PDHonline Course G344 (4 PDH)

RFID Technology

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ABBREVIATIONS

RFID	Radio Frequency Identification
ALE	Application-Level Events
API	Application Programming Interface
ASK	Amplitude Shift Keying
ASN	Advanced Shipment Notification
B2B	Business to Business
CASPAIN	Consumers Against Supermarket Privacy Invasion and Numbering
CPU	Central Processing Unit
CRC	Cycle Redundant Check
DoD	Department of Defense
DNS	Domain Name System
EAN	European Article Numbering International
EAS	Electronic Article Surveillance
ECS	Event Cycle Specification
EPC	Electronic Product Code
EPCIS	Electronic Product Code Information Services
ERP	Enterprise Resource Planners
ESB	Enterprise Service Bus
FDX	Full Duplex
FSK	Frequency Shift Keying
GID	General Identifier
HDX	Half Duplex
HF	High Frequency
IETF	Internet Engineering Task Force

ISO	International Standards Organization
ISM	Industrial Scientific Medical
LF	Low Frequency
MW	Microwave
ONS	Object Naming Service
PSK	Phase Shift Keying
RF	Radio Frequency
RTF	Reader Talks First
SGTIN	Serialized Global Trade Item Number
SSCC	Serialized Shipping Container Code
TCO	Total Cost of Ownership
TCP	Transmission Control Protocol
TTF	Tag Talks First
UARTs	Universal Asynchronous Receiver Transmitter
UCC	Uniform Code Council
UDC	Uniform Decimal Classification
UHF	Ultra High Frequency
UPC	Uniform Product Code

RADIO FREQUENCY IDENTIFICATION (RFID)

NOTE: Before we begin our course, I recommend taking a quick look at the Abbreviations (after the Index) and Glossary found in the Appendix to this document. Doing so will aid your efforts in understanding the vocabulary found in the text.

INTRODUCTION:

Radio Frequency Identification (RFID) is an automated means of using radio waves to identify and track the presence and movement of objects. RFID has been called "the first important technology of the 21st century" and has become one of the most "talked-about" technologies in business and government today. The application of RFID technology has definite benefits relative to tracking objects and physical assets in supply chain movement. It allows for the positive identification and control of tangible objects. The following uses will demonstrate many areas in which RFID is being applied:

- Incoming and outgoing pallets cycling through a warehouse environment
- To aid documentation of cycle times
- Tracking hazardous materials
- Automatic identification of vehicles for toll road collections
- Inventory control for weapons and equipment used by the DOD
- Containerized cargo entering ports of call
- Tracking WIP (work in process) or finished goods inventories
- Airline baggage identification
- "Tags" applied to passports encrypted with information detailing birthdate, country of origin, address, etc.
- Inventories for retail and commercial establishments
- Location of tools used in the construction industry
- Ease in locating and tracking medical devices within a hospital or other facility
- To secure inventories from theft and diversion
- To accurately count inventory in vehicles ready for delivery; i.e., UPS, FedEx, DHL, etc.

There have been several "dooms-day" prophets crying that RFID "chips" will be applied to individuals and these chips will be the "mark of the beast" mentioned in the Bible. Anyone desirous of pursuing commercial ends will need this "mark of the beast" to do business. Until that happens, our course will address the more useful applications of this marvelous technology and strive to aid our efforts to understand the variety of application possibilities and the hardware necessary to bring about those applications. It is very apparent that privacy concerns are foremost when RFID technology is applied to individuals or groups. These concerns are being addressed on an ongoing basis by several organizations in this country and over the world. We definitely will discuss this privacy and safety as the course progresses.

Let me state right now that applying RFID technology **MUST** be a thought-provoking exercise and the incorporation of hardware and software must be accompanied with a great deal of training and thought. There is a need to integrate the technology into an existing system of distribution and material flow, and this integration should be over an extended period of time. Most experienced vendors will recommend running parallel systems; i.e., existing software and RFID, until the methodology is firmly in place and all personnel are properly trained. We will certainly address this point later in our discussion.

Let us now look at six (6) very interesting uses for RFID, all of which lie outside the warehouse environment and do not concern themselves with tracking items in a supply chain.

INTERESTING USES OF RFID TECHNOLOGY:

CASE ONE

In the spring of 2010, our youngest son participated in a one-half marathon sponsored by ING. The "run" was held in Atlanta, Georgia one rainy day in late March. I can remember those races I participated in during my mid and late thirties. We pinned a runner's number to our shirts, laced up our running shoes and hoped to get some indication of how fast (or how slow in my case) we traversed the course. Generally, the best and most accurate time was the time you kept yourself. Not so during this event. The runners in the ING race were given RFID "loops" they affixed to their shoes. The "loops" had embedded tags that were interrogated by readers located overhead at various points along the course; certainly, at the start and finish of the race. There was absolutely no doubt about start time or finish time as well as times for the one-quarter, half and three-quarter points along the way. When the race was over, the runner simply returned the "loop" to a predetermined location and received a printout of the race he had just run. All of the times were accurate to within one second.

CASE TWO:

We have all been subject to "ringing the bell" when walking through an exit and discovering that an RFID tag had inadvertently been left on a garment or other article. The cashier had forgotten to disable or remove the tag from the item as we checked out and we failed to notice. This is an excellent example of "theft prevention" that most retail stores have adopted to lessen, and hopefully, eliminate shop lifting. There are two vertical plates located on either side of the exit that house readers which will identify a tag and send an "audible" or visual alert to the cashier or store management if an item "walks out". This is an example of a one-bit passive tag used only for theft prevention. One issue with this type of RFID system is the inability to disable the tag, if left on the item. This occurs at times and is generally a matter of training personnel in properly operating the equipment. In case you have never noticed, the stationary readers are always at the exits. The JPEG below shows the actual device. There is one reader on each side of the exit so a thief cannot turn to avoid the signal generated by the device. Take a look.

FIGURE 1: STATIONARY READER

CASE THREE:

Recently, I bought another cell phone for my wife. Her "mobile device" would not charge properly for several reasons—most of which are unknown. Since we live in a throwaway society, it is sometimes much cheaper to buy a new phone than attempt to fix or pay for fixing the broken one. Can you say Best Buy? At any rate, we get home and I start to work on getting the device charged, activated, etc. You know the drill. I inadvertently left one very poorly written manual in the box so I start digging through the garbage to retrieve the document. I found, glued to the inside of the container, an encapsulated RFID tag. The purpose was obvious—prevention of theft. This was a very simple one-bit passive tag probably costing no more that $0.35 or $0.40. Worth the cost and worth the effort if you are Best Buy. I have been told that by incorporating RFID technology, retail establishments have saved millions of dollars in costs attributed to shop lifting. With this amount of money at stake, there is a very quick ROI (return on investment).

CASE FOUR:

One of the most inventive uses for RFID technology is automatic toll collection for motor vehicles. The JPEG below will show the basic method used for that purpose. I would ask you to notice the three readers mounted above the pavement. RFID technology can dramatically decrease vehicle queuing at automobile toll plazas, speed throughput, and significantly improve the quality of life for commuters and communities. Open road tolling eliminates plaza barriers and creates a new toll road design that mitigates congestion. High occupancy vehicle tolling is an extension of electronic toll collection. This is a concept that is rapidly gaining favor with transportation agencies and planners as it allows them to make better use of the often-underutilized high occupancy vehicle (HOV) or carpool lanes. With high occupancy tolling, single occupant vehicles (SOVs) can drive on HOV lanes for a fee.

Open road tolling gives authorities the flexibility to set variable pricing for toll services. Pricing types include premiums or discounts based on the time of day and congestion level. Variable pricing models can be pre-established, or modified in real time, responding to existing traffic situations. Variable pricing allows the transportation authority to maximize the use of HOV lanes. This application for RFID accounts for a great deal of early history in the development of the technology. We are going to discuss that history in the next section.

FIGURE 2: AUTOMATIC TOLL COLLECTION

CASE FIVE:

OK, two more cases and then we look at the "nuts and bolts" of the technology. A growing use for RFID is access control and securing physical spaces. The following excerpt comes from the **"RFID Tribe"** publication and is a very brief overview of how the technology is used to provide security.

Security access and control applications may perform the following functions...

1. Limiting access to a restricted area to authorized personnel only.
2. Limiting access to the entire or sections of a building
3. Verifying that an employee has the license to operate a fork-lift, company vehicle or other piece of equipment
4. Knowing which employee performed a particular task, such as assembling a pallet of pharmaceutical products.

RFID technology has long been used as an **electronic key** to control who has access to office buildings or areas within office buildings. The first RFID-based access control systems used low frequency RFID tags. More recently, vendors have introduced 13.56 MHz systems that offer a much longer read range. The advantage of RFID technology is convenience. (An employee can hold up a badge to unlock a door, rather than looking for a key or swiping a magnetic stripe card). Because there is no contact between the card and the reader, there is less wear and tear, therefore less equipment maintenance.

RFID is used to secure automobiles. Most late-model cars come with an RFID reader in the steering column. An RFID transponder is embedded in the plastic housing around the base of the key. The reader must receive the right ID from the key or the car won't start. Automobile immobilizer systems reduce auto theft to a great extent. These security systems are very difficult to hack into or over-ride.

Active RFID tags can be combined with motion sensors so when objects are moved without authorization, an alarm is sounded. RFID tags can be put on laptops and files containing sensitive documents to make sure they are not removed from a building without authorization. The DOD (Department of Defense) has adopted this method of security for PCs, laptops, and external storage medium for highly confidential documents.

After the terrorist attacks on New York and Washington, D.C., in 2001, the U.S. Department of Transportation (DOT) conducted a number of tests of RFID seals to safeguard containers. Since it is not possible to check each of the millions of cargo containers entering United States ports each year, the DOT hopes to reduce the risk of terrorists smuggling weapons and other contraband into the United States through the ports by placing an electronic seal (e-seal) on each container. These seals are active RFID tags that have a bolt or other mechanism for sealing a container. If the container is opened without authorization, that information is communicated to a computer the next time the RFID tag in the seal is read. Warning may be sent and agents can check the container.

My wife and I have memberships in a community exercise “studio”. When we check in, we give our car keys to the attendant and he or she gives us an RFID card that looks just like the one in the photograph below. This card allows access to the gym, basketball court, weight room, showers, etc etc. You get the picture. When we are finished, we return the RFID card and retrieve our car keys. Works well and you can put the key card in your pocket or on the tread-mill for safe keeping. It is not that intrusive and fits nicely into a pocket. (Note the card reader on wall. This is an integral part of the system. The tag and the reader logs us in and out but also captures each visit. At the end of a twelve-month period of time, we get a notification that it’s time to “re-up”. All automatic with no management supervision.

FIGURE 3: ACCESS CONTROL

CASE 6

One of the most intriguing applications of RFID technology is associated with making absolutely sure transmission lines for fluids; i.e., air and water, are connected and connected properly. Imagine the need to drain a reservoir or tank of hazardous material and not making certain the hose connections are properly seated and operational. One very creative company, Colder Products Company, has taken care of that need with the implantation of an RFID tag into quick disconnect couplings. A picture is worth a thousand words. The figures below are actual "cut sheets" for products offered by this company. As you can see, both quick connects are made from polymers and serve as passageways for fluid flow.

FIGURE: 4 INSERTION OF RFID TAG INTO QUICK DISCONNECT

FIGURE: 5 INSERTION OF RFID TAG INTO QUICK DISCONNECT

These are just some of the many applications now being successfully attempted by very creative engineering teams over our country and the world.

We have just seen examples of uses for RFID; now let us take a look at how far the technology has advanced over the past decades since WWII.

HISTORY:

RFID has been around a long time but only in the last few years has the technology been viable and put to great use.

I am going to use excerpts from two primary sources given in the reference document shown in the Appendix to this course. I would like to mention these two now as follows:

1. ***"Shrouds of Time—The History of RFID" by Dr. Jeremy Landt, published by AIM Inc, October 1, 2001***
2. ***"The History of RFID Technology" by The RFID Journal, August 31, 2010***

Both documents are excellent sources for further understanding of "where we are coming from".

It is generally said that the roots of RFID can be traced to World War II. The Germans, Japanese, British and Americans were all using radar, which had been discovered in 1935 by a Scottish physicist named Sir Robert Alexander Watson-Watt. The purpose for that invention was to warn of approaching enemy aircraft while still miles away. One significant problem was no way to identify which aircraft belonged to the enemy and which belonged to friendly forces. The Germans discovered that if the pilots rolled their planes as they returned to base, it would change the radio signal reflected back. This very crude method alerted the radar crew on the ground that these were "friendly forces" and not Allied aircraft. This could be called the first passive RFID system. (A definite stretch but an important discovery nonetheless—and it worked.)

Under Watson-Watt, the British developed the first active identify friend or foe (IFF) system. A transmitter was installed on each British airplane. When the transmitter received signals from radar stations on the ground, it began broadcasting a signal back that identified the aircraft as friendly. RFID works on the very same basic principle. A signal is sent to a transponder (also know as a tag), which "wakes up" and reflects that signal back (passive system) or broadcasts a companion signal (active system).

An early, if not first, work exploring RFID is the landmark paper by Harry Stockman, "Communication by Means of Reflected Power", Proceedings of the IRE, pp 1196-1204, October 1948. Stockman stated then that "Evidently, considerable research and development work has to be done before the remaining basic problems in reflected-power communication are solved, and before the field of useful applications is explored."

Thirty years would pass before Harry's vision would begin to reach fruition. Other developments were needed: the transistor, the integrated circuit, the microprocessor, development of communication networks, changes in ways of doing business. No small task. Like many things, timing is everything, and the success of RFID would have to wait.

Much has happened in the fifty-three (53) years since Harry Stockman's work. The 1950s was a decade of exploration for RFID preceded by the developments for radio and radar in the 1930s and 1940s. Several related technologies were explored, such as the long-range transponder systems of "identification, friend or foe" (IFF) for aircraft. Developments of the 1950s include such works as F. L. Vernon's, "Application of the microwave homodyne", and D.B. Harris', "Radio transmission systems with modulatable passive responder". The wheels of RFID development were turning.

The 1960s through the 1980s: RFID Becomes Reality

The 1960s were the prelude to the RFID explosion of the 1970s. R. F. Harrington studied the electromagnetic theory related to RFID in his papers "Field measurements using active scatterers" and "Theory of loaded scatterers" in 1963-1964. Inventors were busy with RFID related inventions such as Robert Richardson's "Remotely activated radio frequency powered devices" in 1963, Otto Rittenback's "Communication by radar beams" in 1969, J. H. Vogelman's "Passive data transmission techniques utilizing radar beams" in 1968 and J. P. Vinding's "Interrogator-responder identification system" in 1967. Commercial activities began during the 1960s. Sensormatic and Checkpoint were founded in the late 1960s. These companies, with others such as Knogo, developed electronic article surveillance (EAS) equipment to counter theft. These types of systems are often use '1-bit' tags – only the presence or absence of a tag could be detected, but the tags could be made inexpensively and provided effective anti-theft measures. These systems used either microwave or inductive technology. **EAS is arguably the first and most widespread commercial use of RFID.**

In the 1970s developers, inventors, companies, academic institutions, and government laboratories were actively working on RFID technology and notable advances were realized at research laboratories and academic institutions such as Los Alamos Scientific Laboratory, Northwestern University, and the Microwave Institute Foundation in Sweden among others. An early and important development was the Los Alamos work presented by Alfred Koelle, Steven Depp and Robert Freyman "Short-range radio-telemetry for electronic identification using modulated backscatter" in 1975.

