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White
Paper

SUPPLY CHAIN RFID: HOW IT WORKS AND WHY IT PAYS

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SUPPLY CHAIN RFID: HOW IT WORKS AND WHY IT PAYS

Radio frequency identification (RFID) is one of the most promising and anticipated technologies in recent years. Magazine articles, television shows, analyst papers and the like are frequently trumpeting the potential benefits to users of RFID. This white paper will help you to understand what RFID is, how it works, describe the current standard and compliance environment and some considerations to make sure that you have a successful implementation and get the most from your investment. The stakes for RFID implementations are high – for both expenditures and benefits. Arming yourself with a good understanding of the technology and important considerations can ensure that the decisions that you make minimize any missteps and maximize your experience.

Manufacturers, retailers, logistics providers and government agencies are making unprecedented use of RFID technology to track, secure and manage items from the time they are raw materials through the entire life of the product. Manufacturers can especially benefit from RFID because the technology can make internal processes more efficient and improve supply chain responsiveness—for example, early RFID adopters in the consumer goods industry reduced supply chain costs between 3 and 5 percent and grew revenue between 2 and 7 percent because of the added visibility RFID provided, according to a study by AMR Research.

Many drivers have seen RFID in action at automatic toll collection stations used at bridges, tunnels and turnpikes. In business, RFID will be commonly used to identify pallets, containers, vehicles, tools and other assets, monitor inventory, and route materials through production processes.

RFID can provide immediate and tangible benefits throughout the supply chain. Organizations who take the time to understand the technology's capabilities and limitations can increase their inventory visibility while streamlining their operations.

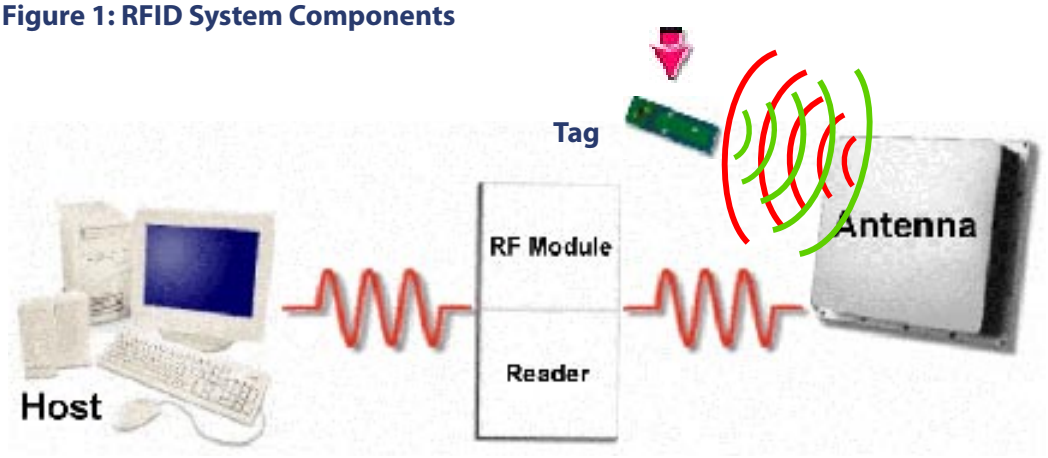
Technology Overview

RFID wirelessly exchanges information between a tagged object and a reader/writer.

An RFID system is comprised of the following components (Figure 1):

- One or more tags (also called transponders), which includes a semiconductor chip and antenna;
- One or more read/write devices (also called interrogators, or simply, readers);
- Two or more antennas, one on the tag and one on each read/write device;
- Application software and a host computer system.

Figure 1: RFID System Components



Source: QED Systems

Radio waves are used to transfer data between the RFID tag (transponder) and the read/write device (interrogator), which are tuned to the same frequency. The interrogator sends out a signal, which is received by all tags tuned to that frequency that are present in the RF field. Tags receive the signal with their antennas, and selected tags respond by transmitting their stored data. The tag can hold many types of data about the item, such as its serial number, configuration instructions, what time the item traveled through a certain zone, even temperature and other data provided by sensors.

