an ongoing process. The following describes some recommendations to meet the challenges of successful global RFID systems' deployment.

4.8.1 Resolutions to technology issues

It is indispensable that RFID systems approach 100% reliability. This could be reached in a number of ways: customizing the tag antenna design for each material type of goods,

installing multiple antennas with different orientations per reader, and installing multiple readers to increase tag readability. The binary search technique is emerging as a viable solution for reading numerous tags simultaneously. Tags that have been read will be put to ‘‘sleep’’ to prevent them from transmitting repeatedly. Ongoing research on tag placement and orientation will help maximize antenna power pattern and probability of successful reading.

4.8.2 Resolutions to standards and regulatory issues

For spectrum allocation and compatible technical specifications government organizations must work out regulations and standards. Despite that, some extent technology itself can compensate for the differences in regulations and standards. For example, broadband RFID chips that can deal with a broad spectrum of UHF frequencies and broadband antennas that can transmit and receive radio frequencies in a broad spectrum band have both been developed. For this reason, in different countries RFID tags can be read by readers emitting radio wave in different spectrum bands. Lastly, multiple-protocol readers that could work with different RFID standards are being developed.

4.8.3 Resolutions to cost issues

Costs remain the largest impediment for the widespread adoption of RFID. Increasing the volume of demand you can have the change to reduce the costs; this can be facilitated if a unified global RFID standard exists. A universal RFID chip, which can be used by different applications in different countries, is an ideal to pursue; this ideal universal RFID chip would have a frequency-independent capability and would be integrated with read/write memory. Moreover, for an RFID chip to satisfy the requirements of multiple applications, a minimum set of commands must be designed so that it can be customized by software for a variety of applications.

Other than the chip costs, the costs of packaging an antenna to a chip to become a module and attaching a module to a merchandise also need to be minimized. Just right now, barcodes appear on labels of almost all merchandises. They are printed with all other information on the label in the print shop. If RFID tags are expected to appear on the labels of all products one day, they definitely cannot be attached by manual labor. Accordingly, print shop automation machines that can print antennas and automatically paste RFID chips on merchandise labels are also critical research topics.

5 POSSIBLE RFID STANDARD

5.1 EPC

The EPC (Electronic Product Code), born from the hands of EPCglobal, a consortium formed by EAN International (European Article Numbering), which has 101 member organizations, represented in 103 countries and UCC (Uniform Code Council) owner of the UPC (Universal Product Code), present in 140 countries and now called GS1 US.

The intention to create the EPC EPCglobal was none other than to promote the EPCglobal Network, a technology concept that aims to change the existing supply chain with one with a global open standard that allows real-time identification of any product In any company anywhere in the world. The EPCglobal Network was developed by the Auto-ID Center, a research team from MIT (Massachusetts Institute of Technology), which has laboratories around the world. This development was carried out in over 1000 companies from around the world.

Also, currently, all standards developed by EPCglobal pass the supervision of the ISO (International Standards Organization), the only condition that creates specific standards are ratified and used ISO in which it believes EPCglobal.

Once we know where the EPC comes from, we'll do a little study on the standard to see what advantages and disadvantages gives.

EPC specifications can be divided into:

- Specifications for the labels, referring to data stored in them, communication protocols with the reader and the RF allows communication.
- Specifications for readers: a protocol for air interface logical communications with tags.

In January 2005 EPCglobal published the new specifications of the latest version of EPC, EPC gen 2.

This publication is called to be the standard worldwide adapted in the use of RFID systems and has been done to meet consumer needs. To meet these needs EPCglobal, and includes

specifications not observed in other regulations previously carried out, has tried to standardize the core standards existing.

In the next table we can see the standards that have as a prerequisite in EPC Gen2, the most important currently available. A very important fact is that it includes the standard EN 302 208 of ETSI, which represents a big step for a single standardization between Europe and USA, the EN 302 208 and the EPC Generation 2 will complement each other .

