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RFID Demystified:
Part 1 The Technology, Benefits and Barriers to Implementation.

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Introduction

Radio Frequency Identification (RFID) has by some commentators been heralded as a technology that will have as big an impact on supply chain operations as the advent of computer based planning systems in the early 1970's. Whereas others say it is just yet another technology fad that in a couple of years will have gone away. We are continually reading conflicting messages about RFID, this is partly due to the term being miss used in some quarters and also because as with all new technologies it takes time for all those involved to define a common language. In this series of articles we hope to demystify the technology and its applications. RFID demystified part 1 will cover the technology and its benefits and possible barriers to implementations. Part 2 will progress to give an overview of the potential applications of the technology and finally part 3 will present an overview of the cases where the technology has been applied. Trials have been undertaken by a variety of organisations including Benetton, Woolworths, Scottish Courage and Figleaves.com to name a few. Each article also includes a series of references and a bibliography which it is hoped will enable both practitioners and academics the opportunity to investigate the areas in more depth if this is required.

Defining RFID

RFID systems (see figure 1) are those automatic identification systems that, using radio frequency signals, provide the automatic identification and location of electronic data-carrying devices attached to items.

Traditionally, an RFID device that did not actively transmit signals to a reader was known as a tag. When signals were actively transmitted the device was known as a transponder (York, 2003). However, it has become common the interchange of both terms when referring to those devices as it will be done here.

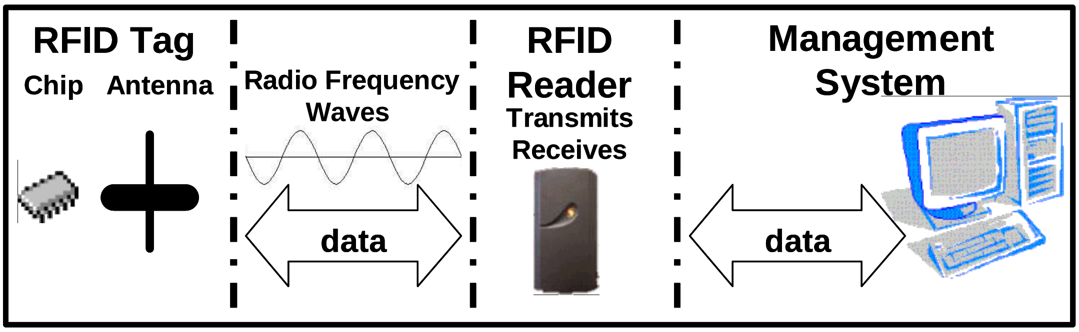

Figure 0: Radio Frequency Identification System (adapted from: Beck, 2002)

These tags can be detected by radio frequencies at a remote distance from a reader without the necessity of contact, or to be in its line of sight because the radio frequencies between reader and tag can normally go through various

materials. A network or a computer management system can use the information retrieved by the readers in order to be processed for a final application like materials management through a supply chain and for other value-adding services.

We will proceed to describe the key variables that impact on the application of RFID. The technology and operating frequency of the tag are key variables that define the potential use of a specific tag.

Types of RFID tags

RFID tags should not be confused with **Electronic Article Surveillance (EAS)** Systems tags due to the fact that RFID tags store information related to the identification of an article. EAS tags are commonly attached to items to protect from theft. The tag is attached to merchandise and then when a sale occurs the tag is removed or de-activated. If an activated EAS tag passes into the sensors magnetic field it disrupts this field and results in an alarm.

RFID tags comprise a semi-conductor chip with memory processing capability and a transmitter connected to an antenna (Finkenzeller, 2003). The memory may be configured to be read only (RO), write once, read many times (WORM), or read/write (RW) (York, 2003; Manning, 2001). Additionally, recent developments have led to the creation of RFID tags that do not require a chip – "chipless tags" (Harrop et al, 2000). However these tags are more limited regarding their performance in data storage, range and data transfer when compared with chip-based tags (IDTechEx Ltd, 2003b) but their low cost may justify the use on some applications that do not require those performance levels (Harrop, 2000), e.g. anti-counterfeiting applications. Therefore RFID tags can be divided in chip-based tags and chipless tags. Table 1 provides a classification of the technology.

