RFID: The Up and Coming Technology

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***Abstract*— RFID has been the up and coming technology that many manufacturing, and warehousing, businesses have been delighted to use, while others still analyse the use, and cost variables, that come with such a technology. This document will serve as an analysis of the use of RFID, and the variables that come along with the future of this technology.**

***Keywords*—** *RFID, variance, cost, technology, simulation.*

1. Introduction

Throughout the years, technology has advanced the views taken by many businesses and corporations to withstand the growth in the demand for many supplies. Some of the key examples in this industry would be; the distribution industry, the manufacturing industry, the general warehouse industry, and even other industries such as the healthcare industry. A history of RFID is seen below in Table 1:

Decade	Event
1940–1950	Radar refined and used, major World War II development effort. RFID invented in 1948.
1950–1960	Early explorations of RFID technology, laboratory experiments.
1960–1970	Development of the theory of RFID. Start of application field trials.
1970–1980	Explosion of RFID development. Tests of RFID accelerate. Very early adopter implementations of RFID.
1980–1990	Commercial applications of RFID enter mainstream.
1990–2000	Emergence of standards. RFID widely deployed. RFID becomes a part of everyday life.

Table 1. Decade and Event table of RFID [1]

Even though this technology has not been taken into account, on such a large scale, RFID has existed in a very premature way. It has thus had to overcome obstacles such as that of the often used, and recognized, bar code system. Bar codes are used in many commercial stores, and many of the packages ,and packaging that companies. This technology has not only been used, but companies have grown familiar with it. Analysing the growth of this technology in the industry will depend on the various amounts of information. This data is taken to obtain the key information, including:

1. Accessibility – how easy it is for employers and its employees to be able to use this new technology.
2. Cost – will the overall cost of RFID give a better revenue or will it be a long cost due to problems that may come up

These are just some of the items that will be analysed, though many more variables will also be analysed extensively. These two aspects will lead this case study to examine the most important aspect of a corporation, or business, which is the ability to make money off of a new technology that not every company is yet using.

Though the technology is still growing, the possibilities that it can bring about are enormous. Just like many pieces of technology, there is a vital time in which people have to adapt to the use of its methods. Some clear examples are things such as televisions, cable, and computers. Many people can learn to grow with the new technology. Much of this technology was in fact, something revolutionary.

In our world money runs a lot of practical decisions that are being made, from expenses, to budgets, to payroll, and even new technological advances. In this kind of world it is something that could revolutionize the manufacturing and distribution industry.

In short, the analysis of this technology will raise questions about the benefits, the negative aspects, the

cost, the usability, and the accessibility. From the mathematical perspective, as well as the intellectual aspect, the overall presentation will help the everyday consumer, and the top CEO, decide whether the use of this technology will revolutionize their business.

2. Fundamentals

Though the terminology may be significantly long, RFID breaks down into two significant versions: *active* RFID and *passive* RFID. A good way to analyse the difference between these two versions will be as follows: "Active tags require a power source—they're either connected to a powered infrastructure or use energy stored in an integrated battery…Passive RFID is of interest because the tags don't require batteries or maintenance. The tags also have an indefinite operational life and are small enough to fit into a practical adhesive label" **[2].** Active RFID tags have to be powered by some source. The most usual way of powering the active tags is by battery. These tags are usually bigger in size, and are prominently used in clothing stores to prevent clothes from being stolen. These of course, have the benefit of being larger in size and thus more visible when employers are trying to use them in stores. Some of the most advanced technologies will power the RFID tag through a laser activator that turns on the tag throughout the day. This power source will generally be more expensive, as there has to be separate source to keep this RFID tag on.

A passive tag is more usable, as it can be turned on and off during the time that it crosses a certain laser or energy source. These will seem to have a much better use, as the separate cost of having to pay for a battery to keep the RFID tag on will seem to be a good idea. Unfortunately, like the active tag, there are also negatives to passive tags. These passive tags could be accessed by people, who may have the ability to activate them, at any point during transportation of product. If the tag is not within a range of a reader, there is the possibility that items could be stolen.

As companies move forward, the use for something more accessible is more accepted, much like how space and weight are important in industry now.

