White paper

ABCs of RFID: Understanding and using radio frequency identification

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Introduction

Radio frequency identification (RFID) is one of the fastest growing and most beneficial technologies being adopted by businesses today. Adoption of this automatic data-collection (ADC) technology has recently been fueled by the establishment of key standards, retailer and government mandates, improved technology performance and falling implementation costs. RFID offers great value for many industries and applications. However, misperceptions about what RFID is and what it can do pose obstacles that discourage some organizations from taking advantage of the technology.

This white paper provides an overview of RFID technology and capabilities, describes the common frequencies and technologies used in business applications, identifies major standards, and introduces ways to take advantage of RFID to improve convenience, accuracy, safety and security.

"RFID" describes a class of technology that exchanges data wirelessly. Data is written to and read from a chip attached to an antenna that receives RF signals from a read/write device—commonly called a reader, encoder or interrogator. Data is exchanged automatically, with no operator intervention required to trigger an RFID read.

RFID offers several notable advantages over other forms of data collection:

- RFID enables monitoring and data collection in environments unfit for workers, because tag reading requires no labor.
- More than a thousand reads can be performed each second, providing high speed and great accuracy.
- The data on an RFID tag can be altered repeatedly.
- RFID does not require direct line of sight between tag and reader, making it suitable for many applications where bar codes are not viable.
- Thousands of organizations in many industries have exploited RFID's advantages to develop operations that monitor processes, provide real-time data accuracy, track assets and inventory, and reduce labor requirements.
- RFID technology can be used in conjunction with bar-code systems and Wi-Fi networks.

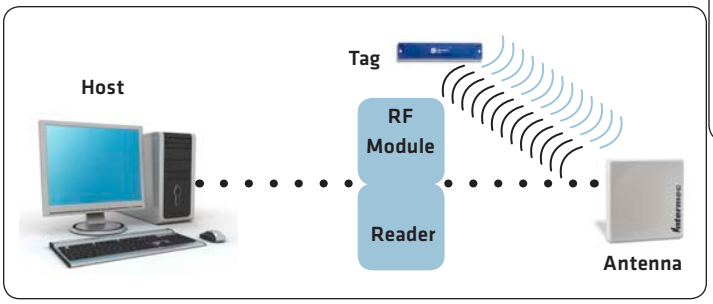

Figure 1: RFID System Components

How RFID Works

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 consist of a semiconductor chip and antenna.
- One or more read/write devices (also called interrogators, or simply, readers).
- Two or more antennas, one or two on the tag and at least one on each read/write device.
- Application software and a host computer system.

Tags are usually applied to items, often as part of an adhesive bar-code label. Tags can also be included in more durable enclosures and in ID cards or wristbands. Readers can be unattended standalone units (such as for monitoring a dock door or conveyor line), integrated with a mobile computer for handheld or forklift use or incorporated into bar-code printers.

The reader sends a radio signal that is received by all tags present in the RF field tuned to that frequency. Tags receive the signal via their antennas and respond by transmitting their stored data. The tag can hold many types of data, including a serial number, configuration instructions, activity history (e.g., date of last maintenance, when the tag passed a specific location, etc.), or even temperature and other data provided by sensors. The reader receives the tag signal via its antenna, decodes it and transfers the data to the computer system through a cable or wireless connection.

The following sections provide more details about RFID tags, readers, printers and performance.

Tags (Transponders)

RFID tags have two basic elements: a chip and an antenna. The chip and antenna are mounted to form an inlay (figure 2). The inlay is then encapsulated in another material to form a finished tag or label (figure 3).

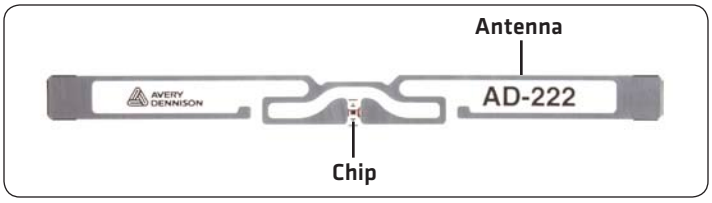

Figure 2: Inlay—RFID Tag Components

Figure 3: Finished Rigid Tags and Smart Label

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 thin and flexible enough to be embedded within an adhesive label. Tags also vary greatly in performance, including read/write ability, memory and power requirements.

Paper-thin labels referred to as "smart labels" usually serve single-use applications, such as 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 satisfy most RFID compliance tagging requirements for cases and pallets.

