Understanding RFID and Associated Applications

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Introduction

Radio Frequency Identification (RFID) technology is garnering considerable attention in the market as the bleeding edge of auto-identification technologies. Not only are purchasing powerhouses like Wal-Mart and the US Department of Defense driving industries to adopt the technology for supply chain applications, but many customers are focusing in on the potential efficiency gains of RFID for their automatic data capture applications in both the supply chain and mobile computing applications.

RFID is not a new technology: the military has employed RFID for decades. The British used RFID to distinguish friendly from enemy aircraft during World War II. Today, the U.S. Department of Defense uses RFID (and GPS) technology to track major shipments of all its military supplies – including the tracking of supplies and hospital patients in Iraq. Other RFID solutions in place today include automatic payment systems such as Mobil/Exxon SpeedPass and many access control applications.

What is new is that businesses across a wide variety of industry sectors have started to pour resources into advancing RFID. This enthusiasm is fueled by the potential efficiency gains of RFID - over manual entry methods (often the clipboard) in mobile computing applications such as field data capture, and over barcodes in data collection environments. Estimates vary, but analysts say today's $1 billion worth of RFID sales could exceed $4 billion by 2008 and $10 billion by 2014. However, bear in mind that most analysts agree that significant market growth is still a few years off – perhaps as far out as 2007.

In North America, purchasing powerhouses such as Wal-Mart and the DoD are helping drive initial RFID demand by phasing in RFID compliance from their suppliers starting in 2005. To apply some context on the impact of these two organizations, Wal-Mart has approximately 10,000 suppliers while the DoD has around 43,000. In Europe, Carrefour is contemplating whether to adopt a similar direction for RFID.

However, even with these major organizations pushing RFID, it does not mean the end of the barcode in the supply chain. It will take several years before the majority of customers are ready and/or willing to make the jump to full RFID systems. Many customers may in fact run hybrid logistical operations that feature RFID for compliance with major customers and the barcode still serving as their primary logistics automatic data capture tool. This is because a full operational reengineering exercise is required for customers to garner the maximum potential benefits of RFID. Therefore, RFID is much more than a technological investment - it requires full business commitment to be a success. When the efficiency benefits of RFID are proven out by early adopter customers, more organizations will be willing to make the requisite business investment. However, this will take time and most analysts forecast 2007 or 2008 to be the timeframe that the RFID market will explode.

Outside of the supply chain, growth may occur much faster as many companies are looking to garner the efficiencies of RFID from a data collection/data control perspective. Opportunities are prevalent in livestock management, manufacturing, airports and various types of field data capture applications. RFID can pose immediate efficiency and accuracy advantages if it is replacing manual data entry, or the perennial clipboard.

This paper outlines the basics of RFID technology and outlines how it delivers value in data collection applications.

RFID Overview

Radio Frequency Identification (RFID) refers to an Auto-Identification system comprised of RFID tags, RFID readers and the requisite RFID middleware that interprets tag information and communicates it to the application software. RFID tags contain specific object information in their memory, accessed via the radio signal of an RFID reader.

On the surface, this appears to be similar to how a barcode infrastructure works: the barcode label contains the relevant product information that is read by a barcode reader, and then communicated to the application software. However, there are significant differences with RFID from an operational perspective that gives businesses the opportunity to redefine their logistical processes.

Many have referred to RFID as a replacement technology for barcodes. However, this is simplistic as RFID tags have advanced capabilities that cannot be duplicated with barcodes.

> **More Markets:** RFID will penetrate more markets than barcodes. Barcodes are primarily an automatic identification tool for the supply chain. In contrast, most current deployments of RFID do not touch the supply chain at all and are more often found in such as livestock tracking, security access control, healthcare and field data capture.
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> **Enhanced Data Capabilities:** An RFID tag is capable of carrying much more data than a barcode and consequently can identify specific, unique items. RFID tags can have read/write capabilities for real-time information updates throughout the supply chain or within a data capture application. Think of the entire maintenance log of a piece of machinery or the manufacturing to consumer supply chain history archived on an RFID tag. Or, tags can be teamed with advanced monitoring devices to provide detailed historical transit information on sensitive goods - such as the temperature for perishables.
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> **Increased Efficiency:** In addition, RFID provides operational advantages with the ability to simultaneously scan multiple tags without the need for contact or line of sight back to the reader. This creates the opportunity to

significantly improve the efficiency and accuracy of automatic data collection applications.

