An RFID Overview

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This report is part of a series of reports produced for the CHPM Center-Designated Project entitled "RFID Technology and Implementation Analysis and Development of RFID Implementation Decision-Support Tool." The reports are intended for the use of member company representatives of CHPM.

An RFID Overview

This is the first report in a series of reports produced for the CHPM Center-Designated Project entitled "RFID Technology and Implementation Analysis and Development of RFID Implementation Decision-Support Tool." Each month from July 2004 to June 2005, we will issue a report on the state of RFID technology. This time period covers the six months directly before and the six months after the January 1, 2005 Wal-Mart/Department of Defense mandate of supplier RFID compliance. This will prove to be a very active and dynamic time in the life cycle of RFID technology.

The sources that we will utilize in assembling these reports are listed in the Appendix (if you know of any others, please e-mail us at RFID@vt.edu as we intend to continually update this list). As you will see, we will be getting our information from many sources and it will be our objective to synthesize this information into one summary report each month. In the process, we will at times directly quote particular sources. Other times we will summarize various sources into one thought. In either case, we will do our best to give credit where credit is due by citing the original sources.

This first report is entitled "An RFID Overview" to level the reader base and to establish a common language when discussing the technology. Those new to RFID technology can think of this report as a primer and those familiar with RFID technology can think of it as a refresher. In addition to a basic definition of RFID technology, we have included a short discussion on the promise of the technology and the main roadblocks to the implementation of RFID. A discussion on EPCglobal, Inc., the current driving force behind RFID technology standardization and adoption, is presented along with a section on the technical details of RFID.

Future reports will provide summary updates on the activity in this industry, more detailed examinations of the different aspects of the technology, and example applications for the various industry types where RFID is being deployed. CHPM member company representatives are encouraged to relay their experiences and their desires for future report coverage to RFID@vt.edu.

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RFID – An Overview

1.0 What is RFID?

Radio frequency identification, or RFID, is a generic term for technologies that use radio waves to automatically identify individual items. The concept of radio frequency identification (RFID) goes back to WWII. Britain pioneered the use of radio wave-based navigation and the identification of friend or foe aircraft for night operations by the Royal Air Force (RAF). The military has continued to use more advanced versions of this technology for many applications. Standardization of RFID technology to enable its commercial use was started at the Auto-ID center (Massachusetts Institute of Technology) and is being continued by EPCglobal, Inc.

In a typical RFID system, individual objects are equipped with a small, inexpensive tag that contains a transponder with a digital memory chip that is given a unique electronic product code. The interrogator, an antenna packaged with a transceiver and decoder, emits a signal activating the RFID tag so it can read and write data to it. When an RFID tag passes through the electromagnetic zone, it detects the reader's activation signal. The reader decodes the data encoded in the tag's integrated circuit and the data is passed to the host computer for processing. The data transmitted by the tag may provide identification or location information, or specifics about the product tagged, such as price, color, date of purchase, etc. Figure 1 gives a diagrammatic representation of the RFID components.

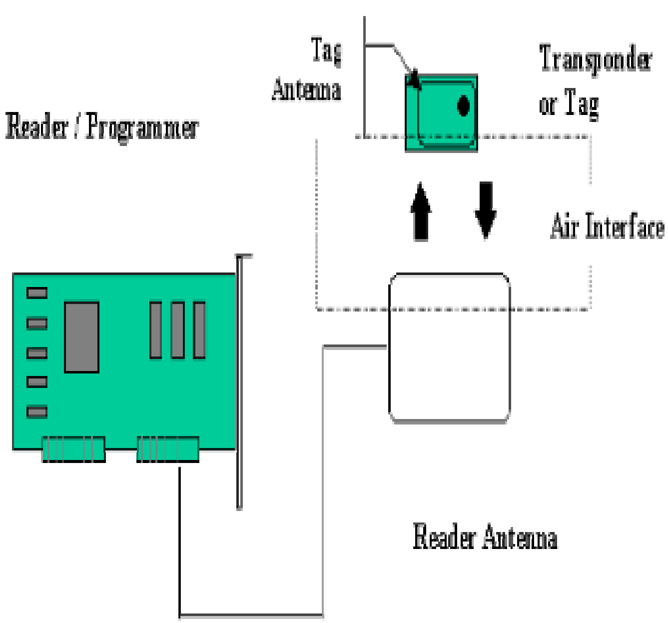

Figure 1: RFID System Components (Source: Reference 1).

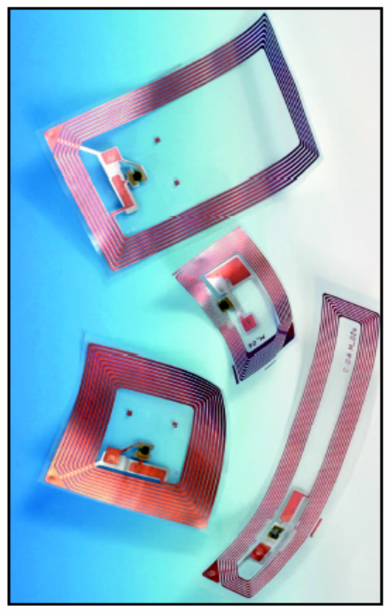

Figure 2: Texas Instruments TagIt Passive RFID Tags.

