

The Cutting Edge of RFID Technology and Applications for Manufacturing and Distribution

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ABSTRACT

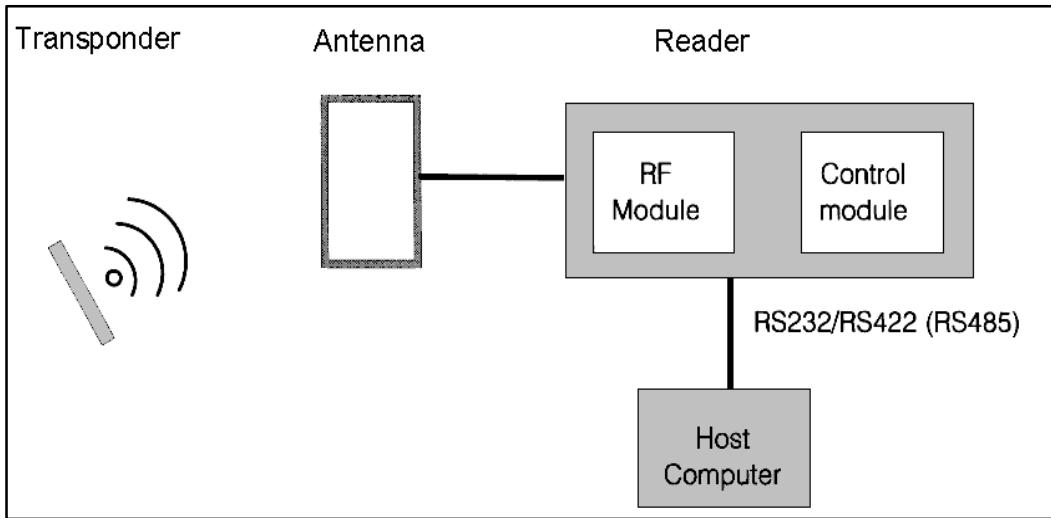
RFID (Radio Frequency ID) is a varied collection of technical approaches for many applications across a wide range of industries. As with its much simpler, older brother, bar coding, this technology used primarily for automatic data capture has the potential to significantly alter how processes occur and how companies operate. Any application of RFID needs to result in obvious business benefits. The last few years have seen several developments that have sped up the adoption of this technology. 1) The emergence of major consumer applications that bring RFID from an experimental technology into the mainstream. As it gains understanding and credibility through highly visible consumer applications that prove its effectiveness, its place as a solution in supply chain automation also grows. 2) The development of “smart labels”—a lower cost, easily integratable version of RFID tags that is beginning to take off on paths where bar codes can not travel.

This paper includes both theoretical information about RFID and real life application profiles—all intended to make clear how the technology can be applied successfully.

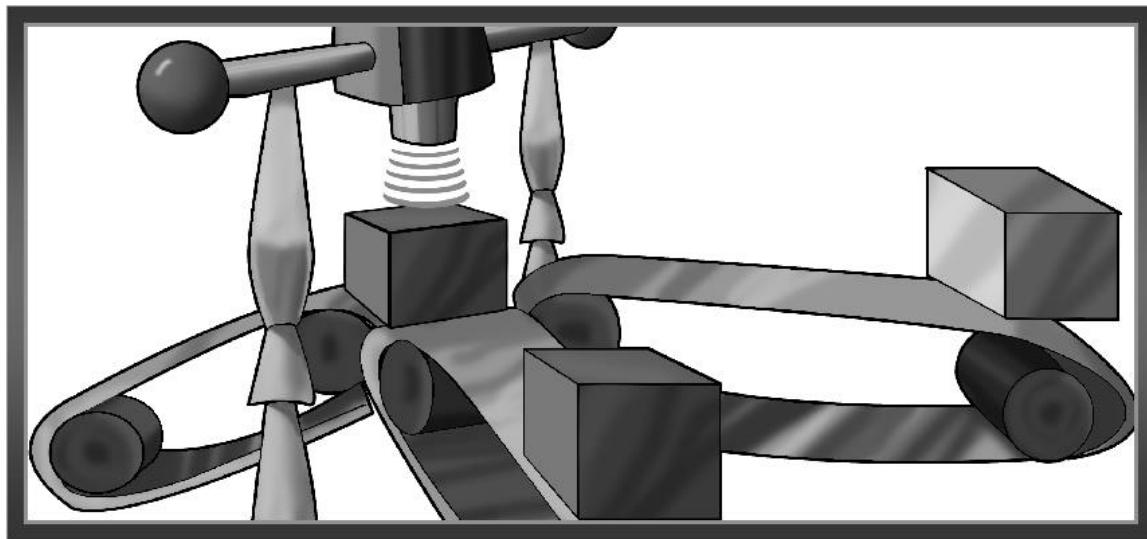
HOW RADIO FREQUENCY IDENTIFICATION (RFID) WORKS