Some of the primary benefits of RFID over traditional data capture methods include:

RFID Capability	Description	Benefits
No Direct Line-of-Sight Required	RFID uses radio waves to exchange data, which eliminates the need for line-of-sight between the reader and the tag. Therefore, unattended reading stations can be set up to identify objects – for example, on a conveyor belt or within a transport container. RFID tags can be read through cardboard, plastic or paint allowing tags to be embedded into pallets or cases, giving much greater flexibility in their placement. By contrast, barcodes require physical line-of-sight, so they must be affixed to a visible, typically stationary location.	**Efficiency –** data acquisition performed with reduced labour requirements. **Flexibility** – fewer constraints to tag placement **Robustness** – tags can be embedded directly into pallets or cases protecting them from harsh environments and/or tampering.
Multiple Simultaneous Reads	RFID allows multiple tags to be read simultaneously while still uniquely identifying the various objects being tracked. Bar codes must be read one at a time. Therefore, RFID can be advantageous in high-speed reading, sorting and material handling applications.	**Efficiency –** increased data collection speed – simultaneous data input as opposed to sequential
Read Range	Active tags can be read from 100+ feet (30+ m) whereas long range scanners have a maximum of approximately 40 feet (12 m)	**Flexibility –** more choices in how data collection is performed
Data Capacities and Read/ Write Capabilities	RFID tags data capacity can exceed 256kb and some tags have read/write capability – information on the tag can be customized or updated. In a field data capture application, such as equipment maintenance, the capability to write to an RFID tag could be highly advantageous for accurate record keeping. Barcodes do not have the same level of data capacity, and data cannot be added to printed barcodes.	**Data Accuracy & Inventory Control** – ability to identify down to an object level. Particularly important in sensitive industries like pharmaceuticals. **Data Management** – tag write capability enables real-time updating of items through the supply chain.
Withstand Harsh Conditions	Damaged barcodes in harsh environments or scanners that do not have clear optics provide a challenge for efficient data capture. RFID systems are not subject to these same limitations, and can therefore perform strongly in harsh applications such as outdoor utility	**Productivity –** harsh conditions do not adversely affect data collection efficiency. In harsh conditions, damaged barcodes or unclear optics can adversely affect barcode

	meter reading.	scanning efficiency and capabilities.
Lifespan	RFID tags can be reusable and can be packaged to be extremely durable. This helps amortize initial system costs and provides strong total cost of ownership (TCO) advantages compared with identification methods that must continually be replaced such as barcoding.	**Cost Savings –** in certain applications, an RFID tag embedded in a pallet for example, RFID can present a cost savings over barcodes that need to be continually replaced.
Advanced Monitoring	In conjunction with monitoring equipment, RFID tags are capable of recording time, temperature or other variables of an object as it travels through the supply chain. This can be an important factor with sensitive cargo such as food or livestock.	**Cost Savings –** can potentially prevent spoilage of time sensitive goods such as food.

RFID will transform data access and collection processes across multiple industries. RFID provided the capability to reduce the amount of direct labor required for data collection, resulting in significant cost savings through increased efficiencies – in both supply chain and mobile computing applications. It will help prevent theft, from the warehouse floor right through to final sale as RFID tags provide a more comprehensive means of monitoring goods passing through distribution centers. RFID can help ensure security by keeping track of employees and even prisoners (via a tamper-proof wristband, embedded with a transmitter that allows guards to track their movement). It will enable unprecedented product visibility and transparency throughout the supply chain, from the manufacturer to the distributor, to store shelves and eventually out the door with customers. And, it will provide much more comprehensive information capabilities in mobile data collection applications - but not immediately.