RFID tags are powered either by an internal battery (Active tags) or may derive its power from the field generated by the reader (Passive tags). Active tags are typically read/write devices with a longer read range, while passive tags are read only devices with a shorter read range.

RFID tags come in a wide variety of shapes and sizes. Some tags are easy to spot, such as the hard plastic anti-theft tags attached to merchandise in stores. Animal tracking tags that are implanted beneath the skin of family pets or endangered species are no bigger than a small section of pencil lead. Figure 2 shows a typical RFID tag.

2.0 The Promise of RFID[1]

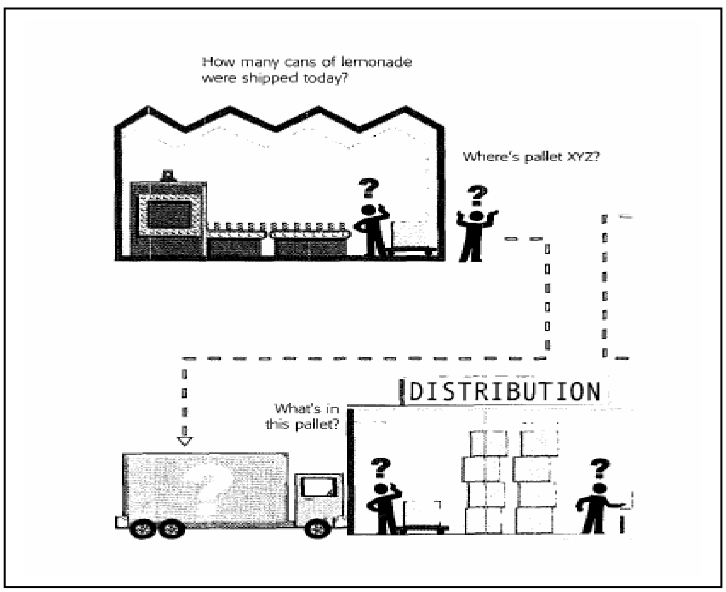

Figure 3: Typical Supply Chain.

Wal-Mart and the Department of Defense (DOD) have become the driving force behind RFID technology today. The enormous impact of their buying power allows them to dictate how and when consumer goods companies (in the case of Wal-Mart) and defense suppliers (expect those supplying bulk materials like sand, gravel or liquids) adopt RFID technology. Most of the back-end infrastructure, such as the information processing systems needed to record, store, transmit and act upon the data captured through RFID are already in use by most companies. These include enterprise resource planning (ERP), supply chain management (SCM) and related distribution and logistics systems. The communications infrastructure is also largely in place with the Internet and advances in wireless communications. Furthermore, the advances in radio frequency (RF) and bar code technology have already proven the advantages of automated data capture and system-directed workflows. The convergence of back-end infrastructure, maturing

[1] Complied from References 2, 3, 4 and 5.

technology, declining costs and accepted standards created the springboard from which Wal-Mart and DOD's decree was launched. Although there are many potential applications with considerable value outside of the Wal-Mart and DOD initiative, the impact of these two behemoths in the marketplace has been the major impetus for the current buzz about RFID.

Besides being a requirement for doing business, RFID technology has many potential benefits for retailers and manufacturers beyond the immediate compliance issues. Some of these can be gained relatively quickly within the enterprise. Others will come with advances in technology and wider adoption across the supply network. For Wal-Mart and DOD, the immediate perceived benefits are new efficiencies and error reduction in receiving and tracking of inventory. The order detail contained on the advanced shipping notice (ASN) will be matched against the receiving detail that is automatically read at the dock door through RFID to verify receipt and direct the warehouse management system (WMS) to put away or cross-dock the received inventory. Wal-Mart would also like to write branch/store information to the tags to further automate distribution. Once item-level tagging becomes economically feasible and retail stores are RFID enabled, more far-reaching benefits are possible. Revenue depleting problems like stock-outs can be greatly reduced through automatic replenishment, and the bane of retailers, lost sales from items in stock, but that cannot be located, will be eliminated. Theft will also be significantly reduced, both in the store and in transit from suppliers. Transmittal and use of RFID information between manufacturers and retailers will be a large contributor to current efforts to reduce the impact of bad data in the supply chain. In a study conducted for the Grocery Manufacturers of America, A.T. Kearney, Inc. estimates that retailers and manufacturers each lose $2 million for every $1 billion in sales due to bad data. They predict that eliminating bad data could save $10 billion per year. Although warehouse management systems have generally brought inventory accuracy into the 99+ percentage range, and ASN transmittals have been in use for years, there are still significant communication problems between manufacturers and retailers, particularly in the area of demand and forecasting data. The result of this bad, missing or incomplete data is stock-outs and oversupply of slow-moving products.