The read/write device receives the tag signal with its antenna, decodes it and transfers the data to the host computer system. RFID tags can be attached to virtually anything – from a semi tractor, to a pallet, to a case, to an item on a store shelf. If multiple tags are present in the field, more efficient RFID implementations have anti-collision algorithms, which determine the order of response so that each tag is read once and only once.

Tags (Transponders)

RFID tags must have two basic elements: a computer chip and an antenna. The chip and antenna are mounted onto an insert (Figure 2). This is then encapsulated with the appropriate material to form a finished tag or label (Figures 3,4).

Figure 2: RFID Tag Components

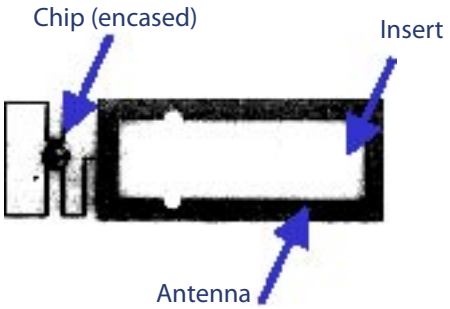


Figure 3: Finished Tag – Pallet Tag

Various types of tags are needed for use in different environmental conditions. For example, tags that perform well when attached to cardboard cases are not the best choice for wooden pallets, metal containers or glass. Tags may be as small as a grain of rice, as large as a brick, or thin and flexible enough to be embedded within an adhesive label and run through a bar code label printer. Tags also vary greatly by their performance, including read/write ability, memory and power requirements.

Depending upon the application and environment, RFID tags have a range of durability. Paper-thin labels, often referred to as "smart labels" are typically used for disposable applications and, as such, are not as durable (Figure 4). Many tags are used for permanent identification applications and can be encased in materials to withstand extremely high heat, moisture, acids and solvents, paint, oil and other conditions that make text, bar code or other optical-based identification technologies unusable in the environment. RFID tags can be reusable and suitable for lifetime identification, which can provide a total cost of ownership (TCO) advantage over bar code labels or other identification methods that are disposable and need periodic replacement.

Figure 4: Finished Tag – "Smart Label"

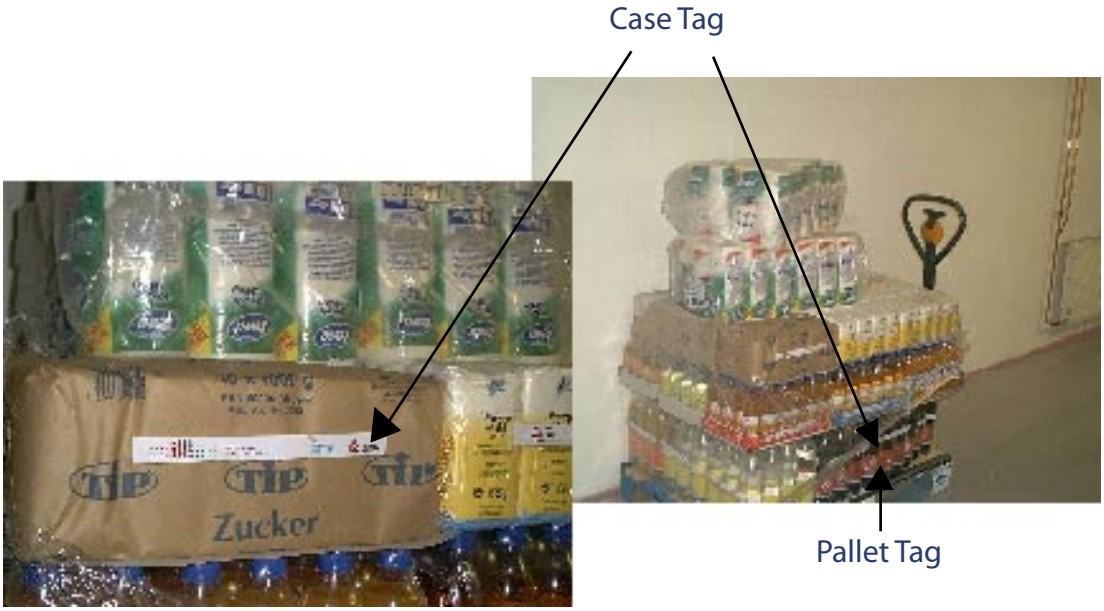
Tags are either passive, active or battery assisted. Passive tags receive their power to exchange data from the signal sent by the reader. Active tags have a battery to power their own transmissions. Battery assisted tags have a battery that powers chip electronics but does not transmit RF energy.