Barcodes will remain the primary means of automatic data capture because they are a ubiquitous, inexpensive technology. It will be several years - perhaps decades - before barcodes are eliminated in the supply chain. Many companies have their logistical operations working extremely well with barcodes, and outside of compliance initiatives, will be reluctant to perform a major, costly re-engineering of their operational processes. This is important as to achieve the potential business benefits of RFID, supply chain customers will need to reengineer their processes. Consequently, many organizations that need to comply with Wal-Mart of DOD initiatives could operate hybrid systems comprised of both barcodes and RFID in the short term. Then, as RFID evolves and has been proven out by the early adopters – both process and technology - more customers will make the investment to jump to RFID.

RFID Applications

RFID should be on the radar screen of any business with automatic data collection and identification applications due to its advanced capabilities and potential business benefits. Influential companies are adopting RFID – and insist that those with whom they do business, follow suit. In addition to the aforementioned Wal-Mart and DoD, other major retailers such as Target and Carrefour are also evaluating how they could implement RFID in their operations. Gillette is running a pilot to use RFID tags on some of its products sold in the U.S. market. If successful, Gillette will likely place up to half a billion RFID tags on its products over the next few years. RFID will supply work-in-process data for manufacturers, shipping data, container and air cargo tracking, and vehicle fleet maintenance enabling rail companies, trucking companies and container carriers to identify cars, vehicles, containers and their contents via readers in ports or terminals. Another potential high growth sector is pharmaceutical companies interested in reducing the amount of drug counterfeiting and falsely labeled drugs through RFID.

Though much of the media attention surrounding RFID is within the supply chain, many of today's fastest-growing RFID application segments are baggage handling, rental item tracking, manufacturing, field utilities, point-of-sale and real-time location system applications. Airlines feel they can significantly reduce incidence of lost baggage via RFID – thereby significantly reducing the associated costs. Many mechanical items that need constant maintenance and/or monitoring, such as fire suppression systems, are also prime candidates for RFID given the increased data log accuracy afforded by the technology. RFID is also a burgeoning technology for wildlife and livestock tracking with more than 50 million pets and 20 million livestock already tagged with RFID chips worldwide. The recent Mad Cow scare in North America is driving the cattle industry to adopt RFID for more accurate herd tracking data.

So, What's Involved?

As with any enterprise application, the overall objectives will drive the specific technologies of the implementation. The primary variables that impact the performance capabilities of an RFID system are listed below:

RFID Tags:

RFID tags contain a microchip capable of holding stored information, plus a small coiled antenna or transponder. The tag's size and shape can vary tremendously: it can be a tiny millimeter-square chip, a thin credit card shape, a screw to be inserted into a crate, a flat label that can be stuck onto inventory items or even a tube, for insertion into the stomach of a cow.

The variables that define tags are detailed below:

- **Active Tags:** battery power transmits the information stored their memory to a reader. The batteries are good for 5-10 years of transmission time.

These tags are relatively expensive (presently up to $20 each), so are used for high-value goods that need to be tracked at ranges of 100 feet or more.

- **Passive Tags:** do not have a battery, but draw power from electromagnetic waves given off by an RFID reader. Passive tags are relatively inexpensive (usually less than $0.50), and last indefinitely, but with a read range typically less than 3 meters. They can be set into units, pallets, cartons or cases. Passive tags are the primary focus throughout this paper.
- **Semi-Passive:** contain a battery to run the microchip's circuitry, but the battery does not power the communication to the reader. Semi-passive tags are typically more than $1 and are used to track high value goods.

- **Tag Memory:**

  Read Only - Stores information (a unique serial number) that can never be changed unless the chip is reprogrammed electronically. Sometimes referred to as Write Once, Read Many (WORM), read only tags are currently the most popular and least expensive kind of tag.

  Read/Write - new information can be added, or existing information written over when the chip is within range of a reader. Generally more expensive than read-only chips and are used to track high-priced, valuable items.

  Capacity: The chip size and price are primarily determined by memory capacity - which can range from 16 bytes to 256kb – or more. Permanently encoded read-only chips that only define the identity of an object are used in price sensitive mass applications with low local information requirements. If data is to be written back to the transponder for read/write capability, EEPROM or RAM memory is required.

RFID Readers:

An RFID reader has an antenna that emits radio waves at a given frequency to "activate" tags within its range – often referred to as inductive coupling. Upon receipt of the RFID reader's radio signal, a tag sends information stored in its memory back to the reader. The reader then converts the data into digital information and forwards it to the appropriate application.