Benefits similar to those achieved between manufacturers and retailers can be gained by manufacturers and their suppliers by using RFID to better track materials, components, sub-assemblies and finished goods in production and in transit. By creating a "glass pipeline," suppliers can better adjust output to demand, and manufacturers can reduce expensive downtime due to shortages of supplies. Besides improving demand planning and reducing stock-outs, manufacturers are also trying to prevent counterfeiting. The use of RFID tags on products and packaging can help to better identify valid products from counterfeit substitutes, potentially saving millions of dollars annually. RFID technology can have considerable benefits within distribution centers as well. Automatic tag reading eliminates the need for workers to stop, pick up RF scan guns and shoot the barcode labels on pallets, cases, rack locations, and dock doors. Unlike with barcodes and scanners, there is no need for line of sight between RFID tags and readers. This streamlines and speeds up operations while improving accuracy, productivity, and ergonomics. As RFID technology matures and becomes widely adopted across supply networks, distribution processes will be transformed. Components, inventory, and demand will be visible across the network; stock-outs, safety stock, theft, and counterfeiting will all be reduced; and many time-consuming tasks such as scanning, cycle counting and searching for misplaced inventory will be eliminated. Supply chains will become faster, more efficient and productive; and more secure and better tuned to consumer preferences. This translates to lower costs, better customer service and increased profits and brand loyalty. Figure 4 shows a RFID-enabled supply chain of the near future.

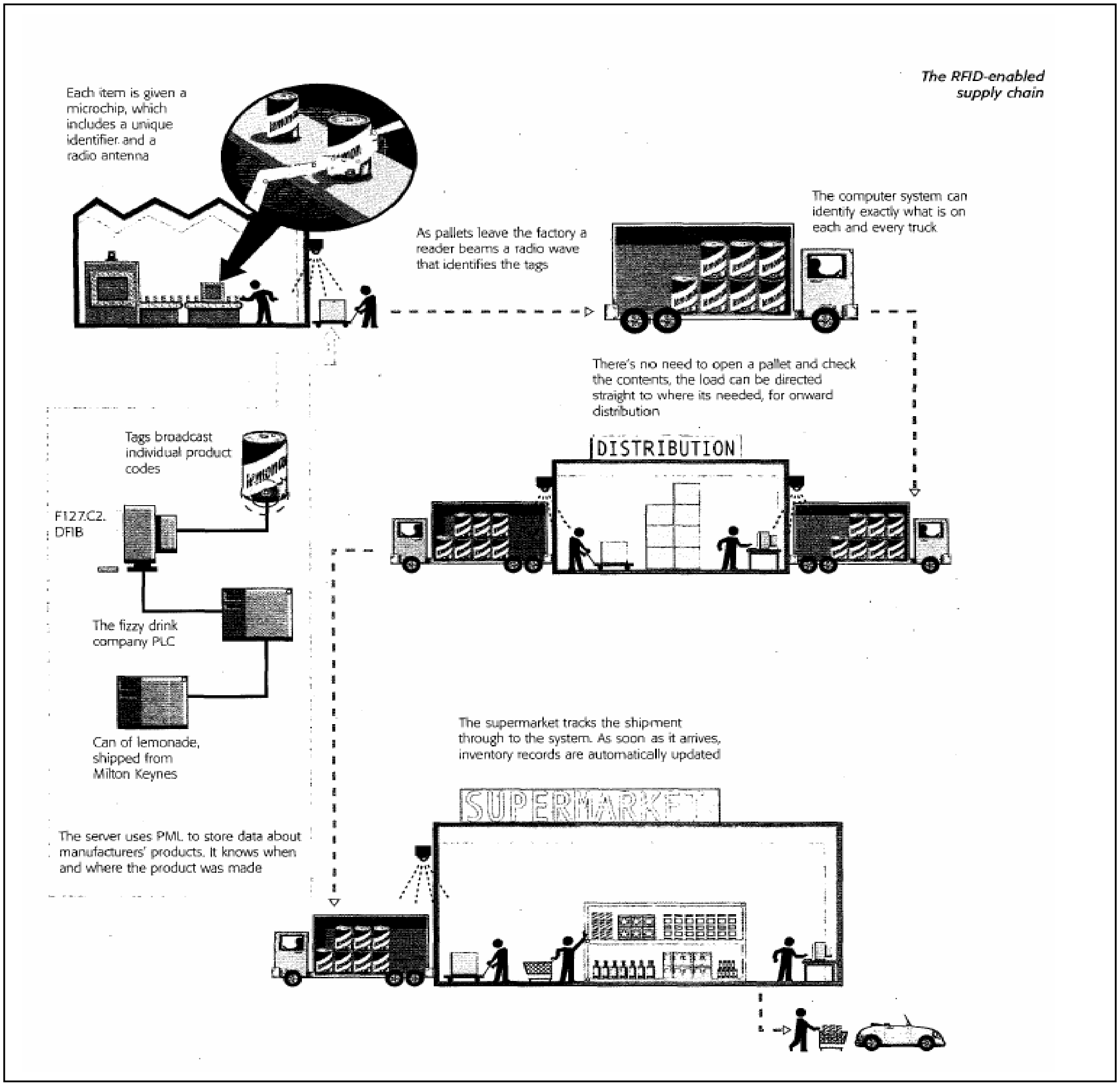

Figure 4: RFID-Enabled Supply Chain (Source: Reference 3).

Besides the benefits RFID has on the supply chain, RFID find enormous applications in other areas: spare parts for surgery, intrusion detection, document tracking (there are reports of the $20 bills being embedded with RFID tags, although there has been no confirmation from US Treasury about this), animal tagging, waste management, postal tracking, airline baggage reconciliation, road toll management etc.

3.0 Roadblocks to the Implementation of RFID[2]

RFID technology in an ideal environment promises to bring about enormous benefits. However, there are a number of technical and non-technical challenges that must be addressed before those benefits can be realized and a full-scale RFID system is implemented.