There are a many uses of this technology around us today, although they are often invisible to users. You may find that you are already carrying and using a RFID tag, or even several. For instance, are you a MobilExxon Speedpass™ user? Do you drive a new model Ford? Have you worn a chip on your shoe while running in a marathon?

At its most basic level, RFID is a wireless link to uniquely identify objects or people. It is sometimes called dedicated short range communication (DSRC). RFID systems include electronic devices called transponders or tags, and reader electronics to communicate with the tags. These systems communicate via radio signals that carry data either uni-directionally or bi-directionally. As the following graphic shows, when a transponder enters a read zone, its data is captured by the reader and can then be transferred through standard interfaces to a host computer, printer, or programmable logic controller for storage or action.



Once a link is established with a unique ID on an item, then automation of an assortment of processes ensues.



One example is the sortation of packages moving along a conveyor system. At read points in a distribution system, the boxes can be ID'd as to their location in their path to their destination. This information can be immediately known to a central monitoring operation. It is realtime information that can be shared with the sender, with forwarders, and with the customer waiting for the shipment. The shipment can be automatically directed to the appropriate dock door, truck, carrier, etc. The shipment can be redirected while in transit if plans change; all without human intervention. This puts real time decision-making power into the hands of many functional operations up and down the supply chain.

Having this vital information readily available enables management to respond rapidly to changing patterns of demand, and allows a company to provide superior service to customers.

RFID tags come in a wide variety of size, shapes, and forms. Reader electronics can be bare boards, electronics modules, or fully enclosed boxes. Tags come with and without batteries, they can be read only or read/write. Typically, tags without batteries (passive) are smaller and lighter than those that are active, and less expensive. They are maintenance free and will last almost indefinitely.

There are more than 100 suppliers of these systems ranging from large semiconductor companies like TI, Motorola, and Philips down to 1-man entrepreneurial businesses. Today, all systems are proprietary, but standards are beginning to emerge.

Prices of tags range from 50 cents to \$150.00 depending upon features and functionality.

RFID COMPARED TO BAR CODES

- Similarly - a support tool to automate processes and to improve operations management.
 - Reduces labor, eliminates human errors.
 - Puts a wealth of data at your fingertips.

Different, in that:

- Tags can be embedded and hidden with no need for line-of-sight. They can be read through wood, plastic, cardboard, any material except metal.
- Tags can re-programmed on-the-fly.
- Applicable in harsh environments, such as outdoors, around chemicals, moisture and high temperatures.

The very popularity of barcode in many areas of the supply chain has clarified its limitations. Conventional barcodes can only hold a small amount of information, typically around 20 characters, and can't be reprogrammed. They are susceptible to damage while enroute, and always require line-of-sight to be read successfully. These are limitations that RFID tags have overcome.

APPLICATIONS IN DISTRIBUTION AND MANUFACTURING

Walking through application examples is the best way to understand the benefits of RFID.

Picking and Sortation System Within a Warehouse

Sanacorp is a German pharmaceutical wholesaler with 15 regional distribution centers serving 6000 retail drugstores. Each warehouse stocks an average of 80,000 products. The company has a service standard “to pick and prepare for delivery every customer order within one hour from receiving a phone call/fax from an individual drugstore.” Since pharmaceutical product prices are

set by government regulation in Germany , this company has chosen *service* as a competitive differentiator.

Each warehouse contains a conveyor system from start of pickline to dispatch; upon which 6000 totes are traveling in the process of putting together orders. A central database coordinates all processes. Each plastic tote represents a unique order.