Most current and proposed consumer goods logistics and retail RFID applications can be satisfied with passive tags, which are less expensive and smaller than active versions because they do not require a battery. Active tags are the best selection when the most important consideration is to be able to read the tags at the longest possible distance.

Just like compact disks, RFID tags can be read-only or read-write. Read-only tags are programmed with a serial number or other data at the factory and cannot be altered. Data on read/write tags can be revised or erased thousands of times by the user. Read/write tags are often partitioned with a secure, read-only area that may encode a unique ID number, and a writeable portion of memory that users can program and reprogram themselves. One application for this technology is to permanently encode a pallet ID number in read-only memory and to use the read-write blocks to record items that have been loaded onto the pallet. When the pallet is unloaded the writeable section can be erased and made available for new information when the pallet is reused. Companies or departments throughout the supply chain can also take advantage of the writeable portion of tag memory to add data to support their own business operations.

Writeable tags can also be interfaced with sensors to capture and record variable information. For example, a frozen foods producer may apply RFID tags to pallets and interface them with a temperature sensor to monitor temperatures during shipment or storage. The system could be set to sound an alarm if temperatures moved outside of the pre-set acceptable range. Temperature sensors could also be used to automatically provide documentation that materials were kept at required temperatures. Sensor applications often use battery-assisted tags and power for the sensor.