The most important challenge is in tag and reader technology. The effective read/write range of readers is currently quite short, about 3 to 5 feet for passive tags. This means that readers must be within a few feet of the object to be identified in order to accurately read the tag data or write to it. Active tags allow slightly longer ranges. This is fine if one is attempting to read cartons on a medium speed conveyer, but does not permit identifying the second or third pallet back in three-deep storage. This is also a potential problem for reading large objects whose tags may be on the opposite side from the reader. Proximity reads are also an issue. How does one distinguish between the correct pallet, carton or location and two or more objects on either side of it? Sorting through multiple reads is still not resolved yet. Similar problems arise when attempting to read all of the product tags on a mixed-case pallet. Since each tag puts out multiple signals in response to the reader stimulus, sorting through all of the reads fast enough and with enough accuracy to identify that this pallet has X cases of product 1, Y cases of product 2 and Z cases of product 3, is still an issue. A significant amount of research is being carried out in the development of software agents that will process the information coming from RFID tags and alert human operators whenever there is a deviation. The Auto-ID center has developed an anti-collision algorithm that takes advantage of the electronic product codes structured numbering scheme. The materials that the tag is fixed to or those around it can affect readability as well, negating the advantage of not requiring line of sight for reads. Liquids can distort or absorb signals. Metals may reflect the signals. Thus, objects to be read can be affected not only by their own composition, but also by the materials surrounding the object when (and wherever) they are read.

The second area of challenge for RFID adoption concerns standards. Standards are very important in open commercial systems where there are a number of competing technologies and vendors to choose from. Generally accepted standards are necessary to ensure that the readers at X, Y and Z companies, can read the tags applied by ABC Company. The Unique ID (UID) numbering sequence followed by DOD will also need to be considered by suppliers in selecting their tags.

[2] Compiled from References 2, 4 and 6.

The third and perhaps the most important roadblock in the implementation of RFID is the still prohibitive cost of the technology. RFID readers typically cost $1,000 or more. Companies will need thousands of readers to cover all their factories, warehouses and stores. RFID tags are also expensive – 50 cents or more – which makes them impractical for identifying millions of items that cost only a few dollars. In addition, active tags – those with a battery – can cost far more (if one bundles in a sophisticated sensor, the cost can rise to more than $100). AMR Research, Inc. estimates that a typical consumer goods company shipping 50 million cases per year will spend $13 million to $23 million to deploy RFID to meet Wal-Mart's requirements. This cost is particularly alarming because there is no payback from this investment – it only buys compliance. Additional costs would be incurred to leverage this effort for internal initiatives that may have cost-saving benefits. Besides the cost of the tags for every pallet, case or item to be tracked, there are the costs of the readers at every identification point, the software development and implementation costs for use of the information, and the supporting infrastructure costs. The biggest risk at this time, however, is that a company will incur these substantial costs only to find out that the solution deployed does not meet future standards or that the technology or vendor used for the deployment has not survived the inevitable shakeout of early contenders in this emerging field.

Concerns on privacy could be another significant factor in the implementation of RFID, especially for item level RFID tagging. There has already been significant backlash from consumers over announcements by Wal-Mart, Gillette and Benetton that they would use item-level RFID tagging. All three companies have had to pull back from these initiatives as a result. Although most of the fears are probably due to lack of proper education, they are still a cause of significant concern.

4.0 The RFID Network – EPCglobal [3]

The Auto-ID Center at MIT that did much of the initial work on RFID was officially closed on October 26, 2003. The center transferred its technology to EPCglobal, Inc., the group that is now administering and developing the EPC standards. EPCglobal, Inc. is a joint venture between EAN International and the Uniform Code Council (UCC). Auto-ID Center now operates under the auspices of the Uniform Code Council.

The EPCglobal Network employs Electronic Product Code (EPC) and Radio Frequency Identification (RFID) technologies. Leveraging these technologies, the EPCglobal Network offers the potential for increased efficiency and accuracy through automation, tracking and security through improved visibility and collaboration by providing a globally standard framework for product information exchange.

Leveraging this technology, the EPCglobal Network will enable trading partners to minimize shrinkage and shortages, accelerate order processing and increase responsiveness to consumer demand by enabling real-time information about goods in

[3] Complied from References 5, 7, 8 and 9.

their supply chain. In addition, it will provide increased efficiency in handling physical goods during processes such as receiving, counting, sorting and shipping.

Version 1.0 of the EPCglobal Network offers a complete set of technical specifications for every component in the EPCglobal Network. Released in September 2003, this version offers technical information on the number system, tag, readers, and reference implementations on many software components.

EPCglobal, Inc. is entrusted with the task of creating the EPCglobal network. EPCglobal offers subscription services to member companies that sign their intellectual property agreement. The services include:

- Assignment and maintenance of Electronic Product Codes (EPCs) in the Object Naming Service (ONS) registry.
- Training and education on implementing and using EPC and the EPCglobal Network.
- Participation in development of business-driven use cases and EPCglobal Network standards.
- Access to EPCglobal Network, network components, research and software specifications.
- Opportunity to influence the future direction of research by the Auto-ID Labs.
- Access to certification and compliance testing.
- Links with other subscribers to create pilots and test cases.

The EPCglobal network is composed of five fundamental elements:

1. Electronic Product Code (EPC).
2. EPC Tags and Readers.
3. Object Name Service (ONS).
4. Physical Markup Language (PML)/EPC Middleware.
5. Savant/EPC Information Services.