The company tried barcode, but experienced a 1% error rate which meant that totes were ID'd incorrectly; leading to delays and even incorrect orders delivered.

An RFID tag is welded to the bottom of each tote. It is a read only tag with 64 bits of data that represent unique ID numbers. Antennas are located under the conveyor belt at pick locations. When an order is initiated, the unique ID of the tote is associated with that specific order in the database, and sent on its fulfillment route.

The ID code indicates “stop” or “go”, tracks orders, and detects bottlenecks.

The benefits that Sanacorp received included:

- Routine maintenance decreased dramatically.
- Errors dropped to .01%.
- Marketshare increased during last 3 years.

Mistakes in customer deliveries are expensive in terms of time and effort to fix them and in terms of damage to the customer relationship.

To get the most from RFID, there is a need for an advanced enterprise-wide information management infrastructure. The application may be designed around a centralized database or use a decentralized approach, maintaining and updating the data directly on the tag, or a combination. In any event, the IMS needs to be prepared to handle real time data quickly, and to pass it to other systems in the chain that can also use the information. Without this backbone in place, the wealth of information can go unused.



RFID data collection is only the front-end to this total solution. It provides the ability to collect large amounts of accurate data to build detailed databases.

Beer Barrel Tracking at Uerige Brewery

In addition to the big international breweries, in Germany there are many smaller but successful breweries who remain competitive through ingenuity. Uerige Brewery is one of these that has put auto ID to work for asset management and supply chain automation.

Barrels are expensive assets of a brewery's business. In this application the barrels each contain a embedded Read/Write tag that uniquely identifies them and whose memory is partitioned and can be encoded by individual page with new data along the cycle of travel from factory to customer and back to factory. Data programmed in at the factory would include: lot number, date/time of fill, use/sell by dates, Barrels are handled by several entities: factory, distributors, pubs.

At various points of dispatch and receipt, date/time are programmed into the tag. Tags can be read by stationary or hand-held readers. Ultimately, each barrel has an audit trail stored in its tag.

The benefits are:

- Manages barrel loss.
- Isolates damage to barrels.
- Compiles complete, automatic records of customer service and generates invoices.

The Frequency Bands Used for RFID

Frequency band allocation for the use of radio devices is regulated by federal agencies such as the FCC in the US, PTT in Germany, and so on. There are limitations to the bands available within which RFID systems can function. However, several bands have evolved throughout the spectrum where you find these systems in use. There are definite tradeoffs to consider for each band. Therefore, it is important to understand the application requirements before selecting a particular type of RFID system.

■ 5.8 GHz	Very high frequency
■ Europe toll standard	
■ 2.45 GHz	
■ 900 MHz	
■ US toll standard	
■ 13.56 MHz	High frequency
■ Smart cards	
■ Smart labels	
■ 125-134 kHz	Low frequency
■ LF/passive tags	
■ Livestock, auto anti-theft	

Comparing Frequencies

Low Frequency

Below 500 kHz

Short to medium range
Medium data rate
Not orientation sensitive
Reads through non-metallics
Low power levels
Inexpensive
Noise sensitive

High Frequency

Above 1 MHz

Medium to long range
Fast data rate
Orientation sensitive
Less able to penetrate
High power levels
Expensive
Not noise sensitive

The design approach to the implementation of the technology differs according to the performance requirements of the application.