RFID tags also range in durability, depending upon the application and environment. Tags for permanent identification may be encased to withstand extreme temperatures, moisture, acids and solvents, paint, oil and other conditions that impair text, bar codes or other optical-based identification technologies. RFID tags can be made reusable and suitable for lifetime identification, thus yielding a total-cost-of-ownership (TCO) advantage over bar-code labels and other disposable/impermanent identification methods.

RFID tags can be either read-only or read-write (though the latter is now standard). Read-only tags are programmed at the factory with a serial number or other unalterable data. Data on read/write tags can be revised thousands of times. Read/write tags are often partitioned with a user-defined secure read-only area that may contain a unique ID number and a writeable portion of memory that users can freely reprogram. Thus a user may permanently encode a pallet ID number in read-only memory and then use the read-write bank(s) to record items loaded onto the pallet. Then once the pallet is unloaded, the writeable section can be erased for reuse.

Tags are also classified as passive, semi-passive or active. Passive tags, by far the most common, receive transmission power from the reader. All RFID smart labels are passive. Active tags include a battery to power transmissions, which also provides a longer range. This makes active tags larger and more expensive than passive tags. Semi-passive tags communicate like passive tags, but also have a battery. Their range falls between passive and active, and though their batteries have a long life, their size is comparable to passive tags.

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 must use battery-assisted tags and power for the sensor.

Reader/Writer Options

RFID devices allow pronounced flexibility for placement because, unlike bar-code readers, direct line of sight is not necessary and read ranges can be extensive. And the ultrahigh frequency (UHF) band used in many commercial RFID systems can provide a read range of more than 30 feet (10 meters).

Fixed-position readers can be mounted to read items traveling through dock doors, conveyor belts, loading bays, gates, doorways and other areas (Figure 4). Readers may also be attached to lift trucks and other material handling equipment to automatically identify pallets and other items that are being moved. Mobile readers can be integrated with mobile computers for easy hand held use.

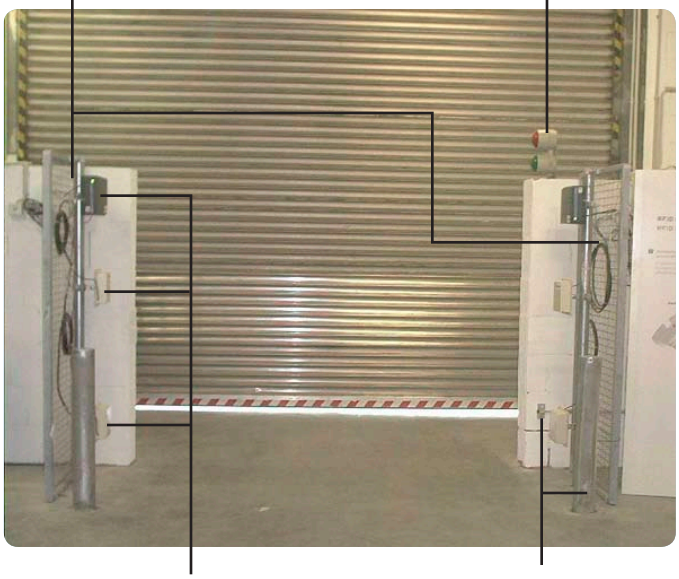

Figure 4: Dock Door Fixed Mount Reader and Portal

RFID systems can also function simultaneously with wireless networks, and are often integrated with wireless LANs to exchange data with host computer systems–Wi-Fi LANs do not cause interference for RFID systems. (Older, proprietary 915MHz wireless networking equipment can interfere with UHF RFID systems, but few of these devices are still in use.)

The ease with which RFID can be integrated into current operations depends on the openness and flexibility of the technology infrastructure, especially the mobile computers and wireless LANs that will be used to collect and communicate RFID data. One way to maintain flexibility is to use mobile computers with card slots, peripheral ports and other expansion options that can be used to add RFID capability without sacrificing other functions.

Smaller readers, such as those designed to work with handheld computers, can enable users to add RFID capabilities to their existing applications without having to reinvest in entirely new systems (Figure 5). Mobile RFID readers 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 reader can also be used with bar code scanners to address applications or environments where both technologies are needed.

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Figure 5 – Portable Handheld RFID Readers

One of the most desirable implementations for RFID readers is mounting them on fork lifts (Figure 6, shown with multiple antennas). The advantage to forklift mounted readers is that there are typically fewer forklifts in a facility than dock doors, so fewer readers are needed to cover a facility. Forklift mounted systems are also portable so that they can go to wherever they are needed.