4.1 Electronic Product Code (EPC)

The Electronic Product Code (EPC) is the next generation of product identification that was originally proposed by Auto-ID labs. Like the UPC or bar code, the EPC is divided into numbers that identify the manufacturer, product, version and serial number. The EPC is based on the basic structures of the Global Trade Item Number (GTIN) an umbrella group under which virtually all existing bar codes fall. The EPC is a number made up of a header and three sets of data. The header identifies the EPC's version number. The second part of the number identifies the EPC Manager – most likely, the manufacturer of the product the EPC is attached to. The third part, known as the object class refers to the exact type of product, most often the stock keeping unit. The fourth is the serial number unique to the item. Since EPC is the only information stored on the EPC tag, it keeps the cost of the tag down and provides flexibility, since an infinite amount of dynamic data can be associated with the serial number in the database.

4.2 EPC Tags and Readers

The EPCglobal Network is an RFID-based system that uses radio frequency to communicate between readers and tags. The EPC is stored on a special tag that will be applied during the manufacturing process. Low-cost readers are being developed that send out electromagnetic waves that power up the RFID tag, enabling it to transmit back the information stored on the chip. The readers are connected via local computers to the Internet or a local network. Therefore, whenever a product code is read from a tag, it can be looked up in the database of objects where its details are stored. The reader device might be built into the entry and exit gates of distribution centers or loading bays.

4.3 Object Name Service (ONS)

Business information systems need a way of matching the EPC to information about the associated item. The ONS is an automated networking service that provides this service by pointing computers to sites that contain information about the product on the World Wide Web. The object name service is analogus to the domain name service used to point computers to sites on the web.

4.4 Physical Markup Language (PML)/EPC Middleware

Specially developed software manages the flow of data, transmitting and receiving information as required. A new computer language, Physical Markup Language (PML), has been developed to describe physical objects so that detailed information and instructions about a product such as its expiration data, where and when it was made and where it should be shipped, are instantly available in a standardized format. PML is based on the standard format eXtensible Markup Language (XML) and thus is easily accessible by script authoring tools.

PML completes the fundamental components needed to automatically link information with physical products. The EPC identifies the product, the PML describes the product, and the ONS links them together. Standardizing these components will provide "universal connectivity" between objects in the physical world.

4.5 Savant/EPC Information Services

Savant is software technology designed to manage and move information in a way that does not overload existing corporate and public networks. Savant uses a distributed architecture, meaning it runs on different computers distributed through an organization, rather than from one central computer. Savants are organized in a hierarchy and act as the nervous system of the new EPCglobal Network, managing the flow of information.

5. 0 Technological Aspects of RFID[4]

The objective of any RFID system is to carry data in suitable transponders, generally known as tags, and to retrieve data, by machine-readable means, at a suitable time and place to satisfy particular application needs. Data within a tag may provide identification for an item in manufacture, goods in transit, a location, the identity of a vehicle, an animal, or an individual. A system requires, in addition to tags, a means of reading or interrogating the tags and some means of communicating the data to a host computer or information management system. A system will also include a facility for entering or programming data into the tags, if the manufacturer does not undertake this at the source.

5.1 Wireless Communication and Air Interface

Communication of data between tags and a reader is by wireless communication. Two methods distinguish and categorize RFID systems, one based on close proximity electromagnetic or inductive coupling and one based on propagating electromagnetic waves. Tags using inductive coupling are widely used in indoor applications. Propagation coupling based tags are more expensive and are used in applications requiring longer read ranges like toll collection systems. Coupling is via antenna structures forming an integral feature in both tags and readers. While the term antenna is generally considered more appropriate for propagating systems, it is also loosely applied to inductive systems.

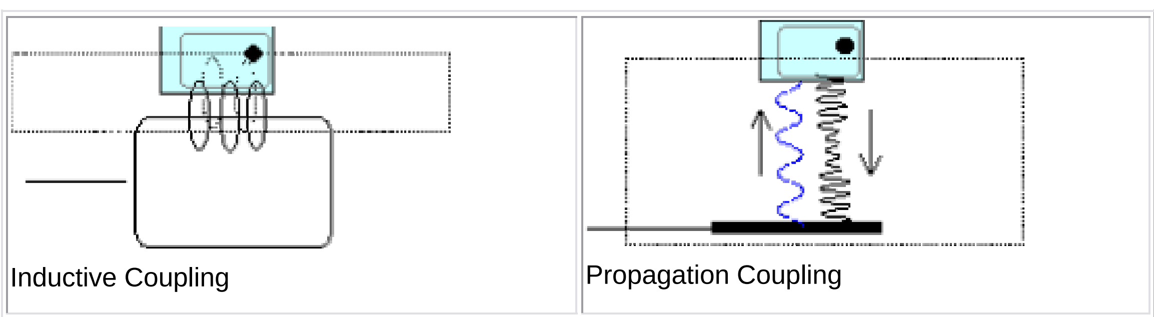

Figure 5: Communication Methods Employed by RFID Systems.