Performance Requirements/Attributes

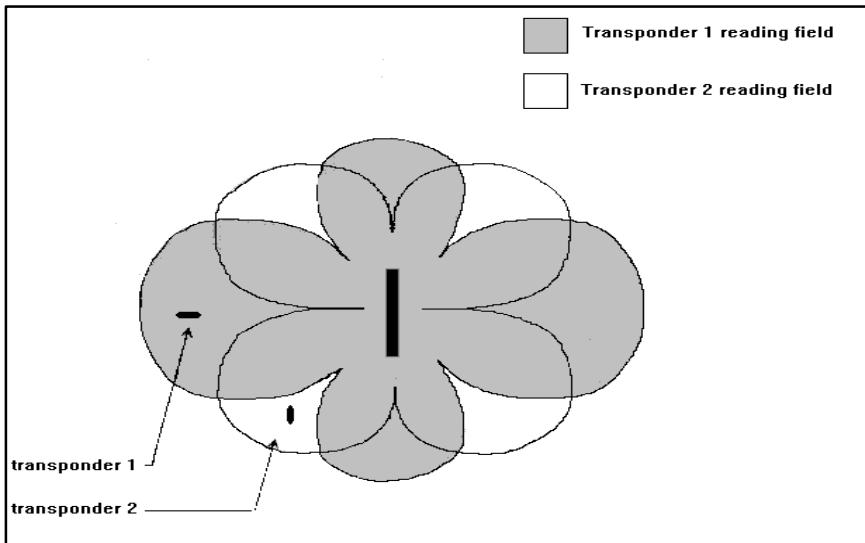
The list includes:

Read range	Penetration
Centralized vs distributed	Form factor
Memory capacity	Collision avoidance
Speed/Data rate	Security
Line-of-sight	Interoperability
Cost	

RFID Read Zones

The electromagnetic field pattern where the transponder is read is highly affected by such things as the size and shape of the readout antenna, the orientation of the transponder as it passes through the field, and other electronics in the environment. There is really an art to designing systems to suit the needs of an application.

The following illustration shows several field patterns. The black rectangle in the center represents a readout antenna. Notice the orientation of the two transponders and how their relationship to the readout antenna creates different field patterns (areas where the transponder can be read).



Production Line Tracking in a Pharmaceutical Plant

Pierrel-Ospedali is an Italian pharmaceutical company whose medical solution products are highly regulated by the government. One step in the manufacturing process requires that these products be sterilized for a period of time at over 120 degrees C. This process must be carefully controlled and documented. If there is any doubt that the sterilization process was not reliable, then full batches of bottles have to be trashed. Bottles enter the oven (autoclave) mounted on very large steel racks. Each rack is tagged with a transponder so that a rack ID number and time/date stamp can be automatically collected at the beginning and end of the process as the rack travels through the autoclave on a conveyor. Prior to installing this system, this information was collected manually allowing for human error to creep in. RFID tags can withstand the harsh environment and high temperature of the autoclave, whereas a bar code label never could.

The automation system ensures the delivery of accurate and complete records for government agencies, plus it has freed up 2 to 3 employees in the operation.

RFID Improves Chip Manufacturers Yields

A number of semiconductor companies, like Motorola, SGS Thomson, and Wacker, use RFID in their clean rooms to gain control, improve quality and operator efficiency, and increase equipment use. The need to keep everything antiseptically clean makes the use of RFID ideal, since no hands are needed for accurate data capture.

Losses and production downtime are very costly in the semiconductor industry. For instance, the production per week can be as high as 200 million chips, so any interruption or misprocessing means significant lost revenue.

In a fab clean room there can be as many as 800 locations where a wafer carrier is moved from one step to the next. On occasion, wafers do get lost by getting attached to the wrong lot. By IDing wafer carriers with an RFID tag, accuracy in processing is greatly improved.

In this application, both wafer carriers (cassettes) and employees have RFID tags (that they wear on their wrists under the "bunny suits"). At every step, both the employee's ID number and the carrier's ID number are read and verified by the host system to ensure that the correct process is followed. The production process for each lot is managed by the host system that keeps track of wafer lot, equipment, recipe, and operator. If there is not a match, then a warning signal emits and the equipment cannot be started until the correct lot is in place.

Prior to automation, this tracking had to be done by operators who scanned bar codes or keyed-in ID numbers and access codes.

The system also monitors the use of equipment to detect bottlenecks or inefficiencies.

Security Access and Convenience for Express Parcel Couriers

Federal Express, headquartered in Memphis, Tennessee, is the world's largest express parcel delivery company. FedEx delivers approximately 3.2 million parcels daily and operates a fleet of more than 42,500 vehicles worldwide.

FedEx couriers have one less thing to keep track of these days—their vehicle keys. The company's couriers use an automatic keyless entry and ignition system that has RFID transponders embedded within a velcro wristband. The system is being tested in 200 FedEx delivery vehicles.