Readers can be hand-held or stationary depending on the application. For example, a stationary reader could be set up at the receiving doors of a warehouse, fixed into a building or a road surface, and attached to antennas that are wired back to a multiplexer. Hand-held readers could supplement fixed readers in a warehouse type scenario or be the primary data collection tool –

such as in field data capture for utilities or for equipment maintenance data collection. Of course, the reader must work at the same radio frequency as the tags it expects to read, and the relevant frequencies are discussed next.

Frequencies

The frequency of an RFID system defines the relationship between the tag and reader, and impacts both the transmission range and speed. Note that there are legal and regulatory restrictions in many countries that precludes the use of some of the frequencies outlined below:

- 125 - 134 KHz low-frequency (LF)
- 13.56 MHz high-frequency (HF)
- 860-930 MHz ultrahigh frequency (UHF)
- 2.45GHz (microwave)

Lower-frequency radio waves provide slower data transfer and only work with immediate contact or up to a distance of 1.5 feet. Higher frequency readers provide faster data transmission rates and at distances up to and over 10 feet with passive tags.

Low-Frequency (LF)

Low-frequency RFID systems are typically 125 KHz, though there are systems operating at 134 KHz as well. This frequency band provides a shorter read range (< 0.5m or 1.5 ft) and slower read speed than the higher frequencies. LF RFID systems have the strongest ability to read tags on objects with high water or metal content compared to any of the higher frequencies. LF tags are typically slightly more expensive than HF or UHF tags.

Typical low-frequency RFID applications are access control, animal tracking, vehicle immobilizers, healthcare applications, product authentication and various point-of-sale applications (such as Mobil/Exxon SpeedPass).

High-Frequency (HF)

High-frequency RFID systems operate at 13.56 MHz, and feature a greater read-range and higher-read speed than LF systems. Also, the price of the tags is among the lowest of all RFID tags. Typical read range is less than 1 meter (3 feet), and the ability to read tags on objects with high water or metal content is not as good as LF systems but stronger than UHF systems.

Applications include smart cards and smart shelves for item level tracking, and are also currently used to track library books, healthcare patients, product authentication and airline baggage. Another common application is maintenance data logging for sensitive equipment that needs regular checking such as fire suppression systems.

Ultrahigh Frequency (UHF)

Ultrahigh-frequency RFID utilizes the 860 to 930MHz band – typically 868 MHz in Europe and 915 MHz in North America. UHF tags typically cost about the same as HF tags. Read range is up to 3m (9.5 ft) and the data transfer rate is faster than HF systems, though still lower than Microwave based RFID systems discussed next. One drawback to UHF systems is a limited ability to read tags on objects with or surrounded by high water or metal content.

This is typically the frequency recommended for distribution and logistics applications and is the basis for the Electronic Product Code (EPC) standard driven through the Auto-ID Center. Of course, the EPC standard is the focus of Wal-Mart and the Department of Defence in the United States. The primary rationale for utilizing this frequency in the supply chain is the greater read range it offers over the other frequency ranges. However, UHF is also widely used for electronic toll collection systems on highways, manufacturing applications and parking lot access based on the greater range provided by the frequency.

Microwave

The final frequency option is the microwave band, either 2.45GHz or 5.8GHz. Though microwave based RFID systems offer the highest data read rates, they are the most expensive systems and have a limited read range of up to 1m (3 ft). Additionally, microwave based systems are not able to penetrate objects with high water or metal content which makes it unsuitable for many applications.

At this time, microwave is constrained to specialized applications such as tracking airline baggage or electronic toll collection. Though it could be used for some supply chain applications with high data content, the inability to penetrate water or metal combined with the higher cost will limit its deployments in this realm.