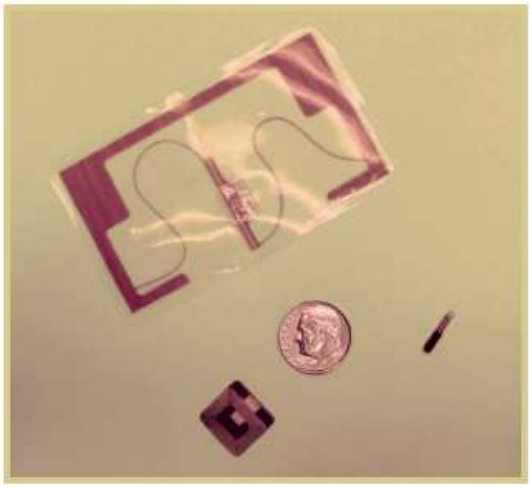

Figure 1. Size of sample RFID tag [3]

As seen in Figure 1, the newer technology is smaller in size, which will allow for any corporation to be able to hide these items within the packaging. This in turn can be tracked by a client or business needing the items being sent to the company itself.

A key question about RFID is, what does it really do? RFID tags carry information that can be used by other businesses, for example, if something is being shipped to a company. RFID tags store information (sometimes sensible information) which companies will use to keep track of inventory **[4]**. Some warehouse distribution companies will use this information to have fulfilment of warehouses or clients easily receive items into inventory. If a company has access to an RFID reader which can be connected to its ERP systems, it can easily get a pallet into a warehouse, run the scanner by the boxes or pallet, and the system on the network will do the rest.

2.1 Functional Frequencies

RFID tags run different frequencies. These frequencies will allow for many parties to understand exactly where and how information will be accessed, and whether or not information will be accessible from certain ranges. Below we will examine a few frequency models.

Figure 2. Tag reader system [5]

As seen in Figure 2, the main way in which RFID travels is through wireless networks. Both active and passive tags must go through this system to be able to process information. As discussed earlier, active tags have the need of having batteries installed in the tag, but the infrastructure has to be that of a passive tag, which also runs through the network. The most basic access of information is through the tag itself. From the tag, the corporations will run readers to gather data, and ERP systems channel that information. Now how many frequencies exist to be able to reach this model? The answer: Many. Readers can reach from within a few inches or feet, to kilometres if there is a need, or necessity, such as tracking airplanes and drones which may be military based.

Name	Frequency range	Read range for passive tags
LW	30-300 khz	50 cm
HF	3-30 Mhz	3 m
UHF	300 Mhz-3 Ghz	9 m
Microwave	> 3 Ghz	> 10 m

Table 2. Description of frequencies [6]

Some basic descriptions of LW, HF, and UHF are given below to better help you understand the frequencies list above:

1. LW is a low frequency range. An example of this would be contained animal tracking. [7]
2. HF is a high frequency tag. An example of this would be building access control. [8]
3. UHF is a higher range, high frequency. An example of this would be item management, including pallets. [9]
4. Microwave tags are the highest range. An example of this would be vehicle identification such as tolls on the road. [10]

The difference between these ranges is not just how far each RF signal can reach, but also how long the battery will stay alive in each tag. The higher the frequency, the more energy is being used by the tag. In this case, the use of passive tags, compared to active tags, would be most beneficial. Cost comparison would be the best method of analysing the above types, which will be shown, and considered, in the later parts of this analysis.

It is not enough to know that the tags are an essential part of power and energy sources, but also it should be understood exactly how they work from the aspect of the signal receiving party. Electromagnetic waves are produced by the reader, which can analyse the data within the chip on the tag. The way that these tags work with the wireless connections has a specific role, and it is fundamental to a business. The wavelength and battery life are key parts due to the fact that many businesses are global. Companies are exporting daily from one country to the next, so every tag must work reliably.

The United States has the ability to ship from the homeland to China. China then has the ability to ship to other part of the world such as Japan or maybe as far as Argentina.

Argentina may have an interest in shipping their goods back to the United States. This entire network is all interconnected by the RFID tags. This allows everyone to have access to the same information, can prove quality of products, and can make sure nothing is lost along the way. All the while, trying to eliminate paper trails and having everything done electronically.