FedEx is constantly looking at ways to streamline their delivery processes. The company's couriers drive millions of miles daily in the U.S. alone. Each time a courier makes a delivery, he/she must spend time searching for keys or use them to lock/unlock multiple doors to their vehicle. If a courier misplaces his keys, he must wait for someone from a FedEx station to bring out a spare, and the vehicle must be re-keyed at a cost of more than \$200 per incident.

With RFID, FedEx delivery personnel are freed from the hassles of juggling their keys while carrying armloads of packages and are more productive along their routes. If a wristband is misplaced, its code can be purged from the system and a new code can be reprogrammed in a matter of seconds.

The FedEx system uses RFID readers mounted at each of the four doors to the delivery vehicle and a reader mounted on the right side of the steering column near the ignition switch. When the courier places his transponder wristband within 6 inches of the readers, the transponder's code is compared to ones in the system's memory. If it is a match, the door unlocks for five seconds. The courier simply pulls on the door handle to enter the vehicle while the three remaining doors stay securely locked to prevent unauthorized entry. To start the vehicle, the courier pushes a

button on the right side of the steering column. The courier pushes another button near the start button to turn off the vehicle.

All exterior door locks can be released from the inside with conveniently located buttons. A fail-safe keyed lock is maintained for the rear roll-up door in case of an electrical failure. Anti-theft features include motion detectors in both the courier and cargo compartments, and a self-contained horn. The system is programmed to ensure that the vehicle will not start until all doors are shut, and all doors automatically lock within five seconds of opening. Each FedEx vehicle is programmed using a master transponder, and can accept up to ten unique transponders. A single transponder can also be programmed to operate multiple trucks.

RFID--Key to Container Positioning System at Port of Singapore

The Port of Singapore (PSA) tracks many thousands of multi-ton cargo containers daily, and also manages arrivals and departures of up to 50 ships. The smallest error might send a container to the wrong destination in the shipyard, resulting in delayed departures or incomplete shipments.

To avoid these problems, PSA spent close to \$910 million in 1993 on development projects. Included in this upgrade effort, was to install thousands of RFID transponders into the asphalt to create a multi-dimensional grid. A centralized EDI system manages the placement and location of containers as they are offloaded into the port shipyard, based on X, Y, Z coordinates that are derived from the unique ID codes in the tags.

Tracking Material Movement In and Out of a Warehouse

Chevrolet Creative Services uses a "red light, green light" system based on RFID to control and track the 3,500 crates coming and going from their Wixom, Michigan storage warehouse. The crates contain materials needed for specific tradeshows. RFID tags are now mounted on each crate carrying a unique ID. The bay doors are equipped with RFID readers and readout antennas are located in the floor. When a crate passes over the antenna on its way to being loaded onto a truck, the tag ID is compared to a manifest held in a host database. If the ID matches the database info—a green light signals "go" to ship the crate. A "no match" activates a red light. The database also records the time and date.

Chevrolet has realized the benefits of:

- Eliminating the human error factor inherent in their old manual system with paper manifests.
- Eliminating emergency shipping charges.
- Greater speed and efficiency and better record—keeping.

Generally, when relying on traditional systems--every time items are moved from one point to another, the pallets on which they are loaded have to be stopped to enable labels to be human read or have their barcodes scanned. With RFID tags, the information is read without the need to stop the pallets, saving time. Also, traditional systems require staff to key in information introducing errors. With tags, manpower can be reduced and errors eliminated. Tags also allow companies to

quickly trace back to where errors might have occurred, containing the damage, and in the event of a product recall, reducing risk to the consumer.

Protecting Valuable Products During Distribution

A bonded warehouse in the UK stores expensive single malt whiskies which are subject to theft even by the warehouse employees. Pallets carrying these stocks are also subject to being misplaced in error, thus delaying ontime deliveries. To prevent these problems, it was necessary to ensure that forklift trucks moving pallets would pass correctly along pre-set routes. Deviations might mean that employees were taking product off to a hiding location intentionally for later theft, or were just misplacing stock in error. To create this security system, the company built a grid of transponders suspended from the ceiling. The forklift trucks are equipped with RFID readers. Routing details are downloaded to the forklift truck from a central computer via a radio frequency communication link. This includes correct loading location, exact sequence of transponders along the route, and the delivery bay location. If the on-board reader detects deviations, the truck is immobilized and a supervisor is needed to reset the vehicle. Automatic weighing is also used in combination with the system.