Large companies were also developing RFID technology, such as Raytheon's "Raytag" in 1973. RCA and Fairchild were active in their pursuits with Richard Klensch of RCA developing an "Electronic identification system" in 1975 and F. Sterzer of RCA developing an "Electronic license plate for motor vehicles" in 1977. Thomas Meyers and Ashley Leigh of Fairchild developed a "Passive encoding microwave transponder" in 1978.

The Port Authority of New York and New Jersey began testing systems built by General Electric, Westinghouse, Philips and Glenayre. Results were favorable, but the first commercially successful transportation application of RFID, electronic toll collection, was not yet ready for prime time.
The 1970's were characterized primarily by developmental work. Intended applications were for animal tracking, vehicle tracking, and factory automation. Examples of animal tagging efforts were the microwave systems at Los Alamos and the inductive systems in Europe. Interest in animal tagging was high in Europe with Alfa Laval, Nedap, and others developing RFID systems.

Transportation efforts included work at Los Alamos and by the International Bridge Turnpike and Tunnel Association (IBTTA) as well as the United States Federal Highway Administration. The latter two sponsored a conference in 1973 which concluded there was no national interest in developing a standard for electronic vehicle identification. This is an important decision since it would permit a variety of systems to develop, which was good, because RFID technology was in its infancy.

About this time new companies began to surface. Companies such as Identronix, a spin-off from the Los Alamos Scientific Laboratory, and others of the Los Alamos team including Amtech (later acquired by Intermec and recently sold to TransCore) in the 80s. By now, the number of companies, individuals and institutions working on RFID began to multiply. A positive sign. The potential for RFID was becoming obvious.

The decade of the '80s saw full implementation of RFID technology; though interests developed somewhat differently in various parts of the world. The greatest interests in the United States were for transportation, personnel access, and to a lesser extent, for animals. In Europe, the greatest interests were for short-range systems for animals, industrial and business applications, though toll roads in Italy, France, Spain, Portugal, and Norway were equipped with RFID.

In the Americas, the Association of American Railroads and the Container Handling Cooperative Program organizations were very active proposing RFID initiatives. Tests for collecting tolls had been ongoing for many years, and the first commercial application began in Norway in 1987 and was followed quickly in the United States by the Dallas North Turnpike in 1989. Also, during this time, the Port Authority of New York and New Jersey began commercial operation of RFID for buses going through the Lincoln Tunnel. RFID was finding a home with electronic toll collection, and new players were arriving daily.

The 1990's

The 1990's was a significant decade for RFID and provided wide scale deployment of electronic toll collection in the United States. Important deployments included several innovations in electronic tolling. The world's first open highway electronic tolling system opened in Oklahoma in 1991, where vehicles could pass toll collection points at highway speeds, unimpeded by a toll plaza or barriers and with video cameras for enforcement. The world's first combined toll collection and traffic management system was installed in the Houston area by the Harris County Toll Road Authority in 1992. A first was the system installed on the Kansas turnpike using a system based on the Title 21 standard with readers that could also operate with the tags installed by their neighbor to the south, Oklahoma. The Georgia 400 would follow, upgrading their equipment with readers that could communicate with the new Title 21 tags as well as the existing tags. In fact, these two installations were the first to implement a multi-protocol capability in electronic toll collection application.

As we mentioned earlier, there were several dependent technologies that greatly affected propelling RFID into the "limelight" and made it the exciting business it is today. Companion technologies greatly affected the ultimate use of RFID and made possible the variety of applications we see as common today. Let us now take a look at those companion technologies.

<u>DEPENDENT TECHNOLOGIES:</u>

Most technologies are evolutionary and not revolutionarily. Technology builds on itself. There was Model "T" long before a Lamborghini. RFID was absolutely dependent upon semiconductor and digital technology. We will follow the chronology in the following paragraphs.

- **Advances in Semiconductor technologies:** RFID would have remained a niche technology if it were not for Moore's Law and the ability of the semiconductor industry to produce chips that package processing power at levels that make it affordable for the mass RFID market. This perhaps has been the greatest advancement for the rapid development of RFID technology.
- **Intelligent devices:** Advances in semiconductor technologies have not just decreased the cost of RFID chips—they also are the primary drivers behind the development of intelligent devices,

including sensors such as RFID tags and readers. Smarter devices and virtually ubiquitous bandwidth have opened up a host of mobility and edge-based applications. RFID is one implementation of the general idea of a "Network of Things" connected together to provide automation beyond the edges of corporate data centers. Smart homes, smart cars, and other smart objects represent additional applications that require processing at the edges. Current implementation of smart home systems incorporates a variety of IP-enabled household devices connected to residential gateways that are in turn connected to the Internet.

- **Broadband wired and wireless networks and cheaper edge processing servers:** The availability of broadband data networks, coupled with affordable yet powerful servers, has led to the development of architectures that move processing to where the business activities are carried out. This means that it is now easier to deploy pieces of enterprise applications in edge locations such as warehouses and stores. (This is a very critical statement and promotes uses unimagined in previous decades.)
- **Edge processing capability:** Edge processing capability results from having powerful yet low-cost personal computers and servers deployed at the edges of the enterprise network as well as a broadband connection to the data center. RFID systems put greater computing power, data management, and bandwidth requirements on these edges. This is not a unique phenomenon but a continuation of an overall trend. *By "edge" we mean any location where business processes are carried out that is outside the data center or central office; i.e., production lines, warehouses or retail stores.*
- **Service-oriented architecture:** Successful adoption of RFID technologies will depend upon how well you integrate RFID data into your business process. RFID readers can generate a tremendous amount of data. Unfiltered downstream applications it can overwhelm them. To prevent applications from being flooded with data and to isolate them from physical devices such as readers and antennas, you can use sophisticated middleware components such as event managers. Service-oriented architectures allow us to develop and deploy loosely-coupled modules that interface with each other using web service-based standards. Many of the RFID middleware components are based on web services standards and the overall RFID system architecture follows the principals widely accepted today as the underpinnings of service-oriented architectures. We will discuss middleware later on in this course.

In the Northeastern United States, seven regional toll agencies formed the E-Z Pass Interagency Group (IAG) in 1990 to develop a regionally compatible electronic toll collection system. This system is the model for using a single tag and single billing account per vehicle to access highways of several toll authorities.

Interest was keen for RFID applications in Europe during the 1990s. Both Microwave and inductive technologies found use for toll collection, access control and a wide variety of other applications in commerce.

A new effort underway was the development by Texas Instruments of the TIRIS system, used in many automobiles for starting vehicle engines. The TIRIS system (and others such as from Mikron - now a part of Philips) developed new applications for dispensing fuel, gaming chips, ski passes, vehicle access, and many other applications.

Other companies in Europe were becoming active in RFID developments including Microdesign, CGA, Alcatel, Bosch and the Philips spin-offs of Combitech, Baumer and Tagmaster. A pan-European standard was needed for tolling applications in Europe, and many of these companies (and others) were at work on the CEN standard for electronic tolling.

Tolling and rail applications were also appearing in many countries including Australia, China, Hong Kong, Philippines, Argentina, Brazil, Mexico, Canada, Japan, Malaysia, Singapore, Thailand, South Korea, South Africa, and Europe.

With the success of electronic toll collection, other advancements followed such as the first multiple uses of tags across different business segments. Now, a single tag (with dual or single billing accounts) could be used for electronic toll collection, parking lot access and fare collection, gated community access, and campus access. In the Dallas - Ft. Worth metroplex, a world's first was achieved when a single TollTag® on a vehicle could be used to pay tolls on the North Dallas Tollway, for access and parking payment at the Dallas/Ft. Worth International Airport (one of the world's busiest airports), the nearby Love Field, and several downtown parking garages, as well as access to gated communities and business campuses.

Research and development didn't slow down during the 1990s and new technological developments would expand the functionality of RFID. For the first time, useful microwave Schottky diodes were fabricated on a regular CMOS integrated circuit. This development permitted the construction of microwave RFID tags that contained only a single integrated circuit, a capability previously limited to inductively-coupled RFID transponders. Companies active in this pursuit were IBM (the technology later acquired by Intermec) Micron, and Single Chip Systems (SCS).

With the growing interest of RFID into the item management work and the opportunity for RFID to work along side bar code, it becomes difficult in the later part of this decade to count the number of companies who enter the marketplace. Many have come and gone, many are still here, many have merged, and there are many new players ... it seems almost daily!

Back to the future: The 21st Century

Exciting times await those individuals and companies committed to the pursuit of advancements in RFID. Its impact is lauded regularly in mainstream media, with the use of RFID slated to become even more ubiquitous. The growing interest in telematics and mobile commerce will bring RFID even closer to the consumer.

Let us now summarize the activity by looking at the following excel spreadsheets.

TABLE 1: THE DECADES OF RFID ACTIVITY

The Decades of RFID

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

From this chart, we get a basic feel for the time line and the progress made during each decade of RFID development.

Patent work over the decades has obviously been very important relative to development of the technology. There have been significant developments involving hardware and software that have given the industry a "jump start" and propelled it into prominence. Here are several very important patents and basic descriptions of the content.

Patent Number	Title
3,713,148	Transponder apparatus and system
3,745,569	Remotely powered transponder
3,852,755	Remotely powered transponder having a dipole antenna array
4,001,822	Electronic license plate for motor vehicles
4,068,232	Passive encoding microwave transponder
4,096,477	Identification system using coded passive transponders
4,114,151	Passive transponder apparatus for use in an interrogator-responder system
4,123,754	Electronic detection and identification system
4,242,663	Electronic identification system
4,345,146	Apparatus and method for an electronic identification, actuation and recording system
4,354,099	Electronic identification system
4,463,353	Animal feeding and monitoring system
4,473,825	Electronic identification system with power input-output interlock and increased capabilities
4,481,428	Batteryless, portable, frequency divider useful as a transponder of electromagnetic radiation
4,490,718	Radar apparatus for detecting and/or classifying an agitated reflective target
4,494,545	Implant telemetry system
4,510,495	Remote passive identification system
4,525,713	Electronic tag identification system
4,546,241	Electronic proximity identification system

TABLE 2: IMPORTANT PATENTS

These two spreadsheets show that the work has truly been evolutionary and not so much revolutionary.

BENEFITS:

We have often heard that necessity is the mother of invention. Sometimes there is a great need for cost reduction, improvement in efficiency and a great adherence to "best practices". There are several significant benefits when incorporating RFID into a facility. Some of these are as follows:

- **Cost savings**: RFID can bring about savings from three (3) to five percent (5%) alone and with a two (2) to seven percent 7(%) improvement in revenues. This is a measurable metric. The cost savings generally results from reduction in labor necessary for inventory management.
- **Asset management**: The ability to track and locate inventories quickly and without endless searching is a definite plus when time and money are on the line. This is a huge problem in manufacturing. The computer says one thing but the actual count presents another.
- **Security**: Access control is very possible using RFID methodology. It is very difficult to counterfeit an RFID tag, so when applied, the original product can be located and identified.
- **Improvement of internal efficiencies**: This translates into increased speed with accompanying accuracy.
- **Improvement of supply chain responsiveness**: Paperwork methodology is time-consuming and takes up space. Digital is far better for record-keeping and mobile.
- **Ability to survive harsh environments**: Bar code labels are much more susceptible to damage than RFID tags. The tags can be encapsulated to further resist wear and tear as well as the elements. Bar code labels smear, tear and can become unreadable. Defective labels when scanned, produce problems with inventory control.
- **Convenience**: An example of added convenience would be automated toll booths for the collection of fares. No stopping, no throwing coins at a "pot", etc etc. Also, there is a growing application for quick payment at service stations. The customer merely points a "fob" with embedded tag at a reader and the charge is later on deducted from a pre-established account.

- **100% accuracy**: One hundred percent (100%) may be a condition to be desired but, it can be accomplished with proper selection of tags and placement of those tags on equipment, merchandise, etc.
- **Prevention of theft**:
- **Documentation of cycle times**: Very accurate cycle times for the movement of merchandise can be obtained by using RFID methods.
- **No line of site required**: Line of site is a must for bar code readers. Not so with RFID. This very fact speeds efficiency and accuracy.
- **Readers and tags can be portable**:
- **Size of tags and readers is shrinking so placement on smaller and smaller items becomes possible**.
- **Very high inventory speeds**:
- **Item level tracking**: RFID can track a pallet, a box on a pallet or an item in a box on a pallet. It all amounts to where you put the tag and how important tracking becomes.
- **Tags are rewritable**: In other words—reusable. (This is an active tag only!)
- **Greater storage**: Greater amounts of data can be stored relative to bar codes on any one given tag.
- **Scalability**: This is a measure of how the system can grow over a period of time. Depending upon the selection of hardware, you can progress from low volume to very high volume with the same basic system and hardware.

DRAWBACKS:

As with any technology, there are certain drawbacks to incorporating and using RFID systems. Some of these are as follows:

- **Privacy:** From RFID Essentials, reference thirteen (13): "It should be noted that even before the advent of RFID technology, companies and governments have had the means to collect, store, transfer, and analyze vast amounts of data about consumers and citizens. Even without RFID, there are many ways in which we willingly surrender our privacy. We routinely buy things with credit cards, use store affinity cards to obtain discounts, give our names and addresses when returning merchandise. We allow website cookies on our computers while we are surfing the WWW. QUESTION: Why is it then that RFID systems have the privacy advocates so concerned? I personally think it is one more example of "piling on". We surrender our privacy in an incremental fashion and not all at once. We sometimes don't consider the fact that every little bit hurts; and erodes, to a greater degree, our sense of well being. With this in mind, there are several "watchdog" organizations addressing the privacy issue. CASPIAN (Consumers Against Supermarket Privacy Invasion and Numbering), Privacy International, EPIC (Electronic Privacy Information Center), the United States Congress, EPCglobal and several industry groups are just a very few of the organizations addressing this concern. We will discuss this later on in our course.
- **Costs:** When discussing costs, most vendors will start with tags although this is only a partial reason for the overall costs of a system. When contemplating costs, it is imperative that implementation, training and possible upgrades over time be factored into the work-up. Many companies have as their goal the elimination of bar codes when implementing RFID systems. This is a definite possibility and can be accomplished—but at a cost.
- **Maturity of available standards:** Standards are becoming more and more set and procedures for modify and incorporating standards are solidified. ISO and EPCglobal standards have been

written to define guidelines for operation and use. These are in use today and serve as an excellent guideline for vendors and consulting concerns implementing systems.