Transmitting data is subject to the vagaries and influences of the media or channels through which the data has to pass, including the air interface. Noise, interference, and distortion are the sources of data corruption that arise in practical communication channels that must be guarded against in seeking to achieve error-free data recovery. Moreover, the nature of the data communication processes, being asynchronous or unsynchronized in nature, requires attention to the form in which the data is communicated. Structuring the bit stream to accommodate these needs is often referred

[4] The whole section has been directly quoted from Reference 1.

to as channel encoding, and although transparent to the user of an RFID system, the coding scheme applied appears in system specifications. Various encoding schemes can be distinguished, each exhibiting different performance features.

To transfer data efficiently via the air interface or space that separates the two communicating components requires the data to be superimposed upon a rhythmically varying (sinusoidal) field or carrier wave. This process of superimposition is referred to as modulation, and various schemes are available for this purpose, each having particular attributes that favor their use. They are essentially based upon changing the value of one of the primary features of an alternating sinusoidal source, its amplitude, frequency or phase in accordance with the data-carrying bit stream.

5.2 Carrier Frequencies

In wired communication systems, the physical wiring constraints allow communication links and networks to be effectively isolated from each other. The approach that is generally adopted for radio frequency communication channels is to separate on the basis of frequency allocation. This requires, and is generally covered by government legislation, with different parts of the electromagnetic spectrum being assigned for different purposes (military, commercial and amateur). Allocations may differ depending on the governments concerned, requiring care in considering RFID applications in different countries. Standardization efforts are seeking to obviate problems in this respect.

Three frequency ranges are generally distinguished for RFID systems: low, intermediate (medium) and high. Table 1 summarizes these three frequency ranges, along with the typical system characteristics and examples of major areas of application. Three carrier frequencies receiving early attention as representative of the low, intermediate and high ranges are 125 kHz, 13.56 MHz and 2.45 GHz.

A degree of uniformity is being sought for carrier frequency usage through three regulatory areas, Europe and Africa (Region 1), North and South America (Region 2) and Far East, Australia and Asia (Region 3). Each country manages their frequency allocations within the guidelines set by the three regions. Unfortunately, there has been little or no consistency over time with the allocation of frequency, and so there are very few frequencies that are available on a global basis for the technology. This will change with time, as countries are required to try to achieve some uniformity among the three regulatory areas by the year 2010.

Table 1: Frequency Bands Used for RFID and Their Applications.

Frequency Band	Characteristics	Typical Applications
Low 100-500 kHz	Short to medium read range Inexpensive low reading speed	Access control Animal identification Inventory control Car immobilizer
Intermediate 10-15 MHz	Short to medium read range potentially inexpensive medium reading speed	Access control Smart cards
High 850-950 MHz 2.4-5.8 GHz	Long read range High reading speed Line of sight required Expensive	Railroad car monitoring Toll collection systems

5.3 Data Transfer Rate

Choice of field or carrier wave frequency is of primary importance in determining data transfer rates. In practical terms, the rate of data transfer is influenced primarily by the frequency of the carrier wave or varying field used to carry the data between the tag and its reader. Generally speaking, the higher the frequency, the higher the data transfer or throughput rates that can be achieved.

5.4 Range and Power Levels

The range that can be achieved in an RFID system is essentially determined by:

- The power available at the reader/interrogator to communicate with the tag(s);
- The power available within the tag to respond;
- The environmental conditions and structures, the former being more significant at higher frequencies, including signal to noise ratio.

Although the level of available power is the primary determinant of range, the manner and efficiency in which that power is deployed also influences the range. The field or wave delivered from an antenna extends into the space surrounding it and its strength diminishes with respect to distance. The antenna design will determine the shape of the field or propagation wave delivered, so that range will also be influenced by the angle between the tag and antenna. In space free of any obstructions or absorption mechanisms, the strength of the field reduces in inverse proportion to the square of the distance. For a wave propagating through a region in which reflections can arise from the ground and from obstacles, the reduction in strength can vary quite considerable, in some cases as an inverse fourth power of the distance. Where different paths arise in this way the phenomenon is known as "multi-path attenuation." At higher frequencies, absorption due to the presence of moisture can further influence range. It is therefore important in many applications to determine how the environment, internal or external, can influence the range of communication, where a number of reflective metal obstacles are to be encountered within the application to be considered, and can vary in number from time to time. It may also be necessary to establish the implications of such changes through an appropriate environmental evaluation.

5.5 Transponder/Tag

The word transponder, derived from TRANSmitter/resPONDER, reveals the function of the device. The tag responds to a transmitted or communicated request for the data it carries, the mode of communication between the reader and the tag being by wireless means across the space or air interface between the two. The basic components of a transponder may be represented as shown in Figure 6.

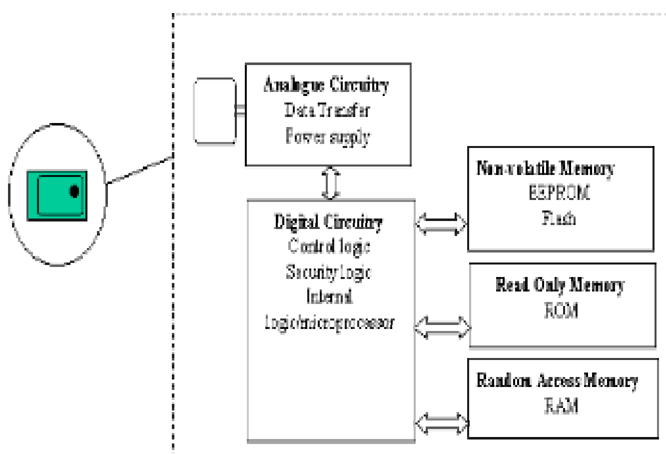

Figure 6: Components of a Transponder.