EPCglobal™: EPC™ Tag Data Standards
EPCglobal™ (2004): FMCG RFID Physical Requirements Document (draft)
EPCglobal™ (2004): Class-1 Generation-2 UHF RFID Implementation Reference (draft)
European Telecommunications Standards Institute (ETSI), EN 302 208: Electromagnetic compatibility and radio spectrum matters (ERM) – Radio-frequency identification equipment operating in the band 865 MHz to 868 MHz with power levels up to 2 W, Part 1 – Technical characteristics and test methods
European Telecommunications Standards Institute (ETSI), EN 302 208: Electromagnetic compatibility and radio spectrum matters (ERM) – Radio-frequency identification equipment operating in the band 865 MHz to 868 MHz with power levels up to 2 W, Part 2 – Harmonized EN under article 3.2 of the R&TTE directive
ISO/IEC Directives, Part 2: Rules for the structure and drafting of International Standards
ISO/IEC 3309: Information technology – Telecommunications and information exchange between systems – High-level data link control (HDLC) procedures – Frame structure
ISO/IEC 15961: Information technology, Automatic identification and data capture – Radio frequency identification (RFID) for item management – Data protocol: application interface
ISO/IEC 15962: Information technology, Automatic identification and data capture techniques – Radio frequency identification (RFID) for item management – Data protocol: data encoding rules and logical memory functions

ISO/IEC 15963: Information technology — Radiofrequency identification for item management — Unique identification for RF tags
ISO/IEC 18000-1: Information technology — Radio frequency identification for item management — Part 1: Reference architecture and definition of parameters to be standardized
ISO/IEC 18000-6: Information technology automatic identification and data capture techniques — Radio frequency identification for item management air interface — Part 6: Parameters for air interface communications at 860–960 MHz
ISO/IEC 19762: Information technology AIDC techniques – Harmonized vocabulary – Part 3: radio-frequency identification (RFID)
U.S. Code of Federal Regulations (CFR), Title 47, Chapter I, Part 15: Radiofrequency devices, U.S. Federal Communications Commission

The physical layer specifications of EPC Gen 2 provides that in communications from the tag to the reader have to be used for dual-band modulation ASK lateral (double sideband amplitude shift keying - DSB-ASK), single-sideband ASK (single sideband amplitude shift keying - SSB-ASK) or phase reversal ASK (amplitude shift keying phase reversal - PR-ASK) with a coding of pulse-interval (pulse-interval encoding - PIE). The reader waits for a response of backscatter (backscattering reply).