Figure 5: Case and Pallet Tags

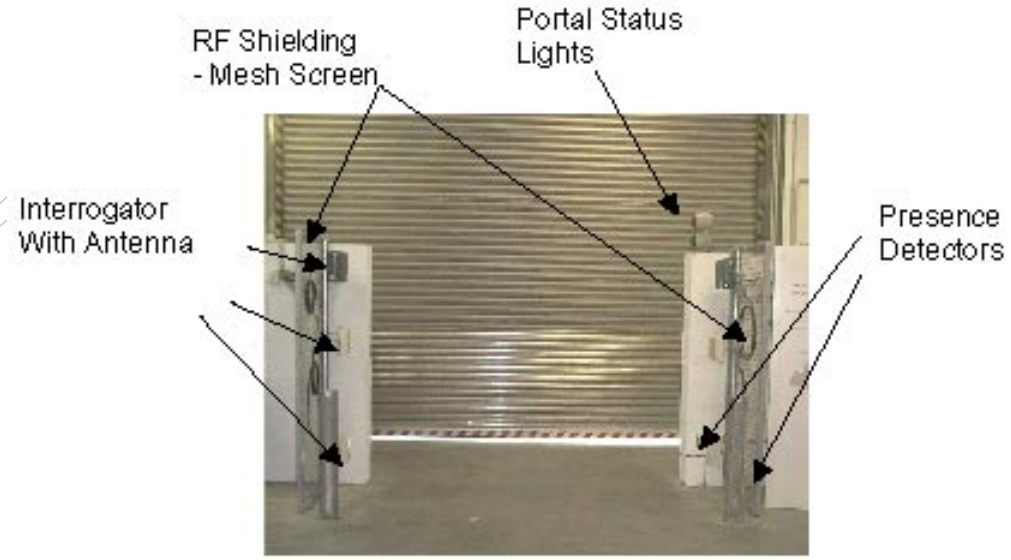


With read/write RFID technology, users are in control of their applications and their technology investments. When customer requirements, application needs or standards change, users can update their system while preserving their initial technology investment. For example, suppose a retailer required suppliers to identify their pallets with a 10-digit serial number, then changed its requirement to a 12-digit number, or an alphanumeric data string. Suppliers using read/write tags could comply with the new requirement with minimal cost or disruption to business by writing the new information to their existing pallets. Suppliers using read-only would have to purchase new tags for each pallet, apply them and remove the old tags to ensure they wouldn't be read by the retailer. Any initial cost savings gained by the initial purchase of read-only tags would be dwarfed by the materials and labor costs required to refit the pallets. For more information about read/write technology and applications, see Intermec's white paper **The Write Stuff: Understanding the Value of Read/Write RFID Functionality.**

Reader/Writer Options

Because direct line of sight between the reader and tags is not necessary, there are many more placement options for RFID readers than were possible with bar code labels. Readers can be either placed in a fixed-position or be portable, just like bar code scanners. Fixed-position readers can be mounted to read items traveling through dock doors, conveyor belts, loading bays, gates, doorways and other areas. Readers may also be attached to lift trucks and other material handling equipment to automatically identify pallets and other items that are being moved. Interrogator capabilities have also been engineered to now be able to fit into smaller mobile devices.

Figure 6: Dock Door Fixed Mount Interrogator



Smaller footprint interrogator devices, such as those in PC Card format or handheld add-on devices can be used to enable users to add RFID capabilities to their existing applications without having to reinvest in entirely new mobile computing systems (Figure 7). Portable interrogators can also be connected to fixed or mobile computers like a forklift mounted PC, a handheld computer, a desktop computer or a laptop. These portable interrogators can be connected either wirelessly or tethered with a wire cable (Figure 8). Mobile RFID interrogators allow users to read and write to tags that may be in remote locations or where it is not feasible or prudent to install fixed–position readers. The RFID interrogators can also include or be used with bar code scanners to address applications or environments where both technologies are needed.

Figure 7: PC Card and Handheld Clip-on Interrogators

Figure 8: Portable Interrogators

"Smart label" tags are typically initially programmed by special printers that have the capability to print bar codes or other visible information on the paper outside of the label while also writing to the memory located on the RFID chip inside the label.

Figure 9: "Smart Label" Printer

PERFORMANCE FEATURES

Radio frequency is not an optical technology and does not require line of site between the tag and reader, which is an important distinguishing feature that gives RFID many performance advantages compared to bar code and other automatic identification technologies. As RFID is a radio based technology, performance considerations for its implementation are that 1) RFID can be susceptible to interference from other radio transmissions and metal 2) some materials absorb RF signals more readily than others 3) sensitivity to interference varies by frequency and the usage environment. These factors can impact the tag read/write range and speed that is seen. Most scenarios can be handled by using the proper specific tags, readers and applications.

Because no line of sight is required, RFID-tagged objects can be read in different orientations at very high speeds. Orientation sensitivity depends on the antenna design and the amount of interference that is present. In some environments tags may be read in any orientation. This gives product and package designers tremendous flexibility in tag placement options, and eliminates the need for human intervention to scan labels or to ensure items are placed properly for reading in conveyor belt or retail checkout applications.

RFID is a flexible technology that is convenient, easy to use and well-suited for automatic operation. It combines advantages not available with other identification technologies: RFID can be supplied as read-only or read/write; does not require contact or line-of-sight between the reader and the object to be identified; can function in harsh environments; enables multiple tags to be read simultaneously; and provides a high level of data integrity. RFID can also provide security and product authentication because tags can be applied discreetly and are extremely difficult to counterfeit.

Some vendors offer systems that can be programmed to search for specific tags within a field. This functionality, called "group select," improves processing speed because only the tags of interest are identified and read, other tags in the field can be ignored. Group select is extremely valuable for logistics and retail operations. For example, distribution center workers could use mobile RFID readers to search dozens of cartons from an incoming shipment and locate the specific items needed to cross dock. Retailers receiving mixed-load shipments could locate hot selling products and promptly place them on the shelves before the rest of the shipment was unloaded.