2.2 Frequency wavelength supply

In order to fully understand the wavelength, the reach of the chip inside the RFID tag, and the electronic reader's potential reach, it is best to analyse a few models which point us in the right direction.

$$Pc = Pa\,\tau$$

The above formula describes the amount of power absorbed by the chip in the RFID tag (Pc). Pa is the maximum amount of power available from the antenna in the chip, and τ represents the power transmission coefficient. **[11]** This helps us analyze the transpose of the wavelength from the chip to the original destination, where the reader is located. Obviously, as the output power increases so will the power absorbed, thus a potential for a larger distance between where the signal can be sent and received.

Below we will analyze the overall range, as a parameter of the power taken in. We will use the help of formulations in "Impedance Matching Concepts in RFID Transponder Design", a scientific article with the focus on scientific research on RFID technology.

$$P_a = P_t G_t G_r \left(\frac{\lambda}{4\pi d}\right)^2$$

"In free-space propagation environment, the power received by an RFID antenna can be calculated using Friis free-space equation [above], where Pt is the power transmitted by the reader, Gt is the gain of the reader antenna, Gr is the gain of the receiving tag antenna, λ is the wavelength, and d is the distance between the reader and the tag." [12] From the information provided, a much broader picture can be obtained to explain the abilities of these tags.

3. RFID facts

3.1 Technology

Nowadays most of the technology developments of RFID systems have been done through ultra-high frequency (UHF), also called decimetre band. This is attributed to the high expectations set by other types of frequency bands, with already consolidated production chains and markets.

Product traceability has been the focus of improvement. New developments for this industry are being implemented, and their main goal is getting rid of technology limitations, and ease processes. When we say new developments, we are referring to the standardization of the system. The different points to be improved are explained during the next paragraphs.

The read range of a tag is completely correlated with the shape, signal range, and type of the tag being used. The efficiency and sensitivity of an RFID system will improve thanks to the variety of the tags offered. Two types of tags are now on the market, passive and active. They both have a very readable range, with the difference that the second one is self-powered. Libera Network's research shows that the size of the tags ranges from 20cm to 4mts depending on the provider.

Another well-known problem are the specifications that exist for one reader – one-tag devices, and not for one reader – various tags. In other words isolated tags and population tags. The main problem is when various readers, coincide with one same tag, or when the signals from multiple tags arrive to one of the reading devices. .

A well-known mechanism that has been implemented is the probabilistic anti-collision, instead of the old binary tree. On the other hand, something that has alleviated the issue of multiple readers interfering is the use of EDMA, where the reader device goes from one signal to another, with the command LBT.

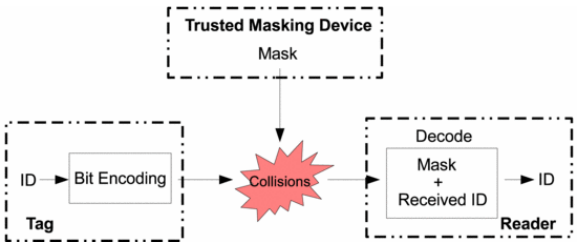

Figure 3. Randomized bit encoding, trusted masking device [13]

A very important fact to consider is the asset where tags are going to be placed. Water and metal affect the tag's quality and its signal. On the case of metal; tags become invisible, and for water, tag's signals get lost. For metal assets, the use of tags with metal surface has been the solution, creating a barrier due to material rejection.

The first tags that went to the market had just enough memory to store product's IDs. To expand the memory's capacity, the user memory was developed where not only identification of the product, but also its characteristics could be found.

Last but not least, is the security of the information contained on the tag. The developments on this aspect of the tags assure credibility, not only for the production, but also for the buyer. Commands such as Lock and Kill had been added to the tags so they can be deactivated at any point of the process, and reactivated on received by the costumer.

Figure 4. Principle RFID readers on the market [14]

3.2 Manufacturers

Manufacturers of RFID systems are divided into three categories; integrated manufacturers, tag manufacturers, and equipment manufacturers.

Integrated manufacturers: Right now the implementation of ultra-high frequency transponders, which main characteristics are size and big memory, is the most common mechanism. Companies such as TI and Philips are pioneers on the integrated manufacture, creating a wide variety of services like "XRAG2, Gen2 and UCODE Gen2." [15]

Tags Manufacturers: The evolution of these industry is flipping to the use of ultra-high frequency tags that contain not only transponders manufactured by the companies listed above, but also that can hold high volume of products information, and a small antenna. As mentioned on section 3.1, manufacturers are creating tags that offer a large range of lecture that is not affected by the material of the asset. A wide variety of wrapping materials is being implemented for costumer's satisfaction.