	Frequency Range	Read Range	Data Rate	Ability to read near wet or metal surfaces	Typical Applications
			Slower	Better	
Low Frequency	125 KHz	< 0.5m (1.5 ft)			Access control, animal tracking, vehicle immobilizers, POS applications
High Frequency	13.56 MHz	1m (3 ft)			Access control, smart cards, smart shelves, item level tracking such as baggage handling
Ultra-High Frequency	860 MHz - 930 MHz	3m (10 ft)			Pallet tracking, electronic toll collection, baggage handling
Microwave Frequency	2.45 GHz / 5.8 GHz	1m (3 ft)	Faster	Worse	Supply Chain applications & electronic toll collection

Source: SAMSYS

Standards

To date, the primary challenge to RFID has been a lack of consistent standards for both the technology specification as well as the application. Consequently, several standards bodies are involved with driving specific standards for RFID to ensure performance and interoperability metrics are met. The International Organization for Standardization (ISO) is highly involved in driving global RFID standards. The International Standards Organization is another important

standards body and has established an RFID standard for shipping container identification.

The Auto-ID Center at MIT has been driving towards development of a standard specification item-level tagging in the consumer goods industry, called the Electronic Product Code (EPC). This has led to a new group, called EPCglobal, a joint venture between the Uniform Code Council (UCC) and EAN International, which maintain the U.P.C./EAN bar code system among others. As stated in the name, a primary goal of EPCglobal is to make the final EPC standard an official global standard.

The current thrust of EPCglobal is known as UHF Generation 2 (UHF Gen 2), a Write Once Read Many tag with more memory (96 bits vs 64 bits) than preceding Class 0 and Class 1 tags. UHF Gen 2 will also provide a bridge to the eventual Class 2 High Memory full Read Write tag. Prior to UHF Gen 2, Class 0 and Class 1 were being utilized for EPC, but they were not interoperable. Consequently, a retailer utilizing an EPC solution – such as Wal-Mart – would need different RFID readers to read different tags, or force all of their suppliers into one technology. UHF Gen 2 will merge the Class 0 and Class 1 standards for a global, interoperable EPC standard.

Applications

Applications are constantly being developed to streamline data capture applications. Whether in the supply chain or in mobile computing, RFID applications typically fall into one of the categories below:

Point-of-Sale - Operate as part of cash collection systems, fast payment systems, and toll road applications. Mobil/Exxon Speedpass is a POS application example that allows customers to pay for their gas (and purchases at some grocery stores) by passing a keyfob embedded with their ID code over an RFID reader at the gas pump. The system automatically charges the customer's credit or debit card with the expense. Electronic toll collection systems and parking garage access are other examples of point-of-sale applications.

Closed Loop or Tightly Coupled - Systems under the control of a single owner or authority as a standalone solution. Closed loop systems are used in assembly operations, manufacturing processes, animal tracking, healthcare, railways and the retail industry. For example, in 2001 Toyota installed RFID technology in manufacturing plants to track car frames as they move through the paint stations. The information is used for inventory and quality control.

Open Systems - Systems with multiple, disparate stakeholders – ie) separate manufacturing, transportation, warehousing and retail entities

utilizing a common system. Because a single universal set of standards and protocols for RFID technology does not yet exist, open systems are not currently in use. However, their potential is tremendous as they would enable companies to track a single pallet, case or item throughout the supply chain, instead of relying upon input from each touch point. The EPC initiative within the supply chain is a good example of an open system.

Supply Chain: The unique capabilities of RFID over traditional bar coding make it an intriguing option to complement data collection and product identification in the supply chain. Almost all major Warehouse Management System providers support RFID applications in their software, and an example of a warehouse implementation follows below:

> A fixed RFID reader placed at the dock door automatically reads inbound pallets, providing real-time data to the warehouse management system (WMS) without the need for labor and time intensive manual barcode scanning. The WMS system determines whether to cross-dock or store the pallet contents based on the information on the RFID tags. By contrast, with barcodes, all received items have to be scanned and damaged or unreadable barcode labels add to the labor-intensive nature of this setup – and of course to the cost. Smart shelves equipped with readers could automatically record object inventory, without the need for manual, time-consuming barcode scanning.

In the example above, RFID is being utilized to perform item-level tracking. This is the eventual goal of RFID in the supply chain because it delivers much greater tracking granularity with a much lower labor investment. In fact, the EPC initiative discussed above is intended to drive item-level information into the RFID tag. However, as noted earlier in this paper, it is not expected to be practically implemented in the next few years as the technology matures. In the interim, it is thought that most RFID implementations will target the pallet and case level to prove out the efficiency gains and consequent ROI, then evolve to item level tracking. Consequently, the prediction is that barcodes will remain an integral component of the logistical process.