- **Technical difficulties with use:** All users of RFID systems are interested in "robust" hardware and the incorporation of that hardware into overall systems. This has become a reality over the years and there are far fewer problems than in times past. The best defense against technical difficulties is selecting the proper system for the job you wish to do.
- **Training:** Proper training is an absolute MUST and the expenditure for that training should not be compromised. Send your accountant on vacation when reviewing the training function and costs when discussing implementation with vendors. Choose a vendor or vendors who can give adequate training AND ongoing support when the system is up and running.
- **Integration with existing technologies:** Many commercial and retail concerns now have bar code systems. These systems have been in use long enough to provide good service over the years. The incorporation of RFID can complement bar codes, replace bar codes or run parallel to bar codes. This is where "up front" planning is critical.
- **Difficulties with implementation:** Choosing system vendors is critical to the process. There may be implementation problems but a wise choice when selecting vendors will negate much of the heartburn that can result. ***This is NOT a do-it-yourself weekend project for a "guy" in your IT department. Please do not treat it as such.***
- **Evolution of hardware:** We still discuss scalability and what that can do for a company after implementation of equipment and software to drive that equipment. Selecting the right system to allow for growth is a very desirable attribute but can be costly. I personally would never purchase a system just for the EAU now running. A five-year plan, or at least, having an idea as to what company growth might occur is critical to being ultimately satisfied with an initial purchase.
- **Disabling of tags and inadvertent tripping:** This goes back to training and is primarily prevalent in retail establishments. Properly disabling a tag is a great service to management and the customers served by that establishment. There is a definite method for negating the effects of a tag and having this piece of equipment is absolutely necessary or complaints will arise and not be adequately solved.
- **Fragile Tags:** This is a problem that is well on the way to being solved with advancements in the design and application of tags to merchandise. New technology that makes possible smooth tags with no bumps or protrusions. In times past, the antenna would make the tags vulnerable to damage and vandalism. Great improvements have lessened, if not completely solved, this issue.
- **Electromagnetic Interference:** This is an electronic "noise" that interferes with the communication between reader and tag and makes it more difficult to receive a clear signal. Motors emit EMI as well as most robotic systems on manufacturing lines. Proper shielding is required, if needed, when this happens.
- **RF Based Interference:** Many older wireless local area networks use the UHF frequency band. These interfere with UHF RFID systems and need to be upgraded to the 802.11 standard. Cordless phones, wireless computer terminals and other devices can also interfere with RFID systems.

BASIC OPERATION OF RFID SYSTEMS:

The RFID information network provides five (5) principal services, as follows:

1. **Assigning unique identities:** Tracking items is not possible without the capacity to uniquely identify them. This is where the EPC (Electronic Product Code) comes in. Like the UPC (Universal Product Code) barcode, the EPC is an identification system for products. However, unlike the UPC, the EPC allows item-level tracking by identifying not only the manufacturer and product type, but also the serial number.
2. **Detecting and identifying items—**The identification system consists of tags and readers. Each tag contains a microchip attached to an antenna. The EPC is stored on this tag. At the most basic level, the EPC provides a coding scheme for RFID tags that helps identify an item's manufacturer, product category and unique serial number. The tag is applied to an item either during the manufacturing process or somewhere down the supply chain. The EPC readers use radio frequency waves to interrogate the EPC tags, which then communicate their EPC codes back to the readers. EPC readers deliver information to local business information systems using EPC middleware.
3. **Collecting and filtering events:** EPC middleware provides specifications for services that enable data exchange between EPC readers and business information systems. Much of the raw EPC observations coming from the readers would be noise to the enterprise applications. Event management middleware is needed to facilitate the collection of observations from the readers and to filter and group them for consumption by the applications.
4. **Storing and querying events:** The EPCIS (EPC Information Service) enables users to exchange data with trading partners based on EPCs. The EPCIS specification aims to provide standards to allow disparate applications to share EPC data. The specification provides standards for capturing and querying EPC data between trading partners.
5. **Locating EPC information:** To enable trading partners to share EPC observations, it is necessary to provide lookup or discovery services that can locate repositories for the required EPC data. For authoritative data from the manufacturer, this role is handled by the ONS (Object Naming Service). The ONS provides the means to look up service resources that provide further information on an EPC. The ONS is very similar to, and is in fact implemented on top of, the DNS technology that handles the billions of domain name queries on the internet today.

The basic operation of RFID technology requires the following components:

- Tags and their associated data structures
- Reader with antenna and the reader's associated software
- Communication protocol suite
- Database providing data synchronization

We are going to consider each piece of hardware and software in our next section, detailing the exact operation and function of each component. First, a very brief definition of each major component, as follows:

BASIC COMPONENTS:

TAG—A transponder, also known as an RF Tag, uses a silicon microchip for storing large amounts of data. The tag or label is usually attached to an item, asset or an individual and can provide the means for case or item level identification. When we say data, we mean information such as, part number, serial number, lot, date of manufacturer, shelf-life, date of receipt, color, location in shelves, etc. Each tag is programmed with a unique electronic product identification code (EPC).

READER—A reader is used primarily to read and write data to RFID tags. A reader can be either hand-held or stationary and work as a portable computer or mounted as a fixed device for access control purposes. In a warehouse environment, many readers are mounted on fork lift equipment allowing access to personnel on an immediate basis. As you recall, the race I mentioned in the introduction to this class indicated that the readers were mounted overhead relative to the runners' course itself. There can be a great deal of flexibility as to the reader's location.

Antenna—An antenna is used to radiate and / or receive energy in the radio frequency spectrum, to and from the tag. It could be either stand-alone or packaged together with a reader.

Software and /or Middleware-- Application software is necessary to interrogate and write to the tag located on the specific item. All of the data resulting from the tag having been read will be stored in a computer. This data may first be stored and filtered by middleware acting to facilitate ease in interpretation of the data.

OPERATION:

A radio signal, emitted by an antenna, activates the tag. The reader sends this radio signal, which is received by ALL tags present in the RF field tuned to that frequency. **(Tuned to that frequency is a critical statement.)** Tags receive the signal via their antennas and respond by transmitting the data stored in a microchip and embedded in the structure of the tag. This allows the tag to be read, and in some instances, allows for data to be written (active tags). A passive tag is a "read only" device. An active tag can be written to, consequently bringing about a significant cost savings. The tag, passing through an electromagnetic field, detects this activation signal. The microchip in the tag reflects back an altered signal to the RFID reader or middleware which decodes and filters the tag's encoded data. This data is then used by enterprise applications for information management and decision making. Frequency is the primary factor in determining RFID range. Most commercial RFID systems operate at either the UHF band, between 859 and 969 MHz, or the high frequency (HF) band, 13.5 MHz. Other common RFID frequencies include 125 KHz (short range frequency often used for vehicle identification) and 430 MHz and 2.45 GHz, both used for long-range identification. The UHF band is most common for supply-chain and industrial automation applications. The graphic below is a very very simplified pictorial of how the components are structured, aligned and interact.

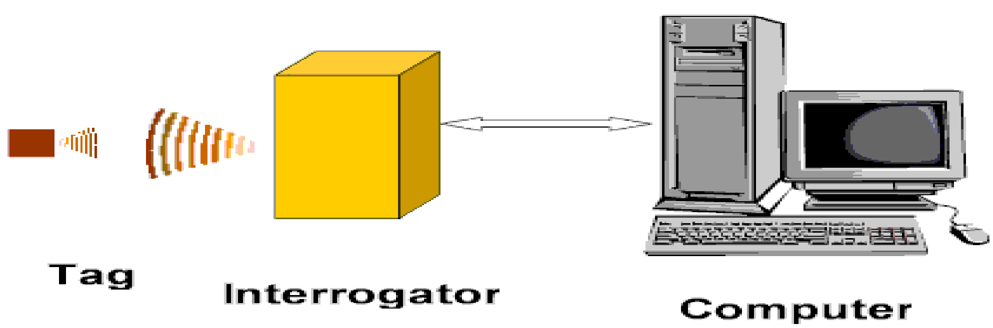

FIGURE 6: OPERATION

In our picture, the interrogator is the reader, which brings up a very good point. The vocabulary used to describe the various pieces of hardware and software is subject to "random" definition. This results from a maturation of the technology over the years. Tags are sometimes called transponders; readers are sometimes called interrogators. You get the picture. As I mentioned before, RFID has been an evolutionary process and not a revolutionary process. That trend is continuing. Another JPEG that will show some degree of detail, relative to operation, is as follows:

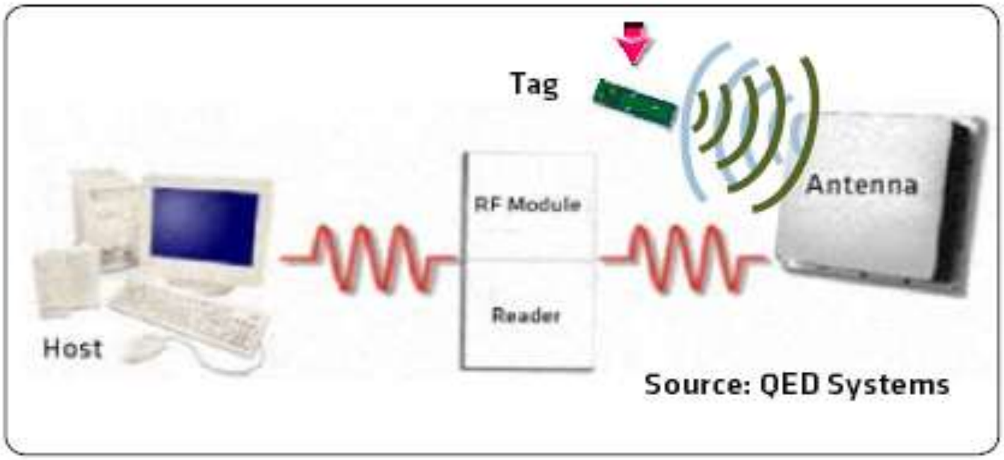

FIGURE 7: OPERATION

An RFID system allows for data to be transmitted from the tag to the reader, which in turn processes it for a particular use.

COMPONENTS:

We will now consider the detailed design and operation of the following components:

- Tags and their associated data structures
- Reader with antenna and the reader's associated software
- Communication protocol suite
- Database providing data synchronization

TAGS:

RFID tags must be physically attached to items of many different shapes and sizes and probably operating in different environments. Consequently, they come in a very wide assortment of shapes and sizes. Also, they may be encapsulated in many different housing configurations. Some of the physical characteristics are as follows:

- PVC or plastic buttons and disks, usually including a central hole for fasteners. These tags are durable and generally reusable.
- RFID tags shaped like credit cards. These are called "contactless smart cards".
- Tags made into layers of paper in a label, called "smart labels". These may be applied with automated applicators similar to those used for bar code labels.
- Small tags embedded in common objects such as clothing, watches and bracelets. These small tags may come in the form of keys and / or key chains.
- Tags in glass capsules, which can survive in corrosive environments or in liquids.

Please note, new applications and new housings for RFID tags must be tested FIRST in those candidate housings. This is extremely important.

RFID tags have two very basic elements: 1.) Chip and 2.) Antenna. The chip and the antenna are mounted to form an inlay. The inlay is then encapsulated in a durable material to form a finished tag or label. The figures below will give some idea as to the basic tag architecture.

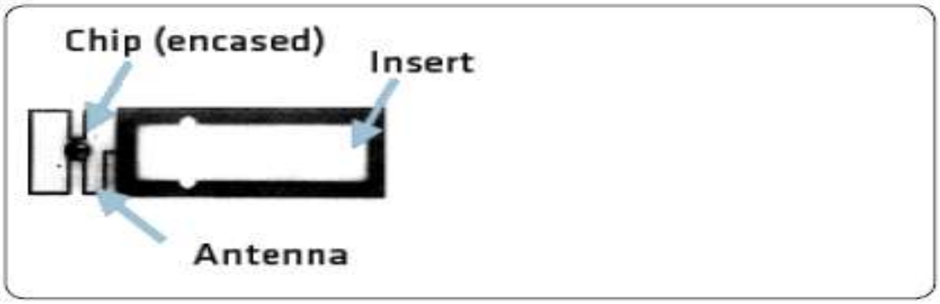

FIGURE 8: TAG CONFIGURATION

The chip is embedded as the "insert "with the completed tag looking as follows:

FIGURE 9: ENCAPSULATED TAG ARCHITECTURE

RFID tags come in a variety of different types according to their functionality, and these types have been defined in an RFID Class Structure by the Auto-ID Center (and later through EPC Global) (Engels and Sarma, 2005), which has been subsequently refined and built on. The basic structure defines five classes in ascending order as follows:

Class	*Class Layer Name*	*Functionality*
1	Identity Tags	Purely passive, identification tags
2	Higher Functionality Tags	Purely passive, identification + some additional functionality (e.g. read/write memory)
3	Semi-Passive Tags	Addition of on-board battery power
4	Active *'ad hoc'* Tags	Communication with other active tags
5	Reader Tags	Able to provide power for and communicate with other tags i.e. can act as a reader, transmitting and receiving radio waves

TABLE 3: CLASSIFICATION OF TAGS

There are two classifications of RFID tags; i.e., 1.) Passive and 2.) Active. Passive tags are read-only and derive their power from that generated by the reader. They have no internal power source themselves. The reading range is typically shorter, up to thirty (30) feet or three meters. The data storage capacity is considerably less also, 96 to 128 bits as compared to active tags. Active tags have both read and write capability and are powered by a battery, either external or internal. This battery power enables data to be read and written to a tag and consequently gives a considerably greater reading range; up to three hundred feet (300 feet) or one hundred (100) meters. Companies are increasingly directing their focus on passive UHF tags because they are cheaper to purchase. The simple ninety-six (96) bit tags are more useful when they will be disposed of with the product packaging. Various types of tags serve different environmental conditions. For example, tags suited to cardboard cases containing plastic items may not be ideal for wooden pallets, metal containers or glass. Tags can be as small as a grain of rice, as large as a brick, or as thin and flexible enough to be embedded within an adhesive label. Tags vary in performance, including read / write ability, memory and power requirements. Paper-thin tags, called smart labels usually serve as single-use applications for case and pallet identification. Printer/encoders produce smart labels on demand, encoding the tag while printing text and/or a bar code on the outer label. Smart labels will satisfy most RFID compliance tagging requirements for cases and pallets. The figure below will show the configuration of a smart label.

FIGURE 10: SMART LABEL CONFIGURATION

You can see how the antenna is structured relative to the chip. Tags for permanent identification may be encased to withstand extreme temperatures, moisture, acids and solvents. Paint, oil and other conditions that could otherwise mar the surface of a smart label will not impair an encased tag. An encased, active tag could yield a total-cost-of-ownership that would ultimately allow considerable savings over the lifetime of the tag. This is one example of ROI that is needed prior to issuing a PO for equipment. Examples of this type of tag are given as follows:

FIGURE 11: ENCAPSULATED TAGS

The chips customarily used as a component for the tags look as follows:

FIGURE 12: CHIP / ANTENNA CONFIGURATION

You will notice that this is a chip / antenna combination. This configuration would be used in a more durable package and would probably be a read / write tag.