This market is trying to promote the use of UHF tags, due to the fact that their range of lecture is higher than the passive tags.

To assure the success on the implementation RFID systems is very important to consider factors such as signal lecture process and the assets to be tagged. It is also very important to be informed with the tags available on the market, and what is offered for each type of asset.

Device Manufacturers: There are four well-consolidated companies that focus on the production of readers. These companies are "Symbol, Intermec, Omron y Alien." [15]

Almost all of these companies offer devices that can read the "standards of ETSI 302-208."

The majority of the reader devices do not count with API's for the integration of RFID systems, neither have been developed. Due to these facts, big corporations with programming languages such as NET and J2EE, have to incorporate on the process companies specialized on these projects. What sets the mark from success or failure on the implementation of RFID systems is the capacity of the reader's software to be configured efficiently.

Besides the points listed above, it is very important to know the variances that antennas have. Antennas can vary gains, polarization, radiation, and frequency. The location where the RFID system will be working also plays an important role on this process. The majority of manufacturers also sell antennas for the convenience of the corporations or costumers.

When the number of assets to be tagged is very large, it is important for the corporation who is implementing this new system, to consider having tag printers. One of the main goals of the companies that provide this service is to support the different bar code standards and numbers. "Zebra is a big name on tags' printer's manufacturers." [19]

Since this market was not very secure and consolidated, the rupture of the market chains had happened before. Leading into systems being removed from the market. The shipment of this type of system is not very effective. Shipments have become a very important part of this industry, so having these packages and pallets delivered correctly with the correct information is vital.

3.3 Software developers: Middleware

Previous discussions about RFID middleware are like this, Middleware plays a fundamental roll in gathering data for RFID. It is a key piece in the implementation of a system. RFID tags are being

incorporated in newer versions of products for well-known companies all around the world.

Recently, Microsoft came to agreements with a few RFID main manufacturer companies to assure operability of its new version BizTalk Server (2006 R2).

However, Microsoft is a beginner in this market. Companies such as IBM lunched its first version of RFID server called WebSphere in 2004. Since then IBM has had agreements with software companies and hardware manufacturers such as OAT Systems, TruDemand software, Webtech wireless; to develop, extend, and supplement its RFID solutions catalogue. To support this, IBM has laboratories that are exclusively dedicated to testing, implementing, and developing of RFID solutions.

Sun Microsystems, with its RFID solution, Java System, offers support for RFID devices base on Java (J2SE, J2EE and J2ME). They are also working with manufacturers for the creation of smart RFID devices base on Java. In the meantime Sun Microsystems focus RFID's Java system marketing base on Java capability and EPCGlobal standards compliance. **[20]**

Tibco, Middleware provider of operability between operation systems, has developed solutions for corporate systems. These solutions add features that allow integration with EPCGlobal red and help in the inventory traceability of products in real time.

SAP, an ERP system provider, has developed a complete RFID package consisting of SAP Auto-ID infrastructure, SAP NetWeaver Exchange infrastructure, SAP R/3, and SAP NetWeaver Business Intelligence, all these base on its SAP web application server. This server allows integration with SAP as well as with other information systems.

To optimize performance of tis products for Intel architecture servers, Oracle has integrated in conjunction with Intel, RFID support in its business suite.

This support is known as "Oracle Sensor-Based Services". The downside of this is that company's corporate systems have to have Oracle servers otherwise they would have a hard time adapting to this system because "Oracle Sensor-Base Services" is not a specific suite.

With the acquisition of Connect Terra, one of the largest RFID infrastructure software providers on 2005, BEA systems entered in the RFID Middleware market. Nowadays, BEA systems has BEA WebLogic platform. This platform is a complete RFID support solution based on EPCGlobal standards.

IAnywhere, a branch of Sybase, offers a complete RFID package anywhere. This package supports integration of much of the equipment in the market as well as standards for the interface with other corporate systems. Other companies with similar products are OAT systems and GlobeRanger **[21]**. On the other hand Savvy Technologies complements its software solution by tracking and tracing its products along the supply chain.