RFID EVOLUTION

Although the technology is still considered young and emerging, it is based on electronics, and therefore, major breakthroughs are not only natural, but are expected. During the last several years, “smart labels” are the “buzz” in RFID. This newer version of the technology was fueled primarily by the need for lower cost tags. The plea from the user community was “if only these tags could be lower in cost (now that we are used to the low cost of bar codes), then we could attach them to many more things”. “Smart labels” represent the next generation in RFID for industries who want to uniquely identify and track millions of items at a low cost.



Features of “smart labels” include:

- Cost of tags in tens of cents range.
- Produced in very high volumes.
- Thin, flexible construction.
- Read/Write—programmable at point of issue.
- Simultaneous ID (SID).
- Easy to integrate into the barcode infrastructure.

Some of the potential applications include:

- Airline baggage tracking.
- Express parcels ID and tracking.
- Product ID and tracking from womb to tomb.
- Brand authentication.
- Document tracking.
- Library material handling.

Smart labels are easily integrated into traditional bar code labels. Many leading companies already produce smart labels, such as, Avery Dennison, Moore, and METO. Leading suppliers of bar

code printers and scanners have integrated the ability to read and program smart labels into their equipment. Some of these include Zebra, Genicom, Intermec and PSC.

Smart Labels for Material Tracking in Libraries

The 3M Digital Identification System, based on RFID smart labels, streamlines the flow of library materials in many ways. Books and other materials are identified with smart labels that carry a unique, tamperproof ID code. Librarians at the circulation desk and patrons using the 3M SelfCheck™ System read the tags with RFID readers to check items in and out. The process is faster and more accurate than with traditional optical barcode labels.

Some economic facts that help justify installing this system are:

- A lost book typically costs the library around \$45.00.
- An average library can have as many as 22 million items circulating each year.
- With RFID smart labels on items, check in and check out saves 1 1/2 minutes per transaction.

Besides the unique identification number, these labels can be programmed with additional information such as type of media and storage location. In addition, the tag is “re-writeable” so libraries don’t have to replace a book’s digital identification tag when updating a book’s status or flagging a book for reservation. Libraries are finding new ways to take advantage of tagged items, such as gathering statistics on what items are most often used.

The main goal of libraries is to improve service to their patrons particularly by having circulating items available when they are needed. RFID tracking greatly improves inventory management and optimizes resources.

RFID Tags for Document Tracking

RFID can be used for this application as a way to improve the management of important document files in industries like insurance and legal where the loss of such files can cause severe problems. RFID improves the tracking of documents so that files can be more quickly located and legal document workflow more easily tracked.

Each file is tagged with a smart label that contains a unique ID and human readable information. The file description is entered into a database along with its tracking number. The file can be assigned certain parameters like expiration date, permitted movement, persons authorized to see it, etc. Over time the database can build up an audit trail of the handling and workflow history of each document file.

Each office or desk can have a local RFID reader. These readers record when an RFID-tagged file passes by, and can include time/date stamping. The first read can indicate that a file has entered an office or desk. The second read can assume that a file has left the office or desk. This will allow any PC on the office network to click onto an entered file ID and have the system indicate the last known office or desk where the file was located, along with the specific date and

time the file was last read at that location. By also tagging employees with an RFID card, the system can record exactly who last handled a document file.

Tagging at Levels in the Supply Chain

RFID experts are now talking about an infrastructure that includes levels of tagging in the supply chain, such as:

Consumer Units – products and individual items

Traded Units – boxes/packaging/product carriers

Distribution Units – pallets/trucks

Benefits of RFID Smart Labels

Can be embedded into products. Durable in harsh environments. Produces independent unique ID. Raises the bar for fraudsters because it is orders of magnitude more difficult to duplicate.

Summary of RFID Benefits

- Offers highly reliable data collection in harsh environments.
- Eliminates manual data entry—slow and prone to errors
- Inspires new automation solutions. Fundamentally changes how processes are managed and how businesses operate. Causes a paradigm shift.
- Good information management structure is a MUST.