The tags, depending upon function, will operate on a range of frequencies. Those frequencies are given in Table 4.

FREQUENCY RANGE	CHARACTERISTICS	APPLICATIONS
Low Frequency 125 to 300 KHz	Short Range (to 18 inches) Low Reading Speed	Livestock ID Reusable Containers
High Frequency 13. 56 MHz	Medium Range (3-10 feet) Medium Reading Speed	Access Control Airline Baggage ID Library Automation
Ultra High Frequency 400 MHz-1GHz	High Range (10 to 30 feet) High Reading Speed Orientation Sensitive	Supply Chain Management Industrial Applications Pallet & Container Tracking
Microwave Frequency > 1 GHz; Primarily 2.45 GHz (US) 5.8 GHz(Europe)	Mediun Range (10 + feet)	Automated Toll Collection Vehicle Identification

TABLE 4: FREQUENCIES

One additional method used to characterize or classify a tag is by distinguishing how a tag "talks to" an associated reader. This is called the ***system communication mode*** and will be either full-duplex (FDX) or half-duplex (HDX). The tag and reader may talk at the same time (FDX) or take turns (HDX).

There are other terminologies used in the technology associated with RFID which are, beyond the scope of this course. These are as follows:

1. Keying
   1. Amplitude-shift keying (ASK)
   2. Frequency-shift keying (FSK)
   3. Phase-shift keying (PSK)
2. Encoding
   1. Biphase Manchester encoding
   2. Pulse interval encoding
   3. Biphase space encoding
   4. Pulsed RZ encoding
   5. EPC Miller encoding
   6. "1 of 256" and "1 of 4"
   7. FSK subcarrier encoding
3. Coupling
   1. Backscatter coupling
   2. Inductive coupling
   3. Magnetic coupling
   4. Capacitive coupling

All of these terms apply to how the reader and the tags communicate with each other. This is interesting technology but delves into communication protocols much beyond the scope of this course.

The overwhelming use of tags is to prevent theft. The greatest number produced and sold is for this purpose. As stated before, these are called Electronic Article Surveillance (EAS). EAS tags are often called 1-bit tags because they are capable of communicating one (1) bit of information only. One bit may be used to store the answer to a ***yes*** or ***no*** question—in this case, "is there a tag present?" If a tag is detected, the answer is yes or "1". If a tag is not detected, the answer is no or "0". These tags are simple and very inexpensive. At present, they are, by far, the most commonly used RFID tags sold today. They are usually disabled at the point of purchase by demagnetizing a hard metal plate in the tag by using a strong magnet mounted on the countertop at the checkout station.

We are going to discuss standards in depth later on in this course but I will show the classification of tags now indicated by EPCglobal. EPCglobal is an industry standard. ISO and other standards have their own classification but they are very much in line with EPCglobal.

CLASS	DESCRIPTION
Class 0	Passive, read only
Class 0+	Passive, write-once but using Class 0 protocols
Class I	Passive, write-once
Class II	Passive, write-once with extras such as encryption
Class III	Rewritable, semi-passive(battery powered chip, reader powered communication), integrated sensors
Class IV	Rewritable, two-way tags that can talk to other tags, powering their own communications.
Class V	Can power and read Class I,II & III tags and read Class V tags, as well as acting as
	Class IV tags themselves.

TABLE 5: EPCglobal TAG CLASSIFICATIONS

As you can see, the classifications go from simple to sophisticated and with increasing capabilities. With that being the case, the associated costs increase accordingly. A company would use a "Class 0", passive read only tag for an article of clothing whereas and a "Class V" tag might be used to track portable MRI equipment.

READERS:

The reader emits electromagnetic waves that induce current in a tag's antenna. This small current, powers the chip mounted on the tag. Readers **MUST** be matched with the tag type: active or passive, although some readers can capture multiple tag types. (This is one of the marvelous developments demonstrating scalability and meeting a significant need in the industry.) When the power to the tag's chip passes a minimum voltage threshold, the circuit turns on and the tag transmits its information to the reader. A passive tag, due to the absence of a battery, has a relatively short range, only a few meters. Please note that a reader is sometimes called an interrogator or scanner. It is a powered device that facilitates data transfer between the tags and the "back end" memory. Readers can be wireless, portable handheld units or flexible devices. They can differ considerably in complexity, depending upon the type of tags supported and the functions performed, such as signal conditioning, parity error checking and correction. The challenge for implementation is--how many readers do you need and where is the ideal placement of those readers in your facility? A poorly placed reader can result in the creation of duplicate "reads" when the read range of the individual tags overlaps. Middleware is many times used to address this problem.

FIGURE 13: READERS

The reader shown as IF5 in the figure above is a fixed reader. IP4 is a portable device and PM4i is a printer receiving the data supplied by the readers. The figure below shows a portable reader mounted on a fork lift used for stocking inventory and moving that inventory to the various manufacturing lines or areas.

FIGURE 14: PORTABLE READERS

The RFID reader must have the following three elements:

1. Antenna
2. Controller
3. Network Interface

Antenna systems vary but generally most installations will keep the reader within about six (6) feet of the most distant antenna. Much longer runs are definitely possible. In a complex system there are two readers, one to send and one to receive. In this configuration, the tag's direction of motion through the reader's fields is particularly important. If the transmitting antenna is "ahead" of the receiving antenna, the receiving antenna will have a longer amount of time to receive signals from the tag. If the antennas are reversed, the tag will spend much less time energized and within range of the receiving antenna.

The controller is the computing device that controls a reader and can vary in complexity from a simple state machine on a chip to a complete microcomputer system capable of running a server operated system. The controller is responsible for controlling the reader-side of the tag protocol as well as determining when information read from a tag constitutes an event to send to the network.

A network interface is the system receiving the data amassed. The reader "talks to the network". Generally, readers have serial interfaces using RS232 or RS422 connections. In the past few years, readers have supported Ethernet, Bluetooth and even Zig-bee.

There are numerous configurations for readers and their associated antennas. The most used are as follows:

- **Portals:** Doorways or entrances. An RFID portal is an arrangement of antennas and readers designed to recognize tagged items entering or leaving through a portal.
- **Tunnels:** A tunnel is simply an enclosure, usually over a conveyor belt in which the antenna(s) may be housed. A tunnel is actually portal.
- **Handhelds:** A handheld reader with integrated antenna, controller, and communication can allow personnel to scan tagged items in situations where it is inconvenient or impossible to move the item. Many handheld readers can also read barcodes.
- **Forklift Readers:** Forklift manufacturers are beginning to offer RFID readers as a part of their optional equipment.
- **Smart Shelves:** Smart shelves and shelving units with antennas incorporated into them in such a way that readers can recognize the arrival and departure of items stored on them—or read all of the items stored around them. Possibly, a great time-saving development.

As with tags, readers have protocols that must be compatible. This compatibility must be with tags, middleware and software. One issue that does exist from to country to country is conformance to permissible power levels. Permissible power levels, frequency variations and regulatory requirements do vary from country to country, even when applied to the same type of tag. For example, EPC UHF readers read the same tag when operating at 915 MHz in the United States and at 869 MHz in Europe. The difference in frequency is due to regulatory constraints. EPCglobal, ISO and other standards organizations are working to develop with standards that will be able to operate globally, but for now, readers must be selected carefully to ensure they comply with local regulations. Vendors can provide you with up-to-date information relative to this problem. **They will list the areas which a reader will operate properly.**

One very quick word on standards—EPC UHF Gen2 specifications require tags and readers to work where two readers are active **simultaneously**. (The key word is simultaneously!) This specification is called a "Dense Interrogator Environment" and prescribes two different approaches to avoid "collisions", depending upon regulatory conditions. This is necessary because under the CEPT regulations in Europe, licensing in some cases requires only a single RF channel but in other cases allows multiple channels. Under FCC (U.S.) regulations, licensing always allows multiple channels in the nine hundred and fifteen (915) MHz range. The EPC Gen2 protocol supports much faster tag / reader singulation than the previous protocol, with tag read rates as fast as sixteen hundred (1,600) tags per minute in North America and in the six hundred (600) tags per minute under more constrained power and frequency ranges in Europe. One of the primary concerns it addresses is added security for the protocol. Key to the solution Gen2 offers is the recognition that signals the reader transmits may be received over a far greater distance than signals generated by the respective tags. The specification considers two readers to be in the same operating environment if they are within one kilometer of each other. (As I mentioned earlier, we are going to devote a somewhat lengthy portion of this course to standards.)

MIDDLEWARE:

RFID systems rely on software that can be categorized into three groups: the front-end tag-reading algorithms; middleware; and the back-end system interface.

The front-end algorithms carry out tasks related to signal processing. Middleware, as the name suggests, connects readers to back-end servers and databases; it filters the data acquired by the reader and handles different kinds of user interfaces.

The primary benefits of RFID technology in supply chain management comes from its interface with the back-end system. This allows the system to filter information received from the reader, perform matching, tracking and storage functions and then route data to the correct application; i.e., "collection" software, generally stored in a PC. Because this "middleware" plays such a significant role in the overall process, we are going to emphasize this software right now.

I think a very good and appropriate place to start is with the various frequency bands available today in RFID technology. Table 4 provides a chart showing frequency, range, characteristics and application.

Frequency Bands:

Systems can be distinguished by their specific radio frequency (RF). The four primary RF bands—ranging from 30 kHz to 5.8 GHz—include low-frequency (LF), high-frequency (HF), ultra-high-frequency (UHF) and microwave-frequency (MW). The choice of RF will depend on the application, the size of the tag and the required **reading range**. We have mentioned before that, in general, the higher the RF, the faster the data transfer or throughput rates, but the more expensive the system. LF, or low frequency, ranges from thirty (30) to three hundred (300) KHz. RFID systems in this band commonly operate between one hundred and twenty-five (125) and one hundred and thirty-four (134) KHz.

HF ranges from three (3) to thirty (30) MHz **HF RFID systems typically operate at 13.56 MHz** and use passive tags with reading ranges up to one (1) m (3.3 ft) and faster data rates than LF tags. Already, HF systems have been widely used in libraries, mass transit, product authentication and 'smart identification' security-related applications, such as electronic passports (e-passports).

UHF ranges from three hundred (300) to one thousand (1,000) MHz **Passive UHF RFID systems typically operate at 915 MHz in the U.S. and at 868 MHz in Europe, while active UHF RFID systems operate at 315 and 433 MHz, respectively**. UHF systems—which are commonly used for logistics applications, including pallet tracking and baggage handling—can send information faster than LF and HF tags and offer the longest reading range of all tags, from three (3) to six (6) m (9.8 to 19.7 ft) for passive tags and more than 30 m (98 ft) for active tags.

A typical MW RFID system operates at either 2.45 GHz or 5.8 GHz. The lower frequency is traditionally used in long-range access control applications, with a reading range of up to 1 m (3.3 ft) with a passive tag or farther with an active tag. The higher frequency has been allocated in Europe for road traffic and automated toll collection systems.

Middleware standards have been defined to support temporary collection of event data for filtering and consolidating the EPC data coming from readers. This standard is called Application-Level Events or ALE. Another communication standard has been defined for the readers in terms of how they capture and communicate event data from tags and sensors. This is called the Reader Protocol (RP).

There are three primary motivations behind using RFID middleware. These are as follows:

- To encapsulate the applications from device interfaces.
- To process raw observations captured by the readers and sensors so that applications see only meaningful, high-level events, thereby lowering the volume of information they need to process
- To provide an application-level interface for managing readers and querying RFID observations

Most RFID middleware today will provide these three features.

DEVICE INTERFACES OR COMMUNICATION PROTOCOL SUITES:

As you might expect, there are many components to RFID, but there are software programs that compensate for the variations in hardware.

When we talk about device interfaces, we are really talking about a physical setup in which the system architecture provides a means by which we eliminate the vagaries or inconsistencies of differing readers. In other words, we are addressing the fact that there may be, and probably will be, readers used manufactured by a number of vendors. It would be very nice to have commonality but that is not necessarily the case with RFID systems.

A typical RFID-enabled distributor or retailer with several hundred or more stores will have hundreds, if not thousands, of readers. Each of these readers will be chirping away several times a second in order to read the RFID tags around them. This can result in millions of RFID observations read each second. Exposing this raw data from the readers to enterprise applications; i.e., software, would be like trying to drink water through a fire hose. In addition, due to the sheer volume of data, the raw observations need further processing to be meaningful. The primary purpose is to lower the volume and improve the relevance of the data before being sent to the application software. This is a process whereby the data is filtered prior to being transmitted for storage as "hard" data. A read cycle is a unit of interaction between the tag and the reader. Each read cycle results in a reader returning a set of observations. Right now, depending upon the physical setup, read rates will produce accuracy anywhere from 80 to 99 percent. This means that if there were 100 tags near a reader, it would probably register anywhere between 80 and 99 tags for every tag cycle read. An item that is picked up in one read cycle could be missed during the next one. Part of the problem is the frequent "collisions" when reading at such rapid rates. Middleware aids the effort in solving this problem.

COST OF PURCHASE:

Both passive and active RFID are used frequently in real-time location systems (RTLS). While they are used to perform a similar function, they use very different technologies. Passive RFID systems use a high-power, low-frequency actuator to radiate energy toward a tag. The tag absorbs the energy and radiates back a coded message to the actuator at a higher frequency and lower power. The primary advantage of passive RFID systems is that tags are very inexpensive, ranging from $0.10 to $1.50 per tag. Think of having a tag on each item of clothing or sporting gear in a single store. The cost would be prohibitive if the individual tag cost was excessive. The more-simple passive tags are used on clothing and other articles to prevent theft and shop-lifting. These tags also don't require batteries, so they last for many years. The disadvantage of passive RFID is that the infrastructure is expensive and can only detect the "presence" of a tag, not its exact location.

Active RFID systems, on the other hand, use battery-powered tags that beacon or connect to various access point readers throughout an area (like a building) and transfer data to the server or cloud. Active RFID tags (like Bluetooth or ultra-wideband), are more expensive ($10+) but have the advantage of using a much less costly infrastructure of readers. Thus, the real tradeoffs between these two types of technology are 1) the shifting of costs from tags to infrastructure, and 2) trading complexity and accuracy for lower total system costs. Depending on the type of RFID system you're planning to implement, the costs you incur will vary. Here's a breakdown of seven RFID costs so you can be prepared before you select and integrate a specific type of technology.

EQUIPMENT COST:

If you choose a passive RFID system, you'll need to consider the RFID reader cost, in addition to the costs of cabling and antennas. For example, an Impinj Speedway reader could run around $1,500, and when additional reader and cabling costs are considered, your passive RFID system could total $3,000 per reader in a manufacturing setting.

To get the location granularity you require, you'll likely need a dense network of these readers, so be sure to budget accordingly. Keep in mind that you also typically have to run power over Ethernet (POE) to passive RFID devices, which can add to your equipment costs.