In conclusion the majority of these products are made for large companies due to their elevated cost.

3.4 Application and pilot plans

Below are some of the most important RFID projects and pilot plans being conducted around the world as we speak. These interventions will help study and revolutionize the study of RFID and help the industry grow as some of these are major game changers in the industry.

- Wal-Mart and United State Department of Defence (DOD) were the first companies implementing RFID on their processes. This forced providers to label all their products with goal of having a better supply chain. Wal-Mart has seen the benefits of these changes. Receiving millions of labelled products each month, Wal-Mart has accomplished a reduction of stock rupture of 16% and a better exchange time of products out of the stock of 300%. **[22]**

- OTAN seeing DOD initiative, is incorporating RFID technology for its logistics

- No only American Express, but Visa and MasterCard have included RFID transponders inside their credit cards. McDonalds, in EEUU, has started accepting this type of payment to minimize costumers waiting time.

- Gillette has estimated a 25% savings in cost operation due to the identification with EPC labels on its products being manufactured.

- Numerous airports in conjunction with the department of home land and security and USA government have developed a pilot plan to include the name, nationality, date and place of birth, photograph and fingerprint in travellers' passports

4. Market Forecasting

There are a series of barriers that still affect the implementation of an RFID technology within a company. A study conducted by IBM and A.T Kearney Consulting Group concluded that RFID proposes a high investing cost for companies. Today the technological platform to support such a system is no more than a pilot and prototype. Companies who are serious about implementing a system with RFID technology must be willing to invest not only in the hardware and software to have such technology running, but also, on a network that will be able to support it. The points below summarize IBM and A.T Kearney's findings:

- The purchase of tags is costly to companies. Tags cost and unreliability are some of the main barriers preventing companies from engaging with a RFID system.
- Current readers and antennas lack the functionality, capacity, flexibility, and sophistication to be compatible with the desired system. Hence, an actual implementation with these current devices would be more costly than desired.
- There is no software capable of providing an integrated EPC solution; while vendors have created a series of alternatives, those do not meet the desired requirements to have an efficient system. As a consequence, companies are even more cautious to invest on EPC solutions.
- Most importantly, all tag application devices up to date are mere pilots and prototypes. Such devices lack reliability. Additionally, their lack of speed and consistency do not meet with the application requirements.
- Lastly, the EPC network required for the application has not been properly developed. As a matter of fact, according to the study, the general vision for the functionality of the network has not been properly understood.

All in all, before RFID implementation in the market can take place, a series of improvements must be met in terms of the overall speed and reliability of the network, application devices, and tags. Once these improvements are achieved, the overall industry output will be better for both the investors on the technology as for the end users of an RFID technology.

According to NORDICiD there are many benefits to implementing RFID in Supply Chain Management. Roskana Parvin, supply chain management professional, says,

"Over the last few years, more and more companies are integrating RFID technology into their strategic planning, since it provides significant advantages to supply chain performance. There are far more benefits gained by RFID implementation into supply chain and logistics operations than just improving identification of products, shipments, and assets. Nevertheless already the most common benefits prove that RFID is worth the investment." [26]

The table below summarizes some of the benefits that implementing RFID has on supply chain management according to Parvin.

Table 3. Supply Chain Benefits

Process	Benefits
Manufacturing	Less manual work Less costs Improved visibility Improved planning
Warehouse Management	Visibility inaccurate real-time information Fast locating of products Possibility to record losses Ability to plan product locations strategically
Tracking and Managing of Shipments	Offers visibility of real time cargo movement Improves efficiency Increases accuracy

Distribution	Accelerates the speed of delivery Improves efficiency Increases accuracy Reduces distribution costs

IDTechEx, British Research Company, foresees the following market facts:

- The sale of RFID tags in the last 60 years will increase to the total of 2.4 million dollars. In 2005 alone it was forecasted that 1.200 million would be generated from the sale of 600million tags. The net profit for the original investment (including additional costs of readers and software services) is of 1.85 million dollars.

- 2006 was expected to have doubled the sale of sold tags from 2005. One half of those tags were used to mark pallets and boxes. Overall, the use of tags will expand to broader markets. For example, luggage and passports, credit cards, and medications.