RFID's ability to read and write to tags automatically, every second could easily produce enough data to overwhelm an information system. Properly analyzing the specific data and timing that is needed for processes and systems is critical. Planning a successful RFID implementation also requires more than extensive knowledge of RFID technology. The enterprise and its technology partners need knowledge and real experience with other data collection technologies, mobile computing, industrial and wireless networking, manufacturing and distribution processes and enterprise software.

Security

It is extremely difficult to counterfeit radio frequency identification chips. A hacker would need specialized knowledge of wireless engineering, encoding algorithms and encryption techniques. Different levels of security can be applied to data on the tag, so information could be readable at some points of the supply chain but not others. RFID is very valuable as an authentication technology as well as an identification technology, and some consumer goods manufacturers are embedding it into their products to fight counterfeiting and diversion.

Range

A RFID system's "read range" — the distance a reader antenna must be from the tag in order to read the information stored on its computer chip — varies from a few centimeters to tens of meters, depending on the frequency used, power output, whether a tag is active or passive, and the directional sensitivity of the antenna. The presence of metal and liquids also affects range and read/write performance because these materials may cause interference. For read/write tags, the read range is typically greater than the write range. Active tags are capable of much longer ranges than passive tags. For example, 433MHz active tags can transmit data about 300 feet, but passive tags at the same frequency are typically readable from up to 25 feet.

Frequency

Frequency is one of the leading factors that effects range. Virtually all RFID systems used today fall into one of four frequency bands, which are described in Figure 10.

Figure 10: Common RFID Frequencies and Passive Ranges

Frequency Band	Description	Range
125 – 134 KHz	Low frequency	To 18 inches
13.553 – 13.567 MHz	High frequency	3 -10 feet
400 – 1000 MHz*	Ultra-high frequency (UHF)	10 - 30 feet
2.45 GHz	Microwave	10+ feet

* Most RFID systems in the UHF band operate between 860 and 930 MHz.

No single frequency is ideal for all applications, even within a single industry. Just as separate bar code symbologies are used at different levels of consumer goods packaging, from U.P.C./EAN symbols at the item level to Code 128 and two-dimensional symbologies on cases and pallets, RFID tags of different frequencies and functionality will be used together within overall supply chain operations. Current logistics and supply chain applications tend to use the UHF band, either between 860 and 930 MHz or 13.56 MHz.

Standards

Standards initiatives for logistics and item-level tracking also specify these frequencies. Major retailers are basing RFID supplier tagging requirements on the proposed Electronic Product Code (ePC) specifications that were developed at the MIT Auto-ID Center (and are now managed by EAN International and the Uniform Code Council through ePC Global) See Figure 11 for a summary of RFID standards of interest for supply chain and item tracking applications.

Figure 11: Supply Chain-Related RFID Standards Activity

Specification	Description	Sponsor	Frequency	Status
ePC UHF Class 0	64 bit factory programmed (e.g. Read Only)	ePC Global	900 MHz	Draft specification
ePC UHF Class 1 Version 1	96/128 bit One-Time-Programmable (OTP)	ePC Global	860 - 930 MHz	Draft specification
ePC UHF Generation 2	96/128 bit One-Time-Programmable (OTP)	ePC Global	860-960 MHz	Draft specification
ePC HF Class 1	96/128 bit One-Time-Programmable (OTP)	ePC Global	13.56 MHz	Draft specification
ANSI MH10.8.4	Returnable Transport Item – RTI (e.g. RPC)	ANSI	902 - 928 MHz	Approved - Published
AIAG B-11	Tire & Wheel ID	AIAG	862 - 928 MHz; 2.45 GHz	Approved - Published
ANS INCITS 256	Item Management	INCITS	13.56 MHz; 902 - 928 MHz; 2.45 GHz; 433 MHz	Approved – First revision published
ISO 18185	Cargo seals	ISO	433 MHz; 860 – 930 MHz	Committee Draft – in review
ISO/IEC 18000 Part 2	Item Management	ISO/IEC	<135 kHz	Final Draft International Standard (FDIS) ballot
ISO/IEC 18000 Part 3	Item Management	ISO/IEC	13.56 MHz	FDIS ballot
ISO/IEC 18000 Part 4	Item Management	ISO/IEC	2.45 GHz	FDIS ballot
ISO/IEC 18000 Part 6	Item Management	ISO/IEC	860 - 960 MHz	Final Committee Draft (FCD)