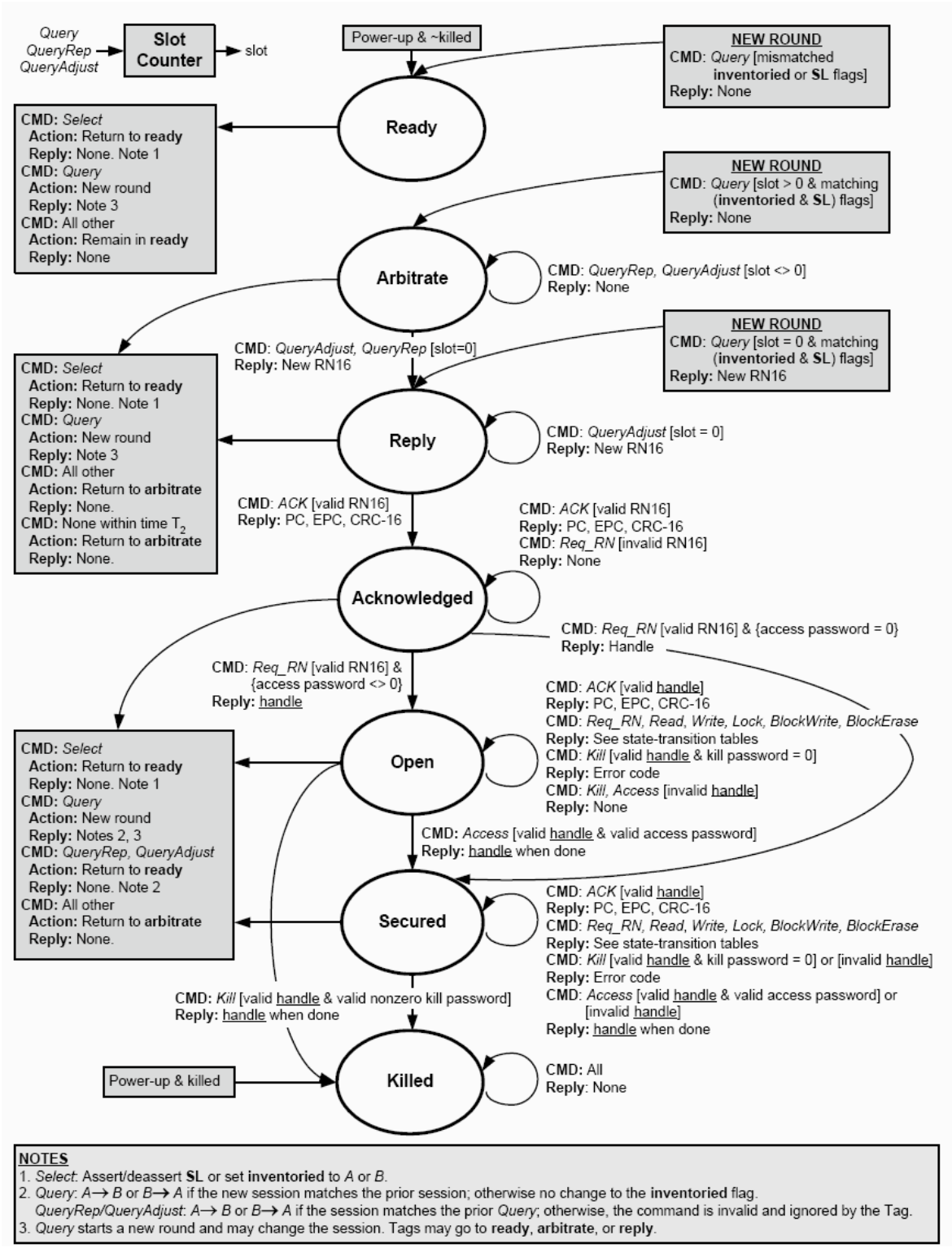
The communication of the label to the reader should send a not modulation signal codified in FM0 or Miller code. In both cases the used communication method is Half Duplex.

3 basic operations exists to proceed with the labels identification that are allowed inside the action range:

- **Select:** this operation allows the reader to see what is the quantity of tags that exists in the action range.
- **Query:** this operation is used to identify labels. This process starts when the reader send the Query command. Then one or more tags can answer to this query at the same time. The reader detects a unique tag answer and interrogates this to obtain its code PC (Protocol Control), the EPC and CRC-16. This process is composed of various commands and it is realized in one session per time.

- **Access:** the access process has few communication operations with the label (read/write). One unique label must be identified before starting the access process.

However, the communication process between the reader and the tag is much more complicated than it may at first seem. In the figure below we can see a state diagram of a label. These states represent the situation in which there is a label on every possible moment of communication with the reader.



5.2 ISO/IEC 15434

Unique identification can occur at many different levels, at item level, on the transport unit, on the returnable transport item, at grouping levels, and elsewhere. Such entities are often handled by several parties, both public and private, throughout their lifecycle. Each

of these parties must be able to identify and trace such distinct entities so that reference can be made to associated information such as quality inspection data, the chemical substance contained, the batch or lot number of parts, components or raw materials, etc.

There are considerable benefits if the identity of the entity is represented as a bar code or other AIDC (Automatic Identification and Data Capture) media and attached to, or made a constituent part of, that which is being uniquely identified so that:

- It can be read electronically, thus minimising errors;
- One identity can be used by all parties;
- Each part can use the identity to look up its computer files to find the data associated with the entity.