<table>
<tr><th colspan="5">Radio Frequency (RF) Devices</th></tr>
<tr><td rowspan="2">Electronic Article Surveillance (EAS)</td><td colspan="4">RFID Systems</td></tr>
<tr><td colspan="3">Chip-based RFID systems</td><td>Chipless Systems</td></tr>
<tr><td rowspan="2">No Data</td><td colspan="2">Contactless Chip Cards</td><td rowspan="2">Other RFID chip-based systems</td><td rowspan="2">Chipless Tags</td></tr>
<tr><td>Smart Cards (with microprocessor chip)</td><td>Memory Chip Cards</td></tr>
</table>

Table 0: Summary of Radio Frequency Devices (source: Das et al, 2002)

RFID tags take on many forms depending on the application and the technology. If they take the shape of a card (e.g. credit card type) containing a microchip they are referred as “**contactless chip cards**” and are mainly used for payments, identification, information collecting or combination of the above (Das *et al,* 2002). In contactless chip cards, the power supply and the data exchange between reader and transponder are achieved by the use of magnetic or electromagnetic fields. In this case, contact surfaces provide energy to the card for the occurrence of data transfer. This type of tag is refered to as a “**Passive tag**”.

Sometimes it is necessary to use batteries in tags when there is the need to achieve increased distances between reader and transponder (Finkenzeller, 2003) but this increases the tags’ price. When tags use support batteries they are referred as “**active tags**”. Active tags have a battery for two reasons: for keeping the tag circuitry running and for communication with the tag reader. The power supply impacts on cost and, to some extent, robustness of the tagging technology. Active tags have a limited life and cost far more than passive tags (Finkenzeller, *idem*).

When the card contains a processor chip that provides computing capacity it is called a “**smart card**” (Das *et al,* 2002). These cards are mainly used in secure sensitive applications like financial transactions, transport tickets or smart cards for mobile communications. In the other hand there are memory cards that do not contain microprocessor chips and are only used in non-flexible specific applications where their function can be optimised. They have cost advantages against the microprocessors’ smart cards and are used in price sensitive, large-scale applications. Table 2 provides a summary of the different characteristics of RFID technology and there type of use.

RFID Tags Technology		
Tag Type	**Characteristics**	**Use**
Active	Fitted with a battery and capable of transmitting data over longer ranges. Normally more expensive and bigger in size but requiring cheaper readers.	Tracking more expensive items over longer ranges like cargo containers.
Passive	Receive power through induction from the reader thus achieving shorter ranges. Cheaper than active tags but requiring more expensive readers.	Inventory control, shrinkage prevention, and automatic checkout.
Chip based	Tags with integrated electronic chip to process	More commonly used

	identification data transfer and other operations.	type of tag.
Chipless	Cheaper tags that do not require integrated chip but have smaller storage capacity and reading range.	Still under technological developments but with great expectations of growth.
Read-Only	Data on the chip cannot be changed unless it is electronic reprogrammed.	Used on assets that will have a unique ID for its lifetime.
Read-Write	A partition of the chip allows changes on stored information by readers allowing other applications. However these chips are more expensive.	Used on articles that need to be traceable through the supply chain. (e.g. airport luggage)

Table 1: RFID Tags Technology (adapted from: Fulcher, 2003)

Frequencies Features of RFID

Table 3 provides an overview of the effect of operating frequency on a number of key variables. As a general rule the higher the frequency the higher the range the tag can be read over but this then needs to be traded off against for example health issues (due to radiation) and also what the radio waves can penetrate for example low frequencies can penetrate some metals whereas high frequencies can be reflected.