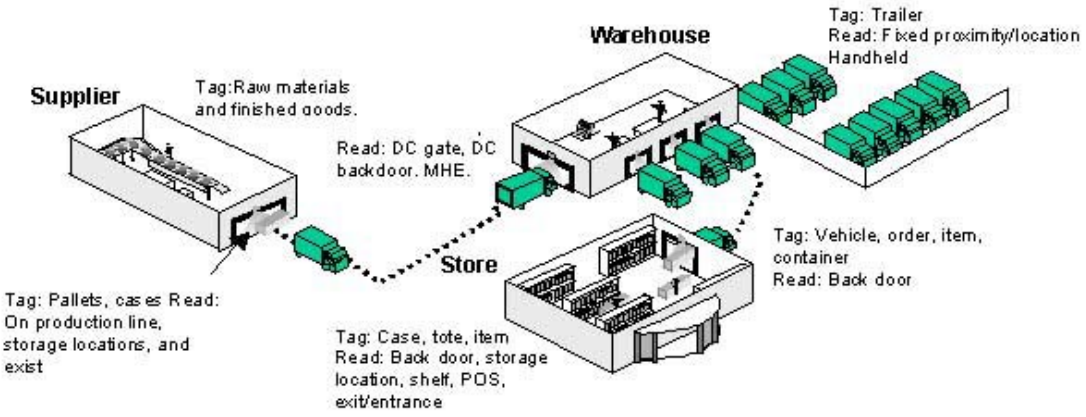
APPLICATIONS

The different available frequencies, tag and reader designs give users many choices to consider when planning an RFID application. Finding the right combination of features is fairly straightforward once users begin planning their applications and develop an understanding of their needs and goals. The following section will provide an overview of how common RFID applications work, the functionality they require and the benefits they provide.

Many highly effective applications can take advantage of existing data collection systems and processes and enhance them with RFID for operations where more functionality is needed. This approach fully leverages existing technology and successful systems, which makes the return on investment for RFID easier to measure and faster to attain. For unit-level identification at some points in the supply chain, bar code systems provide excellent performance and are still the most cost-effective option. Bar code technologies have some limitations and are not as advantageous at other packaging levels, so carton, case and pallet processing applications provide many opportunities to complement bar code systems with RFID.

All segments of the supply chain can take advantage of RFID technology. Retailers in general merchandise, grocery, apparel and other categories are piloting RFID programs and reporting improved sales from greater stock availability, cost savings and increased responsiveness, especially in receiving and inventory control operations. As these applications continue to prove their value, more retailers are expected to announce compliance tagging requirements, so many manufacturers may find themselves being asked or required by a retail customer to apply RFID tags to shipments. See Figure 12 for a high level view of an RFID enabled supply chain.

Figure 12: RFID Use in the Consumer Goods Supply Chain



Source: IBM Business Consulting Services analysis, Auto-ID Center

Many of the same benefits retailers and distributors are attaining are available to manufacturers who take advantage of tagged shipments in their own business processes. Manufacturers can benefit most by applying RFID tags to cases and shipping containers, especially reusable assets like pallets, reusable plastic containers (RPCs), kegs, totes and gas cylinders. RFID tags placed on these items may be reused hundreds of times, which leverages the initial tag cost to provide a very attractive total cost of ownership. Tagging at this level also sets the foundation for numerous labor-saving automated routing, receiving, shipping and inventory control applications, which are highly accurate and improve asset visibility. These benefits enable manufacturers to reduced their fixed assets between 1% and 5% and cut working capital between 2% and 8% because of better asset utilization, according to studies conducted by AMR Research and sponsors of the Auto-ID Center. Here are a few of the ways RFID can save time, reduce labor and improve item visibility from production through delivery to the retail store.