The transponder memory may comprise read-only (ROM), random access (RAM), and non-volatile programmable memory for data storage depending upon the type and sophistication of the device. The ROM-based memory is used to accommodate security data and the transponder operating system. The RAM-based memory is used to facilitate temporary data storage during transponder interrogation and response.

The non-volatile programmable memory may take various forms, electrically erasable programmable read only memory (EEPROM) being typical. It is used to store the transponder data and needs to be non-volatile to ensure that the data is retained when the device is in its quiescent or power-saving state.

Data buffers are further components of memory, used to temporarily hold incoming data following demodulation and outgoing data for modulation and interface with the transponder antenna. The interface circuitry provides the facility to direct and accommodate the interrogation field energy for powering purposes in passive transponders and triggering of the transponder response.

A number of features, in addition to carrier frequency, characterize RFID transponders and form the basis of device specifications, including:

- **Means by which a transponder is powered**

Tags are either passive or active, the designation being determined entirely by the manner in which the device derives its power.

Active tags are powered by an internal battery and are typically read/write devices. They are usually capable of operating over a temperature range of - 50° C to +70° C. The use of a battery means that a sealed active transponder has a finite lifetime. However, a suitable cell coupled to suitable low power circuitry can ensure functionality for as long as ten or more years, depending upon the operating temperatures, read/write cycles, and usage. The trade-off is greater size and greater cost compared with passive tags. In general terms, active transponders allow greater communication ranges than can be expected for passive devices, better noise immunity, and higher data transmissions rates when used to power a higher frequency response mode.

Passive tags operate without an internal battery source, deriving the power to operate from the field generated by the reader. Passive tags are consequently much lighter than active tags, less expensive, and offer a virtually unlimited operational lifetime. The trade-off is that they have shorter read ranges than active tags and require a higher-powered reader. Passive tags are also constrained in their capacity to store data and the ability to perform well in electromagnetically noisy environments. Sensitivity and orientation performance may also be constrained by the limitation on available power. Despite these limitations, passive transponders offer advantages in terms of cost and longevity. They have an almost indefinite lifetime and are generally lower-priced than active transponders

- **Data carrying options**

Data stored in data carriers require some organization and additions, such as data identifiers and error detection bits, to satisfy recovery needs. This process is often referred to as source encoding. Standard numbering systems, such as UCC/EAN, and associated data defining elements may also be applied to data stored in tags. The amount of data will of course depend on the application and require an appropriate tag to meet the associated need.

- **Data read rates**

Data transfer rate is essentially linked to carrier frequency. The higher the frequency, generally speaking, the higher the transfer rates. It should also be appreciated that reading or transferring the data requires a finite period, even if rated in milliseconds, and can be an important consideration in applications where a tag is passing swiftly through an interrogation or read zone.

- **Programming options**

Depending upon the type of memory a tag contains, the data carried may be read-only, write once read many (WORM), or read/write. Read-only tags are invariably low-capacity devices programmed at the source, usually with an identification number. WORM devices are user-programmable devices (Wal-Mart mandates the use of this kind of tag to its suppliers). These tags permit greater flexibility in use, downstream in the supply chain, but are not reusable nor provide most of the supply chain tracking capabilities. Read/write devices are also user-programmable, but allow the user to change data stored in a tag. Portable programmers may be recognized that also allow in-field programming of the tag while attached to the item being identified or accompanied.

- **Costs**

The cost of tags obviously depends upon the type and quantities that are purchased. For large quantities (tens of thousands), the price can range from about 20 cents for extremely simple tags to about hundreds of dollars for the larger and more sophisticated devices.

Increasing complexity of circuit function, construction and memory capacity will influence the cost of both transponders and reader/programmers.

The manner in which the transponder is packaged to form a unit will also have a bearing on cost. Some applications where harsh environments may be expected, such as steel mills, mines, and car body paint shops, will require mechanically-robust, chemical- and temperature-tolerant packaging. Such packaging will undoubtedly represent a significant proportion of the total transponder cost.

Generally, low-frequency transponders are cheaper than high-frequency devices; passive transponders are usually cheaper than active transponders.

5.6 Reader/Interrogator

The reader/interrogators can differ quite considerably in complexity depending on the type of tags being supported and the functions to be fulfilled. However, the overall function is to provide the means of communicating with the tags and facilitating data transfer. Functions performed by the reader may include quite sophisticated signal conditioning, parity error checking, and data correction. Once the signal from a transponder has been correctly received and decoded, algorithms may be applied to decide whether the signal is a repeat transmission, and may then instruct the transponder to cease transmitting. This is known as the "Command Response Protocol" and is used to circumvent the problem of reading multiple tags in a short space of time. Using interrogators in this way is sometimes referred to as "Hands Down Polling." An alternative, more secure, but slower tag polling technique is called "Hands Up Polling," which involves the interrogator looking for tags with specific identities, and interrogating them in turn. This is contention management, and a variety of techniques are being developed to improve the process of batch reading. A further approach may use multiple readers, multiplexed into one interrogator, but with attendant increases in costs.