In a typical manufacturing setting, RFID readers are needed at all entries and exits, as well as in common material storage areas. If a tagged item is placed in an area where readers are not present, the item cannot be located. The location could possibly be inferred by the last seen entry/exit event or by manually "hunting" for the tag using a handheld reader. The use of handheld inventory "guns" is especially common in Aerospace RFID.

The equipment needed for active RFID is significantly less expensive (roughly 10 times less) than the equipment for passive RFID, as the reader equipment isn't as powerful or technologically sophisticated. While ultra-wideband (UWB) systems can be even more costly than passive RFID, they have the advantage of incredibly accurate positioning, generally down to a few centimeters.

A standard Bluetooth-based active RFID system can have varying levels of accuracy. Some RFID systems uses a hybrid approach, where location beacons are placed in areas to aid in the accuracy that can be achieved over standard active RFID alone.

INSTALLATION COSTS:

The installation cost of an RFID system can range from USD two (2) million to dive (5) million for a standard active real-time monitoring system. This cost can differ according to end-use industry and installation area. High installation cost is one of the major restraining factors for the implementation of RFID technology. Adoption of RFID systems in any industry requires high investments, including the purchase cost of RFID tags, readers, and software, and the costs associated with replacement services and electricity. Add-on features such as continuous accuracy checking of systems, IoT integration, and training costs make RFID solutions more costly. Even with this being the case, RFID systems are enjoying great sales and usage for a range of retail and commercial applications.

Passive RFID installation must be accomplished by an expert well versed in tuning the equipment, directing the antennas, running the necessary connectivity tests, and configuring settings and networking details. The readers are generally connected via a LAN network to a central server, which is typically on site and processes all of the RFID data. Once again, an expert is needed our you will have difficulties in getting the system to act and react as you desire. Specialized antennas are used for passive RFID and must be installed and calibrated to ensure appropriate performance. For these reasons, the installation costs of passive RFID are significant.

On the other hand, many RFID active systems can be installed by a member of your IT team in as little as one day, making the process simpler and much less cost-prohibitive. Generally, the exact placement of an active reader is not important; you can position it wherever it's most convenient, negating the cost of having to rework your facility. However, ultra-wideband active RFID systems have installation costs that can exceed even those of passive RFID.

The ongoing maintenance costs associated with both systems are about the same. These costs mainly address issues with equipment that gets unplugged or goes offline for some other reason. Because passive RFID systems have larger standalone antennas, they are more prone to damage in busy industrial settings, so your facility may require some modification to accommodate the hardware. You might factor in as cost a battery backup system if power outages present difficulties on a frequent basis. This will negate "re-starting" efforts and possibly save time and aggravation.

TAG COSTS:

One of the primary benefits of passive RFID is the low cost of tags, which usually run for much less than a dollar. One exception is if you need to tag a metal object, in which case the tags will be slightly more expensive because regular passive RFID tags won't perform appropriately. There are other highly specialized RFID tags for laundry or autoclaves that can run even higher.

Tags are one of the few items that cost more for active RFID. While RF beaconing-style active RFID tags are still less expensive than the tags used for alternative technologies like Wi-Fi and ultra-wideband, you can expect to pay up to (or more than) one hundred (100) times as much for an active RFID tag as for a passive RFID tag, between $5 and $15 each.

In addition, active RFID tags can be coupled with wide-area technology like cellular and GPS to provide seamless indoor/outdoor locating and tracking, so they may very well be worth the additional cost for your application.

Another cost factor for active tags is the cost of maintaining the batteries. Some systems have disposable tags, while others make it possible to replace batteries. Either way, the battery life cycle costs and associated labor must be considered when calculating the overall system costs for an active RTLS system.

SOFTWARE COSTS:

Passive and active RFID readings are useless without asset management software. This type of software can be very expensive. You can learn more about the capabilities to look for in real-time location system (RTLS) software.

Generally, the complexity and specialization of the software drive the cost. A basic tag reading software could be an open-source project, whereas an integrated RFID to ERP enterprise application could cost hundreds of thousands of dollars to maintain.

ON-GOING LICENSE COSTS:

While active RFID licensing costs are typically bundled with the software, passive RFID technologies often require ongoing licensing costs that go toward support and software upgrades. These can be quite expensive, so be sure to account for this cost before you select a passive RFID technology.

These license charges are especially common for Wi-Fi-based RTLS systems where the location technology is an add-on to existing Wi-Fi access points. Cisco Meraki is an example of a Wi-Fi-based active RTLS system that has an ongoing license fee.

MAINTENANCE COSTS:

As mentioned above, passive readers are more complex than active readers due to their extensive cabling, antennas, etc. Because the passive readers are fairly large, they are at a greater risk of being snagged or bumped, which could lead to costly maintenance issues over time.

Active RFID systems are less complex, but their tags do include batteries. This means the tags will need to be maintained anywhere from a few months to every few years, depending on their life expectancy.

Training is another aspect of the ongoing system maintenance that some customers don’t consider. For an RTLS system deployment to be successful, all staff need to be trained initially and on an ongoing basis to fully realize the return on investment for such a system.

INTEGRATOR COSTS:

If you choose to purchase an active or passive RFID solution from an integrator, you'll likely pay a premium over what you would pay if you were to go directly to the technology solution provider. That said, integrators often have teams of experts available to help you select the best technology to fit your problem, which could make the additional expense worth it.

Some RTLS technology companies provide their own installation, design, and support services for their equipment. Some integrators often bundle these services into its ongoing system costs.

It would be wrong to say that active or passive RFID RTLS systems are more appropriate for a customer based solely on cost considerations. Often, both systems can cost nearly the same when you consider all of the aspects discussed above. You need to strike a balance between system capabilities, location accuracy, number of tags, and ongoing maintenance and support to make the most of your investment.

Large enterprises—or companies with complex use cases—may choose standalone asset-tracking software to run a number of tracking and sensing solutions. But many organizations looking for tracking technology are more interested in purchasing a full-stack RTLS solution. If you choose an end-to-end solution, you won't have to deal with the hassle of integrating the hardware and software.

GLOBAL SALES AND MARKETING:

Let us now look at usage on a national and global scale to see just how popular RFID is.

The global RFID market is estimated to be USD 10.7 billion in 2021 and projected to reach USD 17.4 billion by 2026; at a CAGR of 10.2%. Key factors fueling the growth of this market include growing market competitiveness leading to availability of cost-effective RFID solutions, high returns on investment, increasing regulations and government initiatives for various industries, and increasing installation of RFID systems in manufacturing units to improve productivity due to COVID-19.

The following graphic will give some indication as to the size of the market.

FIGURE 15: PROJECTED GROWTH

The United States is expected to register the largest market share in terms of value for RFID tag market globally during the forecast period

The high adoption of RFID systems in the US is a major factor that has led to the prominent position of the Americas in the RFID market. Retail, manufacturing, transportation, logistics and supply chain, animal tracking, healthcare, defense, and IT asset tracking are the major applications for the RFID tag market in the US as well as throughout the Americas. The use of RFID is high in supply chain monitoring for tracking assets in real time. Various hospitals in the US are using RFID tags for applications such as equipment tracking, patient monitoring, and other tracking tasks. These developments are expected to drive the growth of the RFID tag market in the region.

The recent COVID-19 pandemic is expected to impact the global RFID industry. The entire supply chain got disrupted due to limited supply of parts during the first quarter of 2020. For instance, the outbreak of COVID-19 in China resulted in lockdown measures which included the shutdown of manufacturing facilities and warehouses and affected the global exports and shipments of various industries. The lockdown measures announced in several countries across the globe as they got impacted by the COVID-19 pandemic also led to a fall in the domestic and export demand for consumer electronics, automotive vehicles, and other industrial equipment and embedded devices in these countries. Due to slow down in shipment the demand for RFID tags used for tracking these assets also got affected

<u>LEADING MANUFACTURERS IN RFID SYSTEMS, GLOBALLY:</u>

- Datalogic
- Honeywell International
- Zebra Technologies
- Acreo Swedish ICT
- Alien Technology
- Avery Dennison
- Checkpoint Systems

- CipherLab
- CoreRFID
- FEIG ELECTRONIC
- Fujitsu
- GAO RFID
- Impinj
- ORBCOMM
- Smartrac
- Unitech Electronics

STANDARDS:

Portions of the following text are excerpts taken from a white paper entitled "Supply Chain RFID: How It Works and Why It Pays", by Intermec and "An Overview of RFID Technology" by DATA Flows.

In the early days of RFID, there was a lingering misperception that RFID was a proprietary technology lacking standards. Today, numerous standards ensure diverse frequencies and applications. For example, RFID standards exist for item management, logistics containers, fare cards, animal identification, tire and wheel identification, and many other uses. **The International Standards Organization (ISO)** and **EPCglobal Inc.** are two of the standards organizations most relevant for the supply chain. NOTE: EPCglobal is an organization formed by the merging of **EAN International** and the **UCC or Uniform Code Council**. Many national and industry standards are based on ISO or EPCglobal standards, such as the U.S. ANSI standard MH10.8.4, for returnable container identification (based on an ISO specification). By definition, ISO standards can be used anywhere in the world, and serve as the national standard in many countries. The EPCglobal Generation 2 (EPC Gen 2) UHF standard has been submitted to ISO and is expected to become part of the ISO-18000 series of standards. The Gen 2 standard was created to facilitate the use of Electronic Product Code™ (EPC) numbers, which uniquely identify objects such as pallets, cases or individual products. EPC standards provide both RFID technical specifications and a numbering system for unique, unambiguous item identification. Gen 2 and other EPC standards are administered by EPCglobal, a subsidiary of GS1 (the same not-for-profit organization that issues U.P.C. numbers and manages the EAN.UCC system). Many manufacturers, retailers, other companies, public sector organizations and industry associations have adopted or endorsed EPC standards, particularly Gen 2.

The two standards above; i.e., ISO and EPCglobal, etc, demonstrate "air-Interface and tag data structure" standards. The industry motivated group is definitely EPCglobal. This standard was drafted first, and as such, they get to pursue ISO to adopt the standard they propose. Specifically, EPCglobal has laid out the following tag interface specifications:

- EPC tag version 1.1—900 MHz class 0 Frequency (RF) Identification
- 13.56 MHz ISM Band Class 1 Radio Frequency (RF) Identification
- 860 MHz—930 MHz Class 1 Radio Frequency (RF) Identification

The ISO standards, roughly, correspond to the standards listed above. In December 2004, EPCglobal ratified its UHF generation 2 standards for passive class 1 tags. The ISO version of this is the draft standard ISO 18000-6. The new specification improves performance relative to data rates and additional security, including a kill feature (important for privacy) and closer alignment with ISO standard 18000/6, part C. In addition, it will be able to operate on a global basis, not just in a domestic fashion.

The following table will show the ISO specifications and a very basic description of what that standard defines. (NOTE: When we say air interface protocol, we are describing how tags and readers communicate with each other.)

TABLE 6: ISO/IEC 1800 STANDARDS

ISO/IEC 1800 STANDARDS		
STANDARD	TITLE	DESCRIPTION
ISO 18000-1	Generic Parameters for the	Principals and architecture for an RFID standard
	Air Interface for Globally	
	Accepted Frequencies	
ISO 18000-2	Parameters for Air Interface	LF, two tag types optional anti-collision
	Communications below 13.56 MHz	Tag Type A: FDX 135 KHz
		Tab Type B: HDX 134.2 KHz
		Passive inductive coupling
ISO 18000-3	Parameters for Air Interface	HF, two tag (both requiring license from the IP owner)
	Communications at 13.56 MHz	Mode 1: 105.94 Kbps from tag to reader
		Mode 2: 423.75 Kbps from tag to reader
		Passive, both using inductive coupling FDX
ISO 18000-4	Parameters for Air Interface	Microwave, two modes
	Communications at 2.45 GHz	Mode 1: Passive
		Mode 2: Semi-passive, tags talk first
		Passive, backscatter, HDX
ISO 18000-5	Withdrawn	Withdrawn (was 5.8 GHz)
ISO 18000-6	Parameters for Air Interface	
	Communications at 860 to 930 MHz	UHF, two tag types
		Type A: Pulse interval encoding, Aloha anti-collision
		Type B: Manchester encoding, Binary Tree anti-collision
		Passive, backscatter, HDX
		Reader to tag uses biphase space encoding for both
		tag types. (Type C: ISO may adopt EPC Gen2 as the
		Type C tag in later 2005.)
ISO 18000-7	Parameters for Air Interface	UHF long range
	Communication at 433 MHz	Read / write, active HDX

I am printing again the EPCglobal classification for tags. That is given below and as you can see, there is a great deal of similarity relative to the ISO standards.

TABLE 7: EPCglobal CLASSIFICATION FOR TAGS

CLASS	DESCRIPTION
Class 0	Passive, read only
Class 0+	Passive, write-once but using Class 0 protocols
Class I	Passive, write-once
Class II	Passive, write-once with extras such as encryption
Class III	Rewritable, semi-passive(battery powered chip, reader powered communication), integrated sensors
Class IV	Rewritable, two-way tags that can talk to other tags, powering their own communications.
Class V	Can power and read Class I,II & III tags and read Class V tags, as well as acting as Class IV tags themselves.

There are other ISO standards that come into play and provide very valuable governance relative to RFID. Several of these are:

- ISO 11784: Describes how data is structured on an individual tag.
- ISO 11785: Defines air interface payment protocol
- ISO 14443: Defines payment systems used in contactless smart cards or proximity cards
- ISO 15693: Defines payment systems used in vicinity cards
- ISO 18047: Defines testing and conformance of tags and readers
- ISO 18046: Defines testing and performance of tags and readers
- ISO 11784 & ISO 11785: Regulation of RFID for animals regarding code structure and content
- ISO 14223/1: RFID of animals, advanced transponders
- ISO 10536: Close coupled cards

Major retailers use Electronic Product Code (EPC) specifications that were developed at the MIT and Auto-ID Center. These are now managed by EPCglobal. The EPC is a simple, compact, license plate that uniquely identifies objects; i.e., objects, cases, pallets, locations, etc in a supply chain environment. Like many current numbering schemes used in commerce, the EPC is divided into numbers that identify the manufacturer and product type. The EPC uses an extra set of digits and serial number to identify unique items. An EPC number consists of the following:

- Header—Identifies the length, type, version and generation of the EPC code
- Manager Number—Identifies the company or company entity
- Object Class—Refers to a stock keeping unit or product SKU
- Serial Number—Uses an extra set of digits, a serial number, to identify unique items

Additional fields may be used as part of the EPC in order to properly encode and decode information from different numbering systems into their native (human-readable) forms. All of these standards feed into and govern the EPC Global Network. This network defines a framework that enables immediate, automatic identification and sharing of information on items in the supply chain. The network is comprised of five fundamental elements:

1.) Electronic Product Code (EPC)
2.) EPC Tags and Readers
3.) Object Name Service (ONS)
4.) Physical Markup Language (PML)

5.) Savant Software

The Electronic Product Code (EPC)

The EPC is a unique sixty-four (64) to ninety-six (96) bit identifier attached to the physical object. A reader infrastructure of RFID antennas is able to identify the tagged items. The EPC Global Network can virtually connect physical objects and data via the internet. Data about every product, its history or other product related information can be made available through a standardized infrastructure anywhere and anytime.