Mobile Computing: Several RFID scenarios also exist outside of the supply chain and many have been in operation for several years. In addition to the Mobil/Exxon SpeedPass already discussed, RFID solutions have been deployed for airports, utilities, healthcare operations, public services, animal tracking, vehicle tracking and more.

Field data collection for utilities, public service, animal tracking or equipment maintenance logs are some of the most common RFID solutions currently in use. Equipment maintenance logging via RFID would typically displace manual data input. RFID delivers more accurate and efficient data input – particularly

important for equipment that needs to be checked or serviced on a regular basis. Examples of such equipment are: safety hardware (fire extinguishers, fire suppression systems, fire alarms) and any kind of healthcare equipment.

RFID offers several benefits in the healthcare market, particularly around patient tracking. Accuracy of patient records is, of course, paramount and RFID provides opportunities to better manage patient information. By utilizing tags on the caregiver, the patient, the equipment as well as any medication administered to the patient, there is the opportunity for a much more robust record keeping infrastructure. RFID can help document what was administered to whom, by whom.

Product authentication is another potential high growth area for RFID. This application would see an RFID tag embedded into a product to validate its authenticity. Primary markets would be premium consumer goods and pharmaceuticals – in both cases to thwart "knock-off" products" such as counterfeit drugs.

Psion Teklogix and RFID

Psion Teklogix is a leader in the automatic data collection market, and you can count on us to support RFID as it evolves. Psion Teklogix has several RFID implementations globally with our WorkAbout and netpad products. We continue to pilot and introduce new hardware that shows tremendous potential for a variety of marketplaces. We have responded to customer demand with a 7535 that features an integrated, dual mode 13.56 MHz RFID and laser barcode reader. And, we have introduced a tethered 900MHz reader ideal for both hand-held and vehicle-mount applications, enabling both EPC compliance and investment protection of existing hardware infrastructures.

Psion Teklogix understands that our customers will need to incorporate hybrid data collection systems that comprise both RFID and barcode technology into their operations. Consequently, we will continue to offer leading edge solutions for both technologies – RFID readers, laser barcode readers and imaging technology. As always, we will deliver the latest and best solutions to our customers that address their current needs.

Conclusions

Though widespread RFID solutions are on the horizon, there are a number of reasons why it is just growing out of its infancy. In the supply chain, not only does it require high up-front costs - software, hardware, data storage, security solutions, and core technology implementations – but also the tags are still relatively expensive when compared to barcodes. Also, while customers are evaluating which RFID solution would work best for them, many technical issues are unresolved – such as the lack of global standards for tags, the lack of

standard radio frequencies, the wide range of radio frequency transmission distances, potential problems with the use of tags and readers in a small space and finally the affect of metal or liquids on tag performance.

However, the landscape is changing, and none of these challenges are insurmountable. As discussed in this paper, several major industry players are now driving RFID adoption and compliance from their suppliers. Also, as standards bodies continue to focus on RFID, more solid global standards will begin to emerge. RFID will eventually amount to a paradigm shift in global industries in which automatic data collection is a key component. This is because the efficiency gains will drive huge savings – the early adopters will utilize RFID to gain competitive advantage, and the remainder of the market will begin to adopt to remain competitive. Of course, greater adoption will lead to lower costs, eliminating a primary barrier to entry.

Outside of the supply chain, many customers are looking to deploy automatic data collection infrastructures for the first time. For many of these deployments, RFID represents a compelling technology that can be – and has been - implemented with immediate benefits and a quick return on investment. Therefore, RFID could conceivably grow more quickly over the next few years in closed loop, outside the supply chain scenarios (healthcare, manufacturing, field data capture, maintenance logging, etc.) that are not as dependent on open, inter-operable standards for tags and readers. Rather than deploying to accomplish compliance, customers in these markets deploy to achieve business benefits.

RFID represents an exciting opportunity for customers with automatic data collection needs. As the technology continues to evolve, increasing numbers of customers across all markets will choose to implement RFID because of the unique capabilities it can deliver that drive efficiencies into their operations. Although transition to RFID will not occur immediately or quickly, market indications suggest that the shift is beginning.