5.7 Transponder Programmers

Transponder programmers are the means by which data is delivered to write once, read many (WORM) and read/write tags. Programming is generally performed off-line, at the beginning of a batch production run, for example.

For some systems, re-programming may be carried out on-line, particularly if it is being used as an interactive portable data file within a production environment, for example. Data may need to be recorded during each process. Removing the transponder at the end of each process to read the previous process data, and to program the new data, would naturally increase process time and would detract substantially from the intended flexibility of the application. By combining the functions of a reader/interrogator and a programmer, data may be appended or altered in the transponder as required, without compromising the production line.

The range over which the programming can be achieved is generally less than the read range, and in some systems near-contact positioning is required. Programmers are also generally designed to handle a single tag at a time. However, developments are now satisfying the need for selective programming of a number of tags present within the range of the programmer.

6.0 Summary

RFID is making headway to realizing its true potential as an automated, non-line-of-sight technology. Besides making small strides towards pushing us into "The Jetsons" age, advances in RFID technology and standardization are making big strides in automating enterprises right now. There have been significant advances in the efforts towards standardization in the last few months. The future is even more exciting with the Wal-Mart and DOD mandates looming large in the horizon.

This first report, entitled "RFID Overview," focused on providing a concise but thorough explanation of RFID. In our next report we plan to discuss RFID tags in more technical detail, as well as updating the CHPM member company representatives on the latest developments in the field.

7.0 References

1. "Radio Frequency Identification–A Basic primer," *Association for Automatic Identification and Mobility*, http://www.aimglobal.org/technologies/rfid/resources/RFIDPrimer.pdf, June 2004.

2. Yahoo discussion group on RFID (SV_RFID), http://groups.yahoo.com/group/SV_RFID/, March 2004.

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4. "RFID – Just the Facts," *RedPrairie Corporation*, http://www.redprairie.com/Knowledge/whitepapers.asp, June 2004.

5. Schuster, Edmund W., and Brock, David L., "Creating an Intelligent Infrastructure for ERP Systems: Role of RFID Technology," http://www.ed-w.info/Auto-ID%20Articles.htm, June 2004.

6. Weis, Stephen A., "RFID Privacy Workshop-Conference Report," *IEEE Security & Privacy*, pp. 48-50, March/April 2004.

7. EPCglobal, Inc., http://www.epcglobalinc.org, June 2004.

8. Auto-Id Labs, http://www.autoidlabs.org/researcharchive, June 2004.

9. Sarma, Sanjay E., Brock, David L., and Engels, Daniel W., "Radio Frequency Identification and The Electronic Product Code," *IEEE-Micro*, pp. 50-54, November-December 2001.

Appendix - Complete Listing of Information Sources

Trade Associations:

Virginia Bar Coding Association, Richmond, VA.

Websites related to tracking RFID developments:

1. http://www.arcweb.com.

A research advisory forum tracking manufacturing issues.

2. http://www.forrester.com.

An independent and influential research firm tracking a wide variety of issues.

3. http://radio.weblogs.com/0121943/.

Web log tracking RFID development.

4. http://www.rfida.com/weblog/blogger.html.

A web log tracking developments on RFID.

5. http://www.geeknewscentral.com/.

A news site that tracks latest technology developments.

6. http://www.dotmarketer.com/news1.php.

A website that collects RFID news from different sources.

Conferences:

7. RFID Knowledge Center.

ProMat–An MHIA International Exposition 2005, January 10-13, Chicago.

Magazines and Journals:

8. *RFID Journal.*

http://www.rfidjournal.com/.

9. *RFID Gazette.*

http://www.rfidgazette.org.

10. *RFIDBuzz.*

http://www.rfidbuzz.com/.

11. *Using RFID.*

http://www.usingrfid.com/.

12. *RFID News.*

http://www.rfidnews.com/.

13. *On the MHOVE - With the Material Handling Industry of America.*

www.mhia.org/e-Mhove.

14. *Logistics Management.*

http://www.logisticsmgmt.com/.

15. *Logistics Today.*

http://www.logisticstoday.com/.

16. *Packaging Digest.*

http://www.packagingdigest.com/.

17. *Industrial Distribution.*

http://www.manufacturing.net/ind/

18. *International Journal of Retail & Distribution Management.*

19. *Journal of Intelligent Manufacturing.*

20. *Chain Store Age.*

21. *Industrial Engineer*.

22. *Supply Chain Management Review*.

23. *APICS – The Performance Advantage.*

24. *Modern Materials Handling: Warehousing Management Edition.*

25. *International Journal of Electronics.*

26. *InformationWeek.*

27. *Network World.*

28. *Computerworld.*

29. *Wall Street Journal (Eastern edition).*

Online Article subscription services:

30. Ingenta – Online alert service tracking 27000 plus subscriptions.

31. Infotrieve - Large database of 20 million citations and 10 million abstracts of articles from scientific, technical, medical, and other scholarly content.

32. Kluwer Alert – Table of content alerts for 650 journals in a diverse range of subjects.

Newsgroups:

33. RFID.

http://groups.yahoo.com/group/rfid/.

34. RFID Tribe.

http://finance.groups.yahoo.com/group/rfidtribe/.

35. Indus RFID.

http://groups.yahoo.com/group/indusrfid/.

36. Silicon Valley RFID SIG.

http://groups.yahoo.com/group/SV_RFID/.