The Electronic Product Code is the next evolution of product identification, utilizing RFID technology to identify objects in a supply chain.

Based on current numbering schemes (EAN, VIN etc.), EPC is divided into numbers that differentiate the product and manufacturer of a given item. The difference between EPC and previous numbering systems lies in the usage of an extra set of digits to uniquely identify one object.

The Electronic Product Code promises to become the standard for global RFID usage.

PRIVACY AND SECURITY:

The privacy issues surrounding RFID usage will need to be solved if the technology is to flourish and become commonplace on a global scale. The primary issue is activation of the tags without the consumer's knowledge. This could lead to targeted marketing and illicit tracking of individuals, again without their knowledge and consent. In cases where RFID is used in credit cards or store cards, it could be possible to determine the identity of that particular consumer. Obviously, when you can tie the card number to the name on the card, you have a huge privacy issue. It is not uncommon for an RFID tag to remain functional post-purchase, possibly allowing for surveillance of household inventories. Distance would not hinder the ability of a reader to read a tag. An individual with access to a high-gain antenna would be able to activate these RFID tags from a distance.

RFID technology may be used for passports and driver's licenses also, creating additional concerns and controversies. There is absolutely no doubt that incorporating RFID into passports would certainly speed up the processing of individuals entering and exiting a country. An RFID tag embedded into a driver's license would also hasten any access to an individual's police record, or the lack of a record.

There are industry guidelines that help individuals and companies understand the limits of use. Several of these guidelines are as follows:

- **Consumer Notice:** Requires that a consumer be given adequate notice that an RFID tag has been applied to an article or package.
- **Consumer Choice:** The consumer must be informed of their choices to discard, remove or disable EPC tags.
- **Consumer Education:** This is the key to dispelling some of the myths regarding the technology.
- **Record of Use, Retention and Security:** All data storage will be accomplished in light of existing laws and none of the data will be abused regarding individuals.

I mentioned earlier several "watchdog" organizations that have a certain amount of oversight regarding privacy. These are functioning groups within government agencies and industry making certain that individual consumer rights are not violated. Again, these agencies are as follows:

- United States Congress—HR 4673
- Various states in the United States; i.e., California with SB1834
- CASPAIN: Consumers Against Supermarket Privacy Invasion and Numberings
- Privacy International: www.privacyinternational.org
- EPIC: Electronic Privacy Information Center, www.epic.org

TEN (10) QUESTIONS TO ASK WHEN THINKING OF RFID:

I definitely recommend contacting suppliers, vendors, etc prior to any installation work involving RFID systems. In doing so, there are several very basic questions that need to be asked and answered as a part of the process. I would like now to list these for your consideration. First, let us take a look at the hardware:

1.) **Which frequencies and standards do you support?** As we have seen, there are many many used for RFID technology, all of which fill many needs. You may not need a 30-foot yacht when a row-boat will do. It all depends upon your needs and the needs of your company. Straight-forward theft-management requires different systems that one which communicates with 1000 stores in a distribution network.
2.) **Can you back up your performance claims?** In some cases, the technology is still somewhat immature. If a vendor makes claims, he should be able to exhibit adherence to those claims AND provide references from jobs completed. I would definitely recommend visiting a job site in which his equipment and his software are installed and discuss with the owner performance of the overall system.
3.) **Do you do site inspections?** If they won't even come out to visit your facility---dump them in a heartbeat. (You don't have to worry about this one. All of the competent vendors are more than willing to review your needs and look at your facility PRIOR to making recommendations and submitting a quote.)
4.) **How will you help me protect my investment?** Things change in technology. It's important to ensure that any reader you purchase today can be upgraded remotely over a local or wide area network to comply with new standards that emerge. Typically, this involves installing new firmware in the reader. Many, but not all, companies now offer readers that can be upgraded remotely. Some companies are offering readers that can operate using several different protocols and even different frequencies. This is one way to guarantee that whatever protocol emerges as a standard, your hardware will be able to cope. However, there may be some trade-offs. Some multiprotocol readers are more expensive than single-protocol readers, and there can be a decline in performance if the reader is set up to try to run through a series of protocols to detect which types of tags are in the read field. Compare prices and ask vendors to demonstrate the reader using several dozen tags and a variety of protocols.
5.) **How will you help me minimize my maintenance costs?** Make no mistake about it; you will have to maintain the system hardware and the system software for the assemblage of components to remain viable over the years. This is no different than a press, tool room or assembly line.

6.) **Have you done an inoperability testing?** It is important that the hardware and software comply with the latest existing standards. In other words, will it work and continue to work.
7.) **Do you offer middleware?** If a hardware vendor does not offer middleware, it becomes even more critical for him to ensure the hardware will work with recommendations from him relative to companies that do offer middleware. Also, it is imperative that he "hang around" during installation and checkout of the middleware.
8.) **Do you have a partner who can integrate the readers with back-end equipment?** Employing RFID equipment is no easy matter. The antennas must be tuned with the readers and this requires experience and patience. It must be accomplished or the system will not work properly and you will not be satisfied with your investment.
9.) **Will you work with me to customize tags if I need them?**
10.) **Can you deliver the volumes I need?** The ability of a system to read tags at the rate required is one HUGE requirement. The accuracy of those reads is also critical. One read in ten is not acceptable. You must establish, up front, your expectations for your equipment. Now, it is imperative that estimated growth be factored into the mix. Only you can do this. Don't guess.

Now, let us consider the questions needing to be asked if you employ a system integrator. These are as follows:

1.) **What hardware have you integrated successfully?** After he answers that question, go take a look.
2.) **What is your area of expertise?** No one is all things to all people. The same is true for system integration. Some specialize so your installation may require more than one systems integrator. If using more than one integrator, they will be happy to work together to accomplish the task of getting you up and running.
3.) **How much experience do you have with automatic identification and data capture?** You probably would not go to a dentist who had no credentials—would you? Same case here. If they have no experience stay away.
4.) **How much industry knowledge do you have?** Processes in one industry may be far different that process in another. I feel it is better to deal with vendors who know your industry and have accomplished installations and solved problems with entities similar to yours.
5.) **Can you do business case analysis and and develop business processes?** Large consulting companies, such as Accenture and IBM Global Services, have staff with both technical skills and business consulting knowledge. They are able to help companies evaluate the potential return on investment from an RFID system and recommend changes in the company's business processes so it can achieve that return. Many smaller integrators don't have business consultants and can't begin to do the business analysis.

   Companies should also consider hiring a separate company to do the business case analysis. One benefit of this option is the consulting firm is likely to give you a more realistic assessment of the benefits if it is not actually going to deploy the system. But the problem with this approach is that a business consultant might not understand the limitations of RFID technology and build a business case on applications that can't be deployed in the real world. If you go this route, make sure you choose a business-consulting firm that has experience evaluating RFID projects.

6.) **<u>Do you have test facilities available to test my product?</u>** The products you are counting may have tags that readers can't handle with easy accommodation. A vendor must be able to test his product before you get delivery. All of the "tweaks" must be made prior to installation.
7.) **<u>Is your platform based upon industry standard technology?</u>** CRITICAL!! The answer must be YES.
8.) **<u>Do you write code?</u>** All of the code necessary must be integrated and work in a smooth and transparent manner. This may mean "patches" of code necessary for accomplishment of this desired end.
9.) **<u>Who owns the intellectual property?</u>** There are times when entirely new solutions must be sought for proper integration of hardware and software. When this is accomplished, you the buyer, should own the intellectual property rights to the overall system. At least, this needs to be discussed with your integrator.
10.) **<u>Do you have a vision as to how to build onto the system?</u>** Your company will grow and when it does, will your system grow with it? Is it scalable?

As you can see, a great deal of thought and investigative work should go into specifying and incorporating an RFID system. Taking the time will save you money and a great deal of heartburn later on. You can realize your targeted savings and efficiency by doing the proper research up front of any investments made.

<u>MANAGEABILITY:</u>

"If you don't have a strategy and you don't know what the payback is going to be, effectively you're asking your board of directors and your shareholders to underwrite an ongoing cost that could undermine your profitability," says Jonathan Loretto, global technology lead for RFID at Cap Gemini Ernst & Young. "The impact on a business, if RFID is done right, can be significant, but the impact if it's done incorrectly can be devastating."

There is absolutely no doubt that each industry will have differing strategies relative to the incorporation of RFID technology. There is a huge difference between the needs of a retail establishment and one producing a component or assembly of components. The very definition of manageability sums up the differences**. "Manageability refers to how a system allows an operator to control and monitor that system in order to meet other requirements, such as availability or throughput.** Differing systems have differing manageability requirements. You MUST have a viable strategy prior to incorporating this technology and that strategy MUST involve the individuals responsible for operating the system(s), those responsible for maintaining the system and those responsible for any and all upgrades. The following piece of advice was given by Mr. Pete Abell and certainly applies to every business concern looking at incorporating the technology. Take a look.

"Once a company has settled on an RFID strategy, the CEO needs to create a steering committee with senior executives from virtually all areas of the business. Failure to do this will mean missed opportunities. For example, executives in charge of corporate security are seldom put on RFID steering committees, yet RFID could play an important role in helping companies to comply with regulations designed to reduce the chance of a terrorist group using a shipping container to sneak weapons of mass destruction into a country. "It goes beyond just supply chain, logistics and IT," says Pete Abell, cofounder of ePC Group, a consulting firm.

SUMMARY:

This is a marvelous technology and is improving each and every year. The future is rich with possibilities. What if a manufacturer could automatically notify a retailer, through RFID systems, that his order would ship tonight via common carrier for delivery four days from a specific date? What if that same system could give daily updates to that retailer as to the location along the route? The technology is available right now for this to happen. Remarkable efficiencies are possible by the incorporation of RFID. Millions of dollars are saved each year by shaving minutes of unnecessary time from the distribution networks. The DOD is saving millions by the positive location of inventories using the technology. New and better uses are being developed each and every year. I think, in summary, this technology is viable, can be robust and is definitely worth looking at relative to your individual operation.

Let us now summarize by publishing several general guidelines for implementation of RFID technology. These are as follows:

RFID ADOPTION GUIDELINES:

- **Determine the business need:** The current process exists for a reason. Before you even think about changing it, make sure you know its strengths, weaknesses, and reasons for being. Don't start from the premise, "Where can I use RFID?" Instead start by asking, "How can I improve this process?"
- **Evaluate potential changes:** Carefully assess the costs and benefits of any potential changes. For example, if you want to automate a manual process, ask yourself a few questions about the change. Would a bar code work better that an automated process? Could the process be changed in some way to take better advantage of RFID, or conversely, to eliminate it from your process? How will you handle equipment failures or other types of failure? Note that RFID is sometimes mistakenly referred to as a "replacement for bar codes". Bar codes are actually better for some applications than RFID and are considerably less expensive.
- **Develop a long-term roadmap:** Instead of developing RFID systems in an ad hoc manner, develop a long-term business justification for adopting the technology and formulate a vision of how your business processes will look in an RFID environment. Follow this up by developing a master plan that shows which systems will need to change and how. Show what your application and infrastructure architecture will look like after deploying RFID. Doing the design up front will give you a clear goal and will also promote the necessary discussions between you and your business units, end users, operations staff, IT personnel and business partners. Do not underestimate how much RFD will impact these stakeholders.
- **Start small:** Develop a proof-of-concept prototype to validate your assumptions. It is better to fail small and learn early than to fail large and have to recover quickly. Do not be afraid to revise the roadmap based upon the mistakes in your prototype.
- **Run in parallel with your existing system:** Only when everything run smoothly should you begin to depend upon the newly incorporated technology.
- **Be flexible:** The new process will take time to mature. While this happens, be ready to take advantage of new capabilities.
- **Share with partners:** Work with your less-enlightened trading partners and show them how to improve their own processes. RFID is an evolving technology so take a leadership role. This will allow you to define the agenda and the standards around which you have developed the overall process.

I do hope this quick overview helps your efforts in evaluating this exciting technology for incorporation into your facility. I feel it is definitely worth a look.

APPENDIX

- LIST OF VENDORS
- GLOSSARY
- REFERENCES

RFID CONTRACTORS/Integrators

A, B

AARFID:	Integration, Manufacturing RFID
ACG:	Smart Cards
Aleis International:	Animal ID
Alien Technology:	915 / 2450 MHz Tags / Readers
Allsafe Company:	LF, HF, P, SC, SC, SR, RO, WORM, P
Allflex:	Animal Eartag RFID
Amtech (Transcore):	TR/ETTM, UHF, MR, LR, RO, PG, RW, WORM, A, P
AMSKAN:	LF, HF RFID, IR ID, Gemplus, TIRIS
Analytica-India:	Real Time Location - IR / RFID
ASK:	Proximity Cards
ATMEL(Germany):	RFID ICs, Wireless, etc.
AXCESS:	LF, UHF, RTLS
Auto Access ID(AAID):	Long Range UHF
AWID:	Proximity Cards
Balogh:	LF, HF, RW, RO, PG, A, P
Baumer:	LF, HF RFID
Bewator:	LF, HF Passive Tags

C, D

Cavitec (Germany):	LF cards, fobs, wrist band, etc.
Cotag:	(See Bewator)
Crosspoint, b.v.:	Access, EAS, RFID H, LF
Crosslink, Inc:	Transportation, UHF, Long Range, etc.
Copytag (UK):	LF, HF Readers, Tags, Antennas
China-Vision:	RFID Cards & Readers
Champion Chip:	Racing related tags (Nederland)
Checkpoint Systems:	LF, HF EAS, RF Labeling, & Bar Code Labeling
Datamars:	RFID transponder manufacturer
Deister:	LF, HF Tags, Components
DA Electonik:	Animal Tags
Dalton UK:	animal tags
DTE GmbH:	LF, HF RFID
Destron Fearing:	animal tags

E, F, G

Escort Memory Systems: LF, HF Tags, Antennas, Readers

Elatec: LF through UHF Tags and Readers

EM Microelectronic: RFID chips

Ext ELF: LF, HF RFID

Eureka: LF, RO. UK

FEIG: LF, HF, RO, RW, SR, Germany

GAO Engineering: LF, HF, UHF Tags and Readers

Gantner GMBH: Identification Technology

Gemplus: LF, HF Tags, Readers, Antennas

Gnuco: RFID Consulting

H, I, J

HID: Access Control

Hitec ID: UK Pet Identification

ID Systems: LF, HF, UHF RFID

IAID: LF, HF, UK

ID Micro: Trucking, Skiing, General RFID, LF, HF, UHF, RW, RO

IB Technology (UK): LF, HF, Reader on a chip

Identec: UHF, Active, Long-Range Tags

Idesco (Finland): Prox Readers, Access Control, ID Badges

Ingecom: Readers, Active tags, RTLS, Custom designs

Indala Corp: Access Control, RO, LF, HF SR

Inoteclabels: HF Labels, UHF Labels, Genl Labels

Instantel (Xmark): LF/UHF personnel, security, alarm tags and receivers (xmark)

Intersoft: LF tags and readers, inexpensive evaluation kit

Integrated Engineering: Proximity Cards

K, L, M

Korteks: Transponders & Reader PC Boards

LAN-Links Corp: General RFID systems

MBBS: LF system reads through metal

Metget Company: LF Transponders: animal, access, logistics

Microdesign: Access & toll tags

Motorola: Search their main site. Appear to be inactive in RFID.