RFID Systems Frequencies Features				
	Low Frequencies (e.g. 125 kHz)	**Mid Frequencies (e.g. 12.56 MHz)**	**UHF (800-900 MHz)**	**High Frequencies (e.g. 2.45 GHz)**
Range	Usual under one meter (signal drops as cube distance) and impractical for some warehouse operations	Up to 1.5 meters	Up to 4 meters	Up to tens of meters (signal drops as square of distance)
Health Issues (Radiation)	Few health issues	Some issues depending on local regulation	Some issues depending on local regulation	Health issues regarding permitted microwave dose and public awareness
Reflection	Tolerant with metal	Beams able to go	Does not work	Reflections

Issues	presence and able to read through some non-ferrous metals.	through most non-metal materials but harder to 'flood' an area	well in moist environments	problems even through glass.
Data Transfer Speed	Slowest data transfer	Best compromise for speed and cost	Best compromise for speed and cost	Fastest data transfer
Size Issues	Large size due to antennas size. High cost.	Best compromise for size and cost	Best compromise for size and cost	Smaller and cheaper tags that will require more expensive readers.
Benefits	Frequency accepted worldwide and in wide use today	Frequency accepted worldwide and in wide use today	Commercial use is growing rapidly	For long range tracking
Common uses	Animal Identification Beer keg tracking Cars key-and-lock	Library books Pallet tracking Access control Airline baggage	Pallet/container/ trailer tracking	Vehicles access control

Table 2: RFID Systems Frequencies Features (adapted from: Das *et al*, 2002 and Overby, 2002a)

RFID Benefits

When compared against other auto-identification systems like barcoding, magnetic stripes or manual data entry, RFID offers many potential benefits, currently the cost of the technology is a barrier but as implementation costs fall the this will be less of a barrier.

Any cost justification of an RFID should take into consideration the entire system cost for the life of the system. Habitually, potential users of RFID tend to only compare the cost of the tag against that or a barcode label this results in the cheaper bar code option being favoured (Harrop, 2000). However if this comparison is made on a system level, RFID can be the lowest cost technology, with tags being reused and operational costs lower due to cheaper maintenance costs and lower labour requirements for example.

Table 4 provides an overview of the benefits of RFID over barcode type systems as identified by a number of commentators in the area.

Benefits from RFID technology by author

Authors / Benefits	Gerderman (1995)	Milner (2000)	Sarma *et al*, (2001)	Das *et al.* (2002)	Finkenzeller (2003)	Beck (2002)
Lower long term system costs		✓		✓		
Less labour requirements	✓	✓	✓		✓	
Reliability and accuracy		✓		✓	✓	
Higher reading range	✓		✓	✓	✓	✓
Capable of carrying more data			✓	✓	✓	
Reading Speed/ Multiple reading	✓	✓	✓	✓	✓	✓

Read-write capability			✓	✓	✓	✓
Higher security levels			✓	✓	✓	
No requirement for line of sight	✓	✓	✓	✓	✓	✓
Robustness	✓			✓	✓	

Table 3: Benefits from RFID technology referred by some authors

Barriers to RFID Implementation

Cost of RFID tags

The cost of the tags is one of the most important constraints for the full implementation of this technology within supply chains (Chomka, 2003). The low cost of the tags will allow applying them for single use or for low cost multiple use applications where the durability of the tag is suitable. These tags contain data that can be read remotely and cost less than five cents (Harrop *et al*, 2003), therefore cheap enough to be disposable.

Assessing the return of investment of RFID's added features instead of focusing on tag cost might be the strategy to be followed by users. Nevertheless, sometimes, the payback from the implementation of RFID technology can be difficult to calculate.

In order to achieve low price RFID tags it is necessary to trade-off various factors like functionality, data capacity and construction. Presently chipless tags represent the lowest level of cost for RFID tags. The chip with the tag represents the most expensive component this can be up to 90 per cent of the tag value (Das *et al*, 2002),

Many commentators state that for RFID tags to be used widely the price of a chip-based tag must be reduced to below one U.S. cent. This would enable full scale item level tagging within the supply chain. By early 2003 the cost of chip smart labels was around 40 U.S. cents and it is expected that by (IDTechEx Ltd, 2003a).

Common Standards

Frequencies' Standards Development

The development of standards for RFID frequencies is particular important to provide agreed specifications for application requirements on a sector or an entire industry. The main reason for it is that RFID technology will be mainly used in 'open systems' where it is necessary to have compatibility and interoperability between systems (Das *et al*, 2002; Harrop, 2000). The delay on the development of standards will have repercussions on the development of the RFID technology because costs will maintain high (Kay, 2003) and potential users and providers will delay the adoption or development of this technology to avoid wrong standards choices.