- Once the barriers that prevent the smooth development of RFID technology are conquered, RFID market will grow exponentially. Sales were expected to increase from 2006 to 2016 for 26.23 million. This increment is also attributed to the broader market in which RFID served.
- Sales were expected to increase from 2006 to 2016 for 26.23 million. This increment is also attributed to the broader market in which RFID served. Additionally, with the introduction of RTL—whose market alone will reach the 6.000 million in 2016—will also serve to expand the RFID market duet to their technologies' compatibility.

Although these forecasted results depend upon many other factors, the first results already look promising. In 2006 the main manufacturers (Axcess, Symbol, and Omrom) had an increase of 75% over the previous year's sales. This statistic enables us to confirm the forecasted increment on the actual market.

The projection below was released by the same British researcher, IDTechEX. It summarizes the exponential increase in sales of RFID tags.

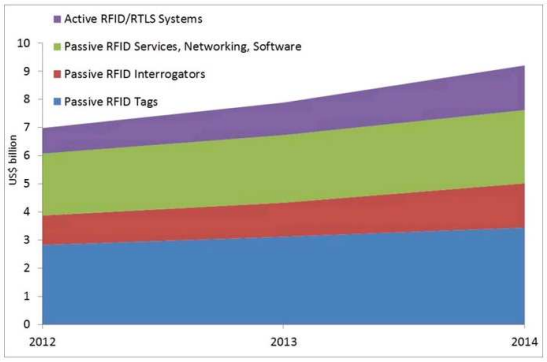

Figure 5. Sales in USD of RFID systems

The growth of the RFID technology will serve in tags for general consumer products, medicine, postal packages, and will serve such industries by reducing inventory, increasing product safety, reducing crime, and even increasing customer satisfaction. [23]

On the other hand, although currently most items are labelled HF, with a small presence of UHF and 2.45 GHz. It is expected that improvements in the performance ratio of the label – cost, and progress in the different specifications and functionality, will produce a greater acceptance of the UHF technology until the market can replace all of the HF tags. Over the next five years, UHF RFID will increase its expansion and, in 10 years, evolve into labels without a chip ("chip less tags"), which would greatly dramatically decrease the estimated price of tags to 0.1 cents of a dollar for the most basic kind. These tags will essentially clear a path for those with budget tightness, or budget focus, to see that it can be a rather inexpensive way of tracking and carrying information.

5. Conclusions

This academic journal has taken for a purpose to review the main features of RFID technology.
This is done in two ways, technically and in terms of its implementation on the market. Through the various analysis of RFID case studies, and with the help of fellow journals, a fair assessment of what RFID can be interpreted.

As mentioned throughout the document, RFID technology is still evolving. However, all industry players foresee great development prospects in the short to medium term. The implementation of RFID labelling for identification and traceability of products internationally is an inescapable reality. These presupposes great responsibility for companies to adapt to, and to integrate RFID technology into their systems and procedures. This is brought about by installing proper reading equipment/tag printing software and an appropriate integrated control system.

But we must not only take into account the development of the RFID technology driven product labelling market. On the contrary, it is crucial to consider convergence and integration with other wireless technologies and autonomous sensor networks. For instance, there are initiatives to incorporate RFID tags to mobile phones and bank cards to carry out payment transactions. Even more outstanding, the incorporation of such RFID tags into official documents to avoid counterfeits and fraud. All of these initiatives make certain the implementation and development RFID technology in the coming years.

The further development of the technology requires a partner software developer who can meet the expectations and requirements for the reader and other applications that technology needs. No proper selection of compatible devices exists with this partnering agent to achieve successful installation. The reader integration with corporate information systems such as inventory management software, storage, and sales, will have to be done by a specialized middleware company. Such agent must present their offering up-front along with all the internal systems, data collected and consolidated in a suitable format. In summary of this article, it can be said that the use of RFID is going to take a giant leap with years to come. The implementation may take some time, but with examples such as toll ways, credit cards, and various other sources, RFID is making its stand in the corporate world.

RFID is the color television in the times of the black and white transmission, in essence, it is an upgrade to the some already standing ideas, in this case, meaning the barcode and manual or paper trail ideas. Generally speaking, RFID is not the one ready for this century, but this century is ready, if not preparing, for the new upcoming RFID change in corporate America.

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