915 MHz Passive 100s tags/sec UHF, RO, LR

Matrics RFID:

N, O, P

New ID: Specialized RFID, Temperature, etc.

Nedap: LF RFID, industrial

Omron: LF, MF, UHF, SR, MR, LR, Cards, Industrial tags

Omega Electronics: Race related RFID

Ordicam: LF contactless tags

On Track Innovations: Contactless cards

Oxley Group: Contact Memory Buttons

Oxygen RFID: Smart Cards, Contactless RFID

PFC Corp: Polymer Flip Chip Manufacturer

Phillips: Chips for RFID, mostly LF, HF transponders

Phi Data: LF, HF, UHF

Pinpoint: 2.45/5.8 GHz Real Time Location System (see RFT)

Q, R, S

Reseaumatic: French POS RFID

RFIDeas, Inc: Proximity Security RFID

RFID Inc: LF RFID

RF Technologies: Wanderer Monitoring, Hospital Security, RTLS

SAMSys Inc: Multi-Frequency RFID products

Savi Technology: RTLS, Supply Chain Software, & DOD RFID products

SCS Corporation: UHF Passive Tags and Readers

Scratchoff: RFID Labels

Scemtec: LF RFID

SkyeTek: HF / UHF Systems

Smartcode: Passive, Active Tags, Inlays, Readers

Sokymat, Inc: LF RFID

Sensormatic: Electronic Article Surveillance & RFID Products

Siemens: (You may need to search for rfid. it changes often)

Sirit: Electronic Toll, etc.

STId: LF, HF, UHF Readers & Tags

Passive & Active HF and UHF RFID systems

Syncroft:

T, U, V

Tagmaster (Confident): Wide variety of Tags, Readers, Antennas

Tagnology: LF, HF RFID Tags, Readers, Antennas (Germany)

Tagtronic:	
TIRIS (TI):	LF Tag and Reader components
Temic:	(You may need to search for rfid. it changes often)
Thingmagic:	UPC Gen 1, Gen 2 Multi-Vendor Readers
Trovan:	Animal ID, LF, AT, P
Trolleyscan Update:	Super Tag Site
UK ID Systems:	Animal ID
United Access AG:	Access Control
UPM Raflatac:	RFID tags and inlays for different applications
W, X, Y, Z	
Wherenet:	2.45 GHz Real Time Location Systems
WaveNet International:	Intermodal/Rail ISO, AAR AEI Equipment
Y-TEX:	Animal ID, LF, Ear Tags

GLOSSARY OF TERMS

A

Active tag: An RFID tag that has a transmitter to send back information, rather than reflecting back a signal from the reader, as a passive tag does. Most active tags use a battery to transmit a signal to a reader. However, some tags can gather energy from other sources. Active tags can be read from 300 feet (100 meters) or more, but they're expensive (typically more than US $20 each). They're used for tracking expensive items over long ranges. For instance, the U.S. military uses active tags to track containers of supplies arriving in ports.

Addressability: The ability to write data to different fields, or blocks of memory, in the microchip in an RFID transponder.

Agile reader: A generic term that usually refers to an RFID reader that can read tags operating at different frequencies or using different methods of communication between the tags and readers.

Air interface protocol: The rules that govern how tags and readers communicate.

Alignment: See Orientation.

Amplitude: The maximum absolute value of a periodic curve measured along its vertical axis (the height of a wave, in layman's terms).

Amplitude modulation: Changing the amplitude of a radio wave. A higher wave is interpreted as a 1 and a normal wave is interpreted as a zero. By changing the wave, the RFID tag can communicate a string of binary digits to the reader. Computers can interpret these digits as digital information. The method of changing the amplitude is known as amplitude shift keying, or ASK.

Antenna: The tag antenna is the conductive element that enables the tag to send and receive data. Passive, low- (135 kHz) and high-frequency (13.56 MHz) tags usually have a coiled antenna that couples with the coiled antenna of the reader to form a magnetic field. UHF tag antennas can be a variety of shapes. Readers also have antennas which are used to emit radio waves. The RF energy from the reader antenna is "harvested" by the antenna and used to power up the microchip, which then changes the electrical load on the antenna to reflect back its own signals.

Antenna gain: In technical terms, the gain is the ratio of the power required at the input of a loss-free reference antenna to the power supplied to the input of the given antenna to produce, in a given direction, the same field strength at the same distance. Antenna gain is usually expressed in decibels and the higher the gain the more powerful the energy output. Antennas with higher gain will be able to read tags from farther away.

Anti-collision: A general term used to cover methods of preventing radio waves from one device from interfering with radio waves from another. Anti-collision algorithms are also used to read more than one tag in the same reader's field.

Auto-ID Center: A non-profit collaboration between private companies and academia that pioneered the development of an Internet-like infrastructure for tracking goods globally through the use of RFID tags.

Automatic Identification: A broad term that covers methods of collecting data and entering it directly into computer systems without human involvement. Technologies normally considered part of auto-ID include bar codes, biometrics, RFID and voice recognition.

B

Backscatter: A method of communication between passive tags (ones that do not use batteries to broadcast a signal) and readers. RFID tags using backscatter technology reflect back to the reader radio waves from a reader, usually at the same carrier frequency. The reflected signal is modulated to transmit data.

Bar code: A standard method of identifying the manufacturer and product category of a particular item. The barcode was adopted in the 1970s because the bars were easier for machines to read than optical characters. Barcode's main drawbacks are they don't identify unique items and scanners have to have line of sight to read them.

Battery-assisted tag: These are RFID tags with batteries, but they communicate using the same backscatter technique as passive tags (tags with no battery). They use the battery to run the circuitry on the microchip and sometimes an onboard sensor. They have a longer read range than a regular passive tag because all of the energy gathered from the reader can be reflected back to the reader. They are sometimes called "semi-passive RFID tags."

C

Carrier frequency: The main frequency of a transmitter, or RFID reader, such as 915 MHz. The frequency is then changed, or modulated, to transmit information.

Checksum: A code added to the contents of a block of data stored on an RFID microchip that can be checked before and after data is transmitted from the tag to the reader to determine whether the data has been corrupted or lost. The cyclic redundancy check is one form of checksum.

Chipless RFID tag: An RFID tag that doesn't depend on a silicon microchip. Some chipless tags use plastic or conductive polymers instead of silicon-based microchips. Other chipless tags use materials that reflect back a portion of the radio waves beamed at them. A computer takes a snapshot of the waves beamed back and uses it like a fingerprint to identify the object with the tag. Companies are experimenting with embedding RF reflecting fibers in paper to prevent unauthorized photocopying of certain documents. Chipless tags that use embedded fibers have one drawback for supply chain uses—only one tag can be read at a time.

Circular-polarized antenna: A UHF reader antenna that emits radio waves in a circular pattern. These antennas are used in situations where the orientation of the tag to the reader cannot be controlled. Since the waves are moving in a circular pattern, they have a better chance of hitting the antenna, but circular-polarized antennas have a shorter read range than linear-polarized antennas.

Closed-loop systems: RFID tracking systems set up within a company. Since the tracked item never leaves the company's control, it does not need to worry about using technology based on open standards.

Commissioning a tag: This term is sometime used to refer to the process of writing a serial number to a tag (or programming a tag) and associating that number with the product it is put on in a database.

Concentrator: A device connected to several RFID readers to gather data from the readers. The concentrator usually performs some filtering and then passes only useful information from the readers on to a host computer.

Contactless smart card: An awkward name for a credit card or loyalty card that contains an RFID chip to transmit information to a reader without having to be swiped through a reader. Such cards can speed checkout, providing consumers with more convenience.

Coupling: See inductive coupling

Cyclic redundancy check (CRC): A method of checking data stored on an RFID tag to be sure that it hasn't been corrupted or some of it lost. (See Checksum.)

D

Data transfer rate: The number of characters that can be transferred from an RFID tag to a reader within a given time. Baud rates are also used to quantify how fast readers can read the information on the RFID tag. This differs from read rate, which refers to how many tags can be read within a given period of time.

Data field: An area of memory on an RFID microchip that is assigned to a particular type of information. Data fields may be protected (see below) or they may be written over, so a data field might contain information about where an item should be sent. When the destination changes, the new information is written to the data field.

Data field protection: The ability to prevent data stored in a specific area of memory of an RFID microchip from being overwritten. Companies might want to protect the data field that stores an Electronic Product Code, which doesn't change during the life of the product it's associated with.

Decibel (dB): A measure of the gain of an antenna.

De-tune: UHF antennas are tuned to receive RFID waves of a certain length from a reader, just as the tuner on the radio in a car changes the antenna to receive signals of different frequencies. When UHF antenna is close to metal or metallic material, the antenna can be detuned, resulting in poor performance.

Die: The silicon block onto which circuits have been etched to create a microchip.

Duplex: A channel capable of transmitting data in both directions at the same time. (Half duplex is a channel capable of transmitting data in both directions, but not simultaneously.)

Duty cycle: The length of time the reader can be emitting energy. Regulations in the European Union say readers can be on only 10 percent of the time.

E

EEPROM (Electrically Erasable Programmable Read-Only Memory): A method of storing data on microchips. Usually, bytes can be erased and reprogrammed individually. RFID tags that use EEPROM are more expensive than factory programmed tags, where the number is written into the silicon when the chip is made, but they offer more flexibility because the end user can write an ID number to the tag at the time the tag is going to be used.

Effective isotropic radiated power (EIRP): A measurement of the output of RFID reader antennas used in the United States and elsewhere. EIRP is usually expressed in watts.

Effective radiated power (ERP): A measurement of the output of RFID reader antennas used in Europe and elsewhere. ERP is usually expressed in watts and is not the same as EIRP.

Electromagnetic interference (EMI): Interference caused when the radio waves of one device distort the waves of another. Cells phones, wireless computers and even robots in factories can produce radio waves that interfere with RFID tags.

Electronic article surveillance (EAS): Simple electronic tags that can be turned on or off. When an item is purchased (or borrowed from a library), the tag is turned off. When someone passes a gate area holding an item with a tag that hasn't been turned off, an alarm sounds. EAS tags are embedded in the packaging of most pharmaceuticals. They can be RF-based, or acousto-magnetic.

Electronic Product Code: (EPC): A serial, created by the Auto-ID Center, that will complement barcodes. The EPC has digits to identify the manufacturer, product category and the individual item.

EPC Discovery Service: An EPCglobal Network service that allows companies to search for every reader that has read a particular EPC tag.

EPCglobal: A non-profit organization set up the Uniform Code Council and EAN International, the two organizations that maintain barcode standards, to commercialize EPC technology. EPCglobal is made up of chapters in different countries and regions. It is commercializing the technology originally developed by the Auto-ID Center.

EPC Information Service: Part of the EPC Network. The EPC Information Service is a network infrastructure that enables companies to store data associated with EPCs in secure databases on the Web. The EPC Information Service will enable companies to provide different levels of access to data to different groups. Some information associated with an EPC might be available to everyone. Other information might be available only to a manufacturer's retail customers. The service also includes a number of applications, such as the EPC Discovery Service.

EPCglobal Network (or EPC Network): The Internet-based technologies and services that enable companies to retrieve data associated with EPCs. The network infrastructure includes the Object Name Service, distributed middleware (sometimes called Savants), the EPC Information Service and Physical Markup Language.

Error correcting code: A code stored on an RFID tag to enable the reader to figure out the value of missing or garbled bits of data. It's needed because a reader might misinterpret some data from the tag and think a Rolex watch is actually a pair of socks.

Error correcting mode: A mode of data transmission between the tag and reader in which errors or missing data is automatically corrected.

Error correcting protocol: A set of rules used by readers to interpret data correctly from the tag.

European Article Numbering (EAN): The bar code standard used throughout Europe, Asia and South America. It is administered by EAN International.

Excite: The reader is said to "excite" a passive tag when the reader transmits RF energy to wake up the tag and enable it to transmit back.

eXtensible markup language (XML): A widely accepted way of sharing information over the Internet in a way that computers can use, regardless of their operating system.

European Telecommunications Standards Institute (ETSI): The European Union body that recommends standards for adoption by member countries.

F

Factory programming: Some read-only have to have their identification number written into the silicon microchip at the time the chip is made. The process of writing the number into the chip is called factory programming. This data can't be written over or changed.

Far-field communication: RFID reader antennas emit electromagnetic radiation (radio waves). If an RFID tag is outside of one full wavelength of the reader, it is said to be in the "far field." If it is within one full wavelength away, it is said to be in the "near field." The far field signal decays as the square of the distance from the antenna, while the near field signal decays as the cube of distance from the antenna. Passive RFID systems that rely on far field communications (typically UHF and microwave systems) have a longer read range than those that use near field communications (typically low- and high-frequency systems).

Field programming: A tag that uses EEPROM, or non-volatile memory, can be programmed after it is shipped from the factory. That is, users can write data to the tag when it is placed on a product.

Fluidic Self-Assembly: A manufacturing process, patented by Alien Technology. It involves flowing tiny microchips in a special fluid over a base with holes shaped to catch the chips. The process is designed to mass assemble billions of RFID tags at very low cost.

Frequency: The number of repetitions of a complete wave within one second. 1 Hz equals one complete waveform in one second. 1KHz equals 1,000 waves in a second. RFID tags use low, high, ultra-high and microwave frequencies. Each frequency has advantages and disadvantages that make them more suitable for some applications than for others.

Frequency hopping: A technique used to prevent readers from interfering with one another. In the United States, UHF RFID readers actually operate between 902 and 928 MHz, even though it is said that they operate at 915 MHz. The readers may jump randomly or in a programmed sequence to any frequency between 902 MHz and 928 MHz. If the band is wide enough, the chances of two readers operating at exactly the same frequency is small. The UHF bands in Europe and Japan are much smaller so this technique is not effective for preventing reader interference.

G

Gain: See Antenna gain.

GTAG (Global Tag): A standardization initiative of the Uniform Code Council (UCC) and the European Article Numbering Association (EAN) for asset tracking and logistics based on radio frequency identification (RFID). The GTAG initiative was supported by Philips Semiconductors, Intermec, and Gemplus, three major RFID tag makers. But it was superseded by the Electronic Product Code.

H

Harvesting: A term sometimes used to describe the way passive tags gather energy from an RFID reader antenna.

