An Introduction to RFID

MORSE WATCHMANS
think inside the box.

Introduction

Radio Frequency Identification, or RFID, is a powerful technology for tracking and identifying a wide range of items. RFID tags can be attached to clothing, boxes of goods for shipping, and similar physical items. Tags can be embedded within items such as employee identification badges and key fobs. They can even be implanted in pets to help return them to their owners if they become lost.

Because of their simplicity, flexibility, and modest cost, RFID systems have become very widely used in retail stores, electronic toll collection, throughout manufacturing supply chains and shipping lanes, and for access control card keys and time clock systems. Chances are good you have used or passed through an RFID system in the last few days.

Moving forward, the use of RFID is only expected to increase. For example, new applications are arising in asset management that will empower employees with shared resources and improve accountability and controls. This paper will provide a basic understanding of the key elements of RFID systems, how they work, and how they support organizational needs as part of integrated application systems.

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RFID: An Enabling Technology for Identification and Asset Tracking

What is RFID, and how does it work?

Its name is an accurate description: Radio Frequency Identification uses electromagnetic radiation in the radio range to identify any nearby tag number. In basic operation, the idea is similar to bar codes – when a reader detects a bar code, it reads it to capture a number – often, a product or tracking code. Similarly, when an RFID tag comes within range of an RFID reader, it is detected and read. There are important differences, however, between barcodes and RFID that will be covered below.

RFID systems are built upon a technical principle that can be broadly called "reflected power communication". In RFID systems, the reader is powered and transmits radio waves. Nearby tags, which normally have no power source of their own, absorb enough energy from the reader transmission to 'wake up' and begin to function. Strictly speaking, such 'passive tags' do not transmit, but they do modulate their own electrical impedance to spell out their stored ID number. The varying impedance changes are seen by the reader in the radio reflection from the tag antenna, and the information is thereby collected by the reader.

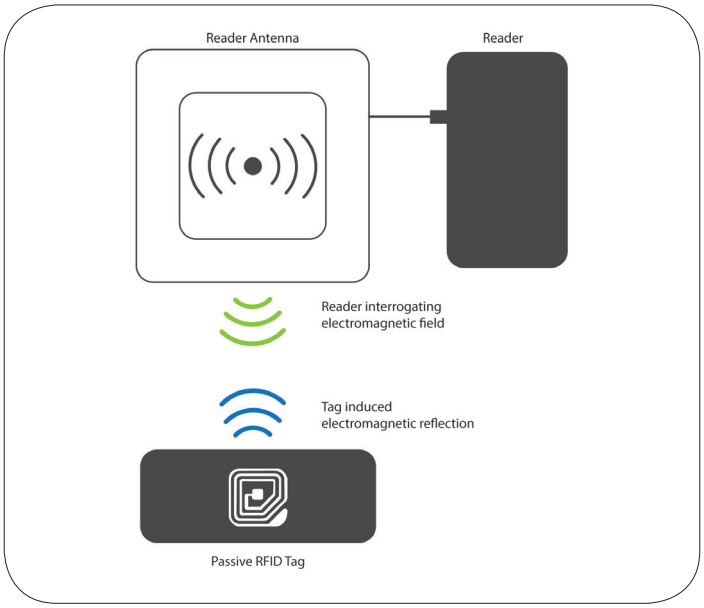

Figure 1: Basic RFID System Elements

Similar ideas were first developed and used in the 1940s for military purposes. The first true ancestor of modern RFID was patented in 1973. Its original 1969 business plan was far ahead of its time, and foresaw applications in electronic toll collection, banking, and security, among others – all common uses today. Since that time, the cost of RFID devices has fallen significantly, and related technologies including computers and communications have just as significantly progressed. This combination is fueling the enormous use and excitement with RFID today.

System Elements

RFID systems consist of a reader, reader antenna, and a tag. See the simple system diagram in Figure 1.

The **reader** drives the interrogation signal that is transmitted via the reader antenna. When a reader is operating, it is always broadcasting the interrogation and looking for reflected signals from nearby tags. If the RFID system is integrated into a larger system, then the reader also provides that interface. If a reflected signal from a tag is detected, then the reader captures and decodes the reflected signal to collect the tag ID number.

The **reader antenna** is carefully designed to match the needs of the application, primarily its main reading direction, distance, and frequency range. A reader antenna is usually made from coils of wire as shown in Figure 2.

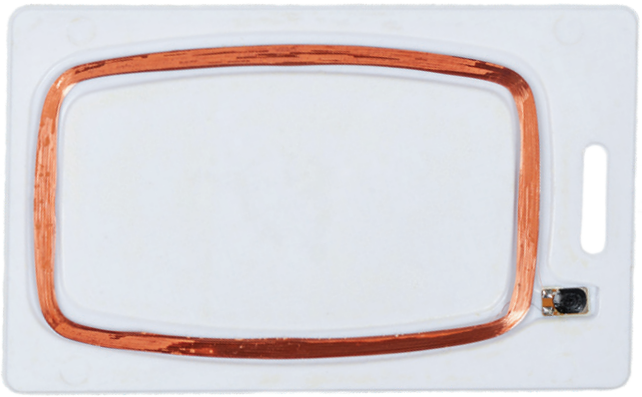

Figure 2: RFID Reader Antenna

"There are several standards in place that specify operating frequencies and other aspects of RFID operation."

Figure 3: RFID readers at retail store and on a street.

Figure 3 shows two common RFID antenna installations. Most retail stores now have RFID antennae installed at entrances and exits to detect anyone leaving the store with tagged goods. Some cities have installed RFID readers as part of traffic monitoring systems; these readers detect and identify electronic toll passes in order to gather data on how traffic is moving.

RFID tags come in a variety of styles and sizes, many with prices less than $1.00 each in volume. Shipping label tags are now below $0.15. In every case, RFID tags include an antenna and an electronic chip that holds the stored information and controls the operation of the tag. Figure 4 shows several common configurations. Note that all the examples in Figure 4 are 'passive' tags that are powered by energy from the reader. There are