All AIDC technologies have the potential to encode an identity. It is expected that application standards, using various automatic identification technologies, will be developed based upon the identity as a prime key. These application standards, which may include additional rules for which level of identification should be used, may be made available from the Issuing Agency.

In the use if AIDC media, users want to use one standard for various kinds of AIDC media because of the convenience and simplicity.

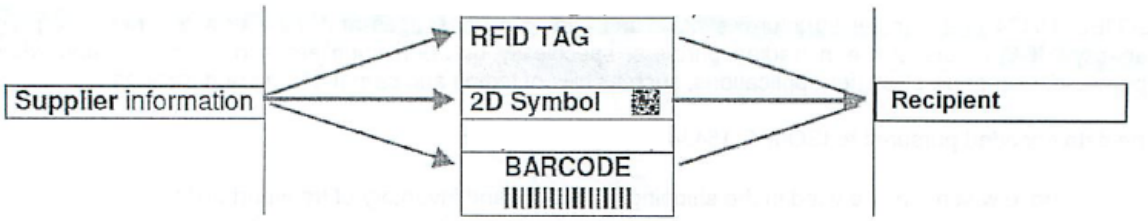


Figure 6.1- Various kinds of AIDC media.

It's important that the identification system can guarantee that each "license plate" is uniquely distinct from all others.

There exists the need in various applications to identify the type of data carrier. Readers and interrogators are able to identify the means by which data was entered: RFID, bar code or key entry. These readers and interrogators are able to preface the entered data with a data carrier identifie, following the rules of ISO/IEC 15434.

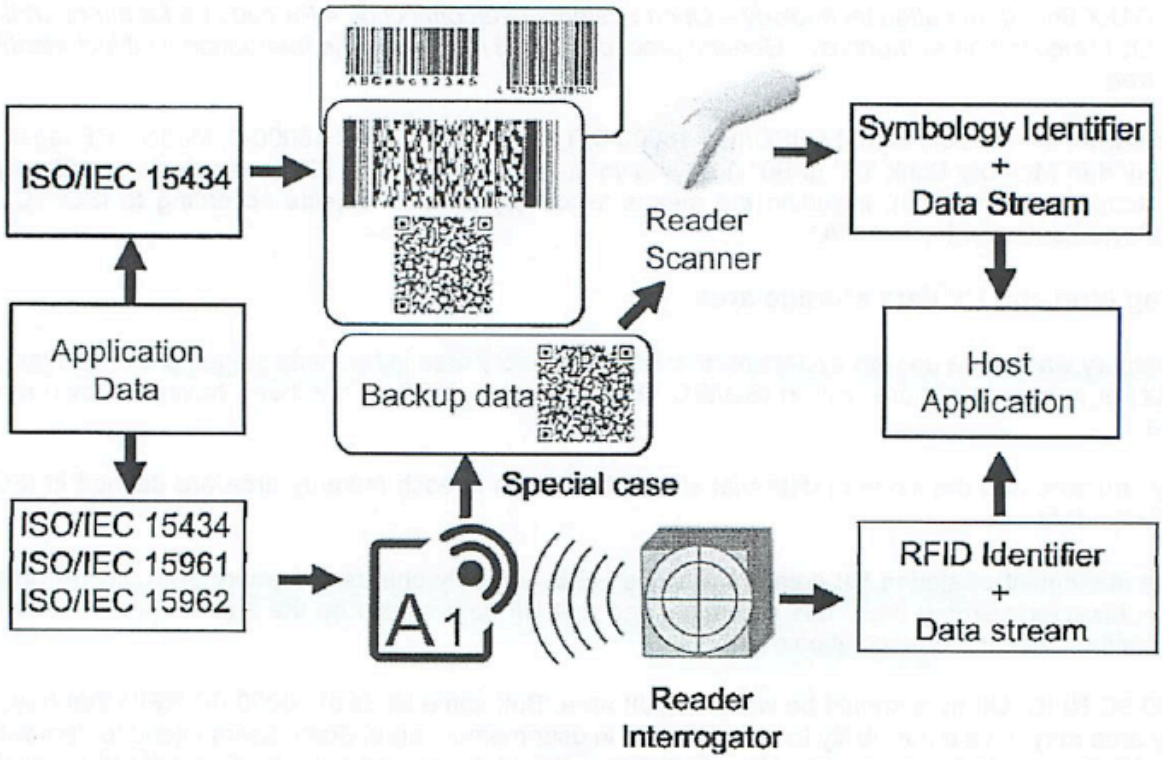


Figure 6.2- Data carrier identifiers operations.