The International Standards Organisation (ISO) is the organization that it is working on the development of standards for RFID, and two main groups have already emerge lobbying for standards harmonization for general use in smart labels: the GTAG initiative and the Auto-ID Center (RFIDJournal, 2003b).

GTAG initiative

The GTAG initiative aims to combine different hardware propositions into a common approach for RFID standards as the air-interference and collision-avoidance mechanisms (Harrop *et al*, 2003). This will assist the definition of an open standard that will allow RFID to be applied in the identification of objects at trade, logistics and consolidated assets levels. It is expected that this initiative standards will become the international standards decided by the ISO - the forthcoming ISO 18,000-6 (Smith, 2003).

Thanks to the different features of each frequency and the different types of necessities it is expected that the referred frequencies will find the market space in which they can be developed (Das *et al*, 2002, Harrop, 2000).

Auto-ID Center

Working towards a global harmonization, is the emergence of a RFID technology developed by the Auto-ID Center together with the Massachusetts Institute of Technology (MIT). Rather than battling for a frequency standard, they are working in collaboration with global standards bodies and the auto-ID industry to specify how items can be identified in a standard environment (Sarma et al, 2001).

Radiation Limits

The remaining problem relating to frequency standards will be the difference in radiation limits between the United States of America's and Europe's radio-communication organizations, which particularly affect those systems that work with UHF - Europe limits=0.5 Watts / USA limits=4 Watts (Harrop *et al*, 2003). The European limits are almost 100 times lower than the American ones and therefore, for the same frequency the readable range of the a tag in Europe would be almost 100 times lower than in the USA.!

Regarding the regulatory requirements within the East Asia region, these are determined on a national basis but they tend to follow the regulations defined by Europe or USA (Harrop *et al*, 2003). However it must be noticed that Japan did not allow the use of UHF for RFID (Finkenzeller, 2003) until very recently, when the Japanese government decided to allocate 950 to 956 MHz for RFID (RFIDJournal, 2003c) allowing the possibility of global adoption of UHF tags for supply chain tracking.

Interferences with Metallic Materials

One of the technical barriers for the implementation of RFID technology in the retailing environment is related to the risk of tags misreading due to metal interferences (Finkenzeller, 2003; Harrop *et al.,* 2000). It is necessary to diminish these risks and this will be possible by developing the technology in order that metal interferences can be minimized and/or modifying retail stores environment in order to be RFID friendly.

Other Challenges

Background Infrastructure

Some other challenges are faced by RFID technology. Among them is the development of a background infrastructure that can manage the expected massive data processing of millions of tags. This means additional costs in new hardware, software and systems integration.

Inadequate chip production

The inadequate chip production capacity that may satisfy the demand of trillion of tags may also be an issue that will have to be solved by the development of new production technologies (Finkenzeller, 2003; Harrop *et al*, 2003).

Environmental concerns

Another challenge is related to the environmental concerns that non-biodegradable, sometimes poisonous materials present in the tags (e.g. batteries, metals) may raise. The disposal of these tags and the fact that they may be used near food will be an issue that can cause public concern alerted by environmental organisations. Additionally, European legislation going into effect by 2006 will oblige producers to recall and recycle the products that they manufactured (Ferguson, 2002). Nevertheless, technological developments that use environmental friendly materials and lower radiation levels can solve this problem before it becomes an issue.

Privacy

Finally, the concern about privacy will probably raise more public discussion. The concerns of being controlled both in movements and habits by other entities catch the public attention (e.g. Benetton's doubts on launching item level tagging (Krane, 2003)). This issue will have to be debated between all parties in order that a satisfying agreement can be reached.

1.1.1 Conclusion

The barriers that still exist for the implementation of RFID technology are rapidly being crossed through technology developments and standards convergence. The first will bring technology costs down and improve technology performances of RFID systems. The last will lead to the interoperability of different open RFID systems in a global scale. Other concerns that might arise due to environmental or privacy issues will have to be dealt with technological answers and agreement debates.

In RFID demystified Part 2 we will proceed to discuss the potential applications of this new technology.

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RFID Demystified: Part 1. The technology, Benefits and Barriers to Implementatio

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