High-frequency: From 3 MHz to 30 MHz. HF RFID tags typically operates at 13.56 MHz. They typically can be read from less than 3 feet away and transmit data faster than low-frequency tags. But they consume more power than low-frequency tags.

I

Inductive coupling: A method of transmitting data between tags and readers in which the antenna from the reader picks up changes in the tag's antenna.

Industrial, Scientific, and Medical (ISM) bands: A group of unlicensed frequencies of the electromagnetic spectrum.

Inlay: An RFID microchip attached to an antenna and mounted on a substrate. Inlays are essentially unfinished RFID labels. They are usually sold to label converters who turn them into smart labels.

Integrated circuit (IC): A microelectronic semiconductor device comprising many interconnected transistors and other components. Most RFID tags have ICs.

Input/output (I/O): Ports on a reader. Users can connect devices, such as an electronic eye to the input port so that when an object breaks the beam of the electronic eye the reader begins reading. Devices can also be connected to an output part, so that when a tag is read, a conveyor is turned on or a dock door opened.

Interrogator: See Reader

L

License plate: This term generally applies to a simple RFID that has only a serial number that is associated with information in a database. The Auto-ID Center promoted the concept as a way to simplify the tag and reduce the cost.

Linear-polarized antenna: A UHF antenna that focuses the radio energy from the reader in a narrow beam. This increases the read distance possible and provides greater penetration through dense materials. Tags designed to be used with a linear polarized reader antenna must be aligned with the reader antenna in order to be read.

Low-frequency: From 30 kHz to 300 kHz. Low-frequency tags typically operate at 125 kHz or 134 kHz. The main disadvantages of low-frequency tags are that they have to be read from within three feet and the rate of data transfer is slow. But they are less subject to interference than UHF tags.

M

Memory: The amount of data that can be stored on the microchip in an RFID tag.

Memory block: Memory on the microchip in an RFID tag is usually divided into sections, which can be read or written to individually. Some blocks might be locked, so data can't be overwritten, while others are not.

Microwave tags: A term that is sometime used to refer to RFID tags that operate at 5.8 GHz. They have very high transfer rates and can be read from as far as 30 feet away, but they use a lot of power and are expensive. (Some people refer to any tag that operates above about 415 MHz as a microwave tag.)

Modulation: Changing the radio waves traveling between the reader and the transponder in ways that enable the transmission of information. Waves are changed in a variety of ways that can be picked up by the reader and turned into the ones and zeroes of binary code. Waves can be made higher or lower (amplitude modulation) or shifted forward (phase modulation). The frequency can be varied (frequency modulation), or data can be contained in the duration of pulses (pulse-width modulation).

Multiple access schemes: Methods of increasing the amount of data that can be transmitted wirelessly within the same frequency spectrum. Some RFID readers use Time Division Multiple Access, or TDMA, meaning they read tags at different times to avoid interfering with one another.

Multiplexer: An electronic device that allows a reader to have more than one antenna. Each antenna scans the field in a preset order. This reduces the number of readers needed to cover a given area, such as a dock door, and prevents the antennas from interfering with one another.

N

NanoBlock: The term Alien Technology uses to describe its tiny microchips, which are about the width of three human hairs.

Near-field communication: RFID reader antennas emit electromagnetic radiation (radio waves). If an RFID tag is within full wavelength of the reader, it is said to be in the "near field." If it is more than the distance of one full wavelength away, it is said to be in the "far field." The near field signal decays as the cube of distance from the antenna, while the far field signal decays as the square of the distance from the antenna. So passive RFID systems that rely on near-field communication (typically low- and high-frequency systems) have a shorter read range than those that use far field communication (UHF and microwave systems).

Noise: Unwanted ambient electrical signals or electromagnetic energy found in the operating environment of RFID equipment. Noise can be caused by other RF devices, robots, electric motors and other machines.

Nominal range: The read range at which the tag can be read reliably.

Null spot: Area in the reader field that doesn't receive radio waves. This is essentially the reader's blind spot. It is a phenomenon common to UHF systems.

O

Object Name Service (ONS): An Auto-ID Center-designed system for looking up unique Electronic Product Codes and pointing computers to information about the item associated with the code. ONS is similar to the Domain Name Service, which points computers to sites on the Internet.

One-time programmable tag: Also called a field-programmable tag. An RFID tag that can be written to once and read many times (see WORM).

Orientation: The position of a tag antenna vis-a-vis a reader antenna. With UHF systems, readers can be either circular-polarized or linear-polarized. When using a linear polarized antenna, the tag reader and antenna reader must be in alignment in order to achieve the longest reading distance. If that tag antenna is aligned vertically and the reader is sending out signals horizontally, only a small portion of the energy emitted by the reader will hit the tag antenna.

P

Passive tag: An RFID tag without a battery. When radio waves from the reader reach the chip's antenna, the energy is converted by the antenna into electricity that can power up the microchip in the tag. The tag is able to send back information stored on the chip. Today, simple passive tags cost from U.S. 20 cents to several dollars, depending on the amount of memory on the tag and other features.

Patch antenna: A small square reader antenna made from a solid piece of metal or foil.

Penetration: The ability of a particular radio frequency to pass through non-metallic materials. Low-frequency systems have better penetration than UHF systems.

Phantom read (also called a phantom transaction or false read): When a reader reports the presence of a tag that doesn't exist.

Physical Markup Language (PML): An Auto-ID Center-designed method of describing products in a way computer can understand. PML is based on the widely accepted eXtensible Markup Language used to share data over the Internet in a format all computers can use. The idea is to create a computer language that companies can use to describe products so that computers can search for, say, all "soft drinks" in inventory.

PML Server: A server that responds to requests for Physical Markup Language (PML) files related to individual Electronic Product Codes. The PML files and servers will be maintained by the manufacturer of the item. The name PML server has been replaced by EPC Information Service.

Power level: The amount of RF energy radiated from a reader or an active tag. The higher the power output, the longer the read range, but most governments regulate power levels to avoid interference with other devices.

Programming a tag: Writing data to an RFID tag. This is sometimes called "commissioning a tag."

Protocol: A set of rules that govern communications systems. (See Air-interface protocol.)

Proximity sensor: A device that detects the presence of an object and signals another device. Proximity sensors are often used on manufacturing lines to alert robots or routing devices on a conveyor to the presence of an object. They can be used in RFID systems to turn on readers.

R

Radio Frequency Identification (RFID): A method of identifying unique items using radio waves.

Typically, a reader communicates with a tag, which holds digital information in a microchip. But there are chipless forms of RFID tags that use material to reflect a portion of the radio waves beamed at them.

Range: See read range.

Read: The process of retrieving data stored on an RFID tag by sending radio waves to the tag and converting the waves the tag sends back into data.

Reader: A device used to communicate with RFID tags. The reader has one or more antennas, which emit radio waves and receive signals back from the tag. The reader is also sometimes called an interrogator because it "interrogates" the tag.

Reader (also called an interrogator): The reader communicates with the RFID tag via radio waves and passes the information in digital form to a computer system.

Reader field: The area of coverage. Tags outside the reader field do not receive radio waves and can't be read.

Read-only tags: Tags that contain data that cannot be changed unless the microchip is reprogrammed electronically.

Reader talks first: A means by which a passive UHF reader communicates with tags in its read field. The reader sends energy to the tags but the tags sit idle until the reader requests them to respond. The reader is able to find tags with specific serial numbers by asking all tags with a serial number that starts with either 1 or 0 to respond. If more than one responds, the reader might ask for all tags with a serial number that starts with 01 to respond, and then 010. This is called "walking" a binary tree, or "tree walking." (See Singulation.)

Read range: The distance from which a reader can communicate with a tag. Active tags have a longer read range than passive tags because they use a battery to transmit signals to the reader. With passive tags, the read range is influenced by frequency, reader output power, antenna design, and method of powering up the tag. Low frequency tags use inductive coupling (see above), which requires the tag to be within a few feet of the reader.

Read rate: Often used to describe the number of tags that can be read within a given period. The read rate can also mean the maximum rate at which data can be read from a tag expressed in bits or bytes per second. (See Data transfer rate.)

Read-write tag: An RFID tag that can store new information on its microchip. These tags are often used on reusable containers and other assets. When the contents of the container are changed, new information is written to the tag. Read-write tags are more expensive than read-only tags.

RFID tag: A microchip attached to an antenna that is packaged in a way that it can be applied to an object. The tag picks up signals from and sends signals to a reader. The tag contains a unique serial number, but may have other information, such as a customer's account number. Tags come in many forms, such smart labels that can have a barcode printed on it, or the tag can simply be mounted inside a carton or embedded in plastic. RFID tags can be active, passive or semi-passive.

S

Scanner: An electronic device that can send and receive radio waves. When combined with a digital signal processor that turns the waves into bits of information, the scanner is called a reader or interrogator.

Savants: Middleware created by the Auto-ID Center to filter data from EPC readers and pass it on to enterprise systems. It was envisioned that Savants would reside on servers across the EPC Network and pass data to one another and act as a kind of nervous system for the network. The term is being phased out by EPCglobal and many of the functions of Savants are being incorporated in commercial middleware products.

Semi-passive tag: Similar to active tags, but the battery is used to run the microchip's circuitry but not to broadcast a signal to the reader. Some semi-passive tags sleep until they are awakened by a signal from the reader, which conserves battery life. Semi-passive tags can cost a dollar or more. These tags are sometimes called battery-assisted tags.

Sensor: A device that responds to a physical stimulus and produces an electronic signal. Sensors are increasingly being combined with RFID tags to detect the presence of a stimulus at an identifiable location.

Silent Commerce: This term covers all business solutions enabled by tagging, tracking, sensing and other technologies, including RFID, which make everyday objects intelligent and interactive. When combined with continuous and pervasive Internet connectivity, they form a new infrastructure that enables companies to collect data and deliver services without human interaction.

Signal attenuation: The weakening of RF energy from an RFID tag or reader. Water absorbs UHF energy, causing signal attenuation.

Singulation: A means by which an RFID reader identifies a tag with a specific serial number from a number of tags in its field. There are different methods of singulation, but the most common is "tree walking", which involves asking all tags with a serial number that starts with either a 1 or 0 to respond. If more than one responds, the reader might ask for all tags with a serial number that starts with 01 to respond, and then 010. It keeps doing this until it finds the tag it is looking for. (See Reader talks first.)

Smart label: A generic term that usually refers to a barcode label that contains an RFID transponder. It's considered "smart" because it can store information, such as a unique serial number, and communicate with a reader.

Smart cards: See Contactless smart cards.

SAW (Surface Acoustic Wave): A technology used for automatic identification in which low power microwave radio frequency signals are converted to ultrasonic acoustic signals by a piezoelectric crystalline material in the transponder. Variations in the reflected signal can be used to provide a unique identity.

Synchronization: Timing readers or reader antennas near one another so that they don't interfere with one another.

T

Tag: See RFID tag

Tag talks first: A means by which a reader in a passive UHF system identifies tags in the field. When tags enter the reader's field, they immediately communicate their presence by reflecting a signal. This is useful when you want to know everything that is passing a reader, such as when items are moving quickly on a conveyor. In other cases, the reader wants to simply find specific tags in a field, in which case it wants to broadcast a signal and have only certain tags respond. (See Reader talks first.)

Time Division Multiple Access (TDMA): A method of solving the problem of the signals of two readers colliding. Algorithms are used to make sure the readers attempt to read tags at different times.

Transceiver: A device that both transmits and receives radio waves.

Transponder: A radio transmitter-receiver that is activated when it receives a predetermined signal. RFID transponders come in many forms, including smart labels, simple tags, smart cards and keychain fobs. RFID tags are sometimes referred to as transponders.

U

Ultra-high frequency (UHF): From 300 MHz to 3 Ghz. Typically, RFID tags that operate between 866 MHz to 960 MHz. They can send information faster and farther than high- and low-frequency tags. But radio waves don’t pass through items with high water content, such as fruit, at these frequencies. UHF tags are also more expensive than low-frequency tags, and they use more power.

Uniform Code Council (UCC): The nonprofit organization that overseas the Uniform Product Code, the barcode standard used in North America.

Unique Identifier (UID): A serial number that identifies the transponder. The U.S. Department of Defense has also developed an identification scheme called UID.

Universal Product Code (UPC): The barcode standard used in North America. It is administered by the Uniform Code Council.

W

WORM: Write once, read many. A tag that can be written to only once by the user. Thereafter, the tag can only be read.

Write rate: The rate at which information is transferred to a tag, written into the tag's memory and verified as being correct.

X

XML: See eXtensible Markup Language.

XML Query Language (XQL): A method of searching a database based on the extensible markup language (XML). Files created using the Auto-ID Center's Physical Markup Language can be searched using XQL.

REFERENCES

1.) Intermec Corporation, "Supply Chain RFID: How It Works and Why It Pays", (Intermec Technologies Corporation, Everett, Washington, 2007)
2.) Arun N. Nambiar, "RFID Technology: A Review of its Applications", (Proceedings of the World Congress on Engineering and Computer Science 2009, Vol II, WCECS 2009, October 20-22, 2009, San Francisco—USA)
3.) Great Eastern Impex Pvt. Ltd, "RFID Technology" (Plot #285 Udyog Vihar, Phase II, Gurgaon—122 016 (Haryana) India--2009)
4.) RFID Journal, "RFID Business Applications", (April 14, 2010)
5.) DataFlows Dimensions, Inc., "An Overview of RFID Technology", (DataFlows Dmensions, 2007)
6.) Dr. Qinghan Xiao, "RFID Logistics Challenges and Opportunities". (Defence Research and Development Canada, Ottawa, January 26, 2010)
7.) RFID Tribe, "History of RFID Technology", March 2010)
8.) Association for Automatic Identification and Mobility, "Technologies: RFID/What is RFID?", March 2010)
9.) RFID Journal, "10 Questions to Ask RFID Vendors", (RFID Journal, LLC, 2002-2010)
10.)RFID Journal", "10 Questions to Ask Your Integrator", (RFID Journal, LLC, 2001-2010)
11.) Su-Won Yoon, Sangyoon Chin, Yea-Sang Kim, Soon-Wook Kwon, "An Application Model of RFID Technology on Progress Measurement and Management of Construction Works", (Sungkyunkwan University, Suwon 400-746, S. Korea, 2006)
12.) http://members.surfbest.net/eaglesnest/rfidhist.htm
13.) Bill Glover & Himanshu Bhatt, "RFID Essentials, O'Reilly, Copyright: 2006
14.) Dr. Jeremy Landt, "Shrouds of Time—The History of RFID", The Association of Automatic Identification and Data Capture Technologies, October 1, 2001.
15.)RFID Journal, "The History of RFID Technology"
16.)University of B.C. School of Library, Archival and Information Studies, "A History of Development—RFID Radio Frequency Identification, April 13, 2005
17.)The Eagle's Nest, "RFID: The Early Years 1980—1990, September 27, 2002
18.)The Eagle's Nest, "RFID Company Sites on the Web", August 19, 2006