6 POSSIBLE TAG SOLLUTIONS

6.1 Multi-frequency RFID tag

A multi-frequency tag can be used to read and write data in several frequencies. The only frequency band that changes depending on the country is UHF (is the most used band in industry). Using that kind of tags is possible to write in a country using UHF and read in another country (with different UHF range) using HF or 2.45 GHz UHF.

In the next figure we can se an example of that kind of tags.

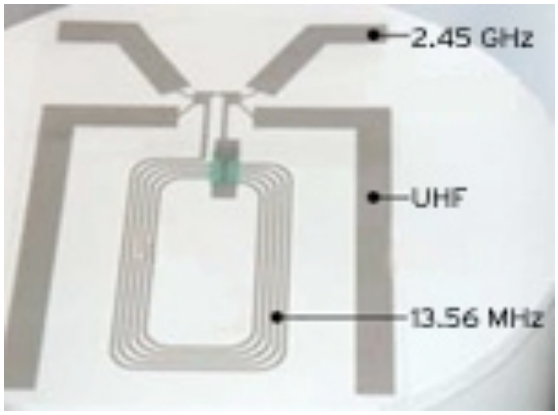


Figure 7.1- Multi-frequency RFID tag

Nevertheless, the utilization of the UHF band is preferable for its manipulation in the industry.

6.2 Universal UHF RFID chip.

Another possible solution is to build a Universal RFID tag that provides a bandwidth from 850MHz to 960MHz. This can be done with a T-Match adaptation dipole. Some recent experiments and simulations have been successful and a new generation of RFID will born soon. These new RFID will be focused on 900MHz and they will be able to be used from 850MHz to 960MHz including all the RFID UHF spectrum of the world.

In the next figure we can see one of the first prototypes that uses this technology.

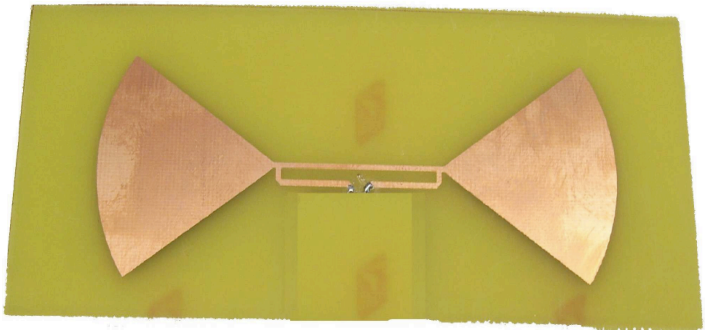


Figure 7.2- Universal UHF RFID Prototype

But this technology is not perfect yet because it will have a lot of interferences of the entire ambient UHF spectrum.

7 CONCLUSIONS

With the new ISO/EIC 15434 implantation a big jump will be done for the global RFID adoption. An industry will use indistinctly RFID, bar code and 2d codes all together with unique product identification. Then the industries could adopt RFID in a progressive way and what it is most important thing, all the world countries are going to have the chance to use the same product codes.

With the introduction of the new tags (multi-range and multi-frequency) and the multi-frequency antennas it will become easier to send one tag for one country to another one. The only problem will become the interferences that will exist using "foreign" frequencies that match with own country frequencies, so filters must be used to solve these problems.

Nowadays RFID technology is still becoming mature and the industry is still young. Its full impact is not yet foreseeable and there is still much promise for the future. It will simply take some time to realize its full potential.

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