Asset management

RFID tags can be permanently attached to capital equipment and fixed assets including pallets, RPCs, cylinders, lift trucks, tools, vehicles, trailers and equipment. Fixed position readers placed at strategic points within the facility can automatically track the movement and location of tagged assets with 100 percent accuracy. This information can be used to quickly locate expensive tools or equipment when workers need them, eliminating labor-wasting manual searches. Readers can be set to alert supervisors or sound alarms if there is an attempt to remove tagged items from an authorized area.

By tracking pallets, totes and other containers with RFID, and building a record of what is stored in the container as items are loaded, users can have full visibility into inventory levels and locations. With visibility and control, manufacturers can easily locate items necessary to fill orders and fulfill rush orders without incurring undue managerial or labor time.

RFID tags or labels on pallets, cylinders, RPCs and other shipping containers can be automatically read at the dock door as they leave with an outgoing shipment. By matching the reading with specific shipment information in a database, manufacturers could automatically build a record of what specific shipping containers were sent to each customer. This information could be used to document cycle times, improve returns and recoveries and aid in disputes with customers about lost or damaged assets. Chep, the world's largest pallet pooling company, is applying RFID tags to the 250 million pallets it manages to gain the automated tracking benefits. Applications like these enable manufacturers to lower their asset base and realize some of the cost savings identified in the Auto-ID Center and AMR Research studies. For more information about this application, see the Intermec white paper **Radio Frequency Identification for Tracking Plastic Pallets and Reusable Containers.**

Production Tracking

The Auto-ID Center study found manufacturers can reduce their working capital needs between 2% and 8% by taking advantage of RFID to provide greater visibility into work-in-process tracking and materials inventory. By applying RFID tags to subassemblies in the production process, rather than to finished goods, manufacturers can gain accurate, real-time visibility into work-in-process in environments where bar codes are unusable. Industrial control and material handling systems can integrate with RFID readers to identify materials moving down a production line and automatically route the items to the appropriate assembly or testing station. This capability, which requires no human intervention to look up item serial numbers or other identification marks, provides the accuracy and labor savings needed to efficiently execute complex sequencing and make-to-order production.

Inventory Control

The main benefits to using RFID in the supply chain come from improved inventory tracking, especially when the technology's capabilities are used to collect information and provide visibility in environments where tracking was not done before. Manufacturers, distributors, logistics providers and retailers can all use RFID for inventory applications, and in carefully planned systems, may share the same tags to reduce implementation costs. Because it can be read through packaging, without concern to orientation, without direct line of sight between object and reader and can withstand exposure to dirt, heat, moisture and contaminants that make bar codes unusable, RFID can remove blind spots from inventory and supply chain operations.

By using the highly accurate, real-time and unattended monitoring capability of RFID to track raw materials, work-in-process and finished goods inventory manufacturers can improve visibility and confidence into their inventory to enable overall inventory levels, labor costs and safety stocks to be reduced. Readers covering warehouse racks, shelves and other storage locations could automatically record the removal of items and update inventory records. If an item was misplaced or needed urgently to complete an order, fixed-position readers or a worker with a mobile computer and RFID reader could automatically search for the item by reading for its specific ID number.

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To secure inventory from theft and diversion, readers could be set to sound alarms or send notification if items are placed in unauthorized areas of the facility or removed from storage without prior approval. An Auto-ID Center study found consumer goods manufacturers would reduce shrink (inventory loss) by an estimated 10 percent by implementing secure storage areas.

Direct store delivery (DSD) and other remote sales and service personnel could take advantage of RFID readers integrated with mobile computers to quickly and accurately count inventory held in stores or in the vehicle. The automated counting would save significant time in the field, enabling representatives to visit more customers in a day. For field service applications, permanent asset tags applied to equipment could store its ID, configuration and service history information to ensure accurate and appropriate service is performed in the field where access to a central records database may be unavailable.

Shipping & Receiving

The same tags used to identify work-in-process or finished goods inventory could also trigger automated shipment tracking applications. Items, cases or pallets with RFID tags could be read as they are assembled into a complete customer order or shipment. The individual readings could be used to automatically produce a shipment manifest, which could be printed in a document, recorded automatically in the shipping system, encoded in an RFID tag, printed in a 2D bar code on the shipping label, or any combination. For example the Serial Shipping Container Code (SSCC) data structure, which is commonly used in bar codes on shipping labels, could be encoded into RFID to facilitate automated handling. The new RFID application could be very effectively integrated into existing business processes because it takes advantage of data structures that are already supported in enterprise databases and software applications.

Manifest information encoded in an RFID tag could be read by the receiving organization to simplify the receiving process and to satisfy requirements like those for advance shipping notices (ASN), so there would not be processing delays if the physical shipment arrived before the electronic data interchange (EDI) transmission with the ASN information.

Having complete shipment data available in an RFID tag that can be read instantly without manual intervention is very valuable for cross dock and high-volume distribution environments. Incoming shipments can be automatically queried for specific containers. If a sought-after item was present, it could be quickly located and selected.

Regulatory Compliance

Companies that transport or process hazardous materials, food, pharmaceuticals and other regulated materials could record the time they received and transferred the material on an RFID tag that travels with the material. Updating the tag with real-time handling data creates a chain-of-custody record that could be used to satisfy FDA, DOT, OSHA and other regulatory reporting requirements. RFID tags are also an effective way to satisfy the tire traceability requirements of the TREAD Act.

Returns & Recall Management

Companies could supplement the basic shipment identification information by writing the specific customer and time of shipment to the tag immediately prior to distribution. Producing and recording this information would provide several benefits. In the event of a recall, companies could trace specific shipments to specific customers, which would enable a highly targeted notification and return operation and avoid a costly general recall. For general returns, companies could verify that the customer returning merchandise is actually the customer who received it, which would deter diversion, counterfeiting and other forms of return fraud.

Service and Warranty Authorizations

Authenticating the product and customer with proprietary information could also be used to authorize warranty and service work. Upon completion of repairs or service, a record of the activity performed could be encoded on the tag to provide a complete maintenance history that travels with the item. If future repairs or service are required, a technician could access the item's complete maintenance and configuration information without accessing a database simply by reading the tag. This application ensures workers have necessary information if no database access is available, and eliminates the need and expense of making phone calls or wireless data inquiries to access records.

Conclusion

There is no reason to wait to take advantage of RFID technology and its benefits. The technology is mature in many applications, highly functional and supported by current and emerging standards. Companies in all segments of the supply chain are proving the business value of RFID every day. With the help of an experienced partner to help plan business process changes, select the best tag designs, frequencies and equipment options, and implement and support the system, your company can use RFID to improve your accuracy, speed and responsiveness.

Intermec Technologies offers a complete range of services and products to help organizations evaluate if they could benefit from RFID and how it could be integrated into business processes. Intermec is a leader in RFID technology and standards development with extensive experience helping manufacturers, distributors, logistics providers, retailers, service companies and other businesses implement complete data collection systems. Our products include the Intellitag® family of RFID tags and read/write devices, the Intellitag RFID Online Assessment Tool, which leads the user through a targeted assessment to determine if RFID-based technology is a good fit for their company, and Intellitag Ready-To-Go Retail RFID, an integrated package of hardware, software and professional services designed to give companies everything they need to develop a pilot application for RFID pallet and case tracking. Intermec also offers a complete line of industrial data collection and computing products and services. Products include bar code readers and printers, wireless networking equipment, rugged handheld computers, vehicle-mounted and stationary industrial computers. Intermec systems support RFID and other data input and networking options plus related software and peripherals. Intermec has been helping companies profit by taking advantage of data collection technologies for more than 35 years. Visit us today at www.intermec.com to learn more about how Intermec can help you prepare for RFID.

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