Figure 6 – Forklift Mounted RFID Systems

"Smart label" tags are typically initially programmed by printers (Figure 7) that have the capability to print bar codes or other visible information on the paper side of the label while also writing to the memory located on the RFID chip inside the label.

Figure 7 - RFID and Barcode Printers

RFID Performance
The basic characteristics described above apply to all RFID technologies. RFID systems vary by the range and frequency used, chip memory, security, type of data collected and other characteristics. Understanding these variables is key to understanding RFID performance and how it can be applied to operations. The following sections briefly describe the most important RFID characteristics.

Frequency
Frequency is the leading factor that determines RFID range, resistance to interference and other performance attributes. Most commercial RFID systems operate at either the UHF band, between 859 and 960 MHz, or high frequency (HF), at 13.56 MHz. Other common RFID frequencies include 125 KHz and 2.45 GHz, both used for long-range identification, often with expensive, battery-powered tags. The UHF band is most common for supply-chain and industrial-automation applications. EPCglobal's popular Gen 2 standard (which will be detailed later) is a UHF technology. Figure 6 compares the different frequencies.

Frequency Band	Description	Range	Common Applications
125 – 134 KHz	Low Frequency	To 18 inches	Vehicle identification
13.56 MHz	High Frequency (HF)	Near contact – 3 feet	Electronic ticketing and fare collection; contactless payment; access control; commercial laundry and garment tracking; sample tracking.
858 – 930 MHz	Ultra-high Frequency (UHF)	1 to 30 feet	Compliance tagging and other case and pallet ID; returnable container tracking, work-in-process tracking; asset management; baggage tagging; WiFi-based RTLS.
2.45 GHz	Microwave	10+ feet	Long-range identification with active tags

Range
An RFID system's read range—the proximity to the tag that a reader antenna must be within to read the information stored on the tag's chip—varies from a few centimeters to tens of meters, depending on the frequency used, the power output and the directional sensitivity of the antenna. HF technology is used for short-range applications and can be read from up to about three feet. UHF technology provides a read range of 20 feet or more. Range also depends greatly on the immediate physical environment—the presence of metals and liquids may cause interference that will affect range and read/write performance. Thus multiple systems within the same facility may function within differing ranges depending on immediate surroundings and antenna location. For read/write tags, the read range typically exceeds the write range.

Security
RFID chips are extremely difficult to counterfeit. A hacker would need specialized knowledge of wireless engineering, encoding algorithms and encryption techniques. Furthermore, different levels of security can be applied to data on the tag, making information readable at some points in the supply chain, but not others. Some RFID standards entail additional security. Because of this innate security, the U.S. Food and Drug Administration (FDA) has encouraged RFID as a safeguard against pharmaceutical counterfeiting. Thus, drug makers have begun to exploit RFID's relative impregnability, as have electronics, apparel and other manufacturers.

Standards
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. 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 is now also the ISO 18000-6C standard..

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. Visit Intermec's Web site (www.intermec.com/RFID) for more white papers and additional resources about Gen 2 and other RFID technology.

Using RFID
RFID provides options when it is impractical or impossible to use other technologies or manual labor to collect data. RFID can operate in environments where factors such as indirect line of sight, high-speed reading requirements, temperature extremes, and exposure to gases and chemicals prevent the use of other data collection methods. RFID also provides convenience for innumerable common tasks. Consumers regularly use RFID to unlock car doors remotely, to quickly check books in and out of libraries, and to speed gas-station transactions by waving a key fob at the pump. Businesses rely on RFID to securely track and report the locations of thousands of assets, shipments and inventory items.

And RFID still has a wealth of untapped potential—especially when integrated with other technologies and software applications. Imagine a temperature or shock sensor integrated into an RFID tag to automatically issue warnings about changing conditions that could damage or spoil products. RFID and wireless network systems could be integrated to provide full-time, wide-scale monitoring. Inventory movements from monitored locations could automatically trigger a replenishment request, or contact security if the item was moved by unauthorized personnel. These applications are already in the works, as are other future-looking systems to further convenience and efficiency in consumer transactions, healthcare, personal identification, manufacturing, logistics, asset management and many other operations.

Conclusion
Intermec Technologies Corp. offers a complete range of services and products to help organizations evaluate whether they will benefit from RFID, and how it can be integrated into existing business processes. Intermec is a leader in RFID technology and standards development, with extensive experience helping organizations implement complete RFID data-collection systems. Visit our Web site at www.intermec.com/RFID to see complete case studies on RFID users from multiple industries, and additional white papers on RFID technology and other data-collection topics. Intermec has been helping companies profit by taking advantage of data-collection technologies for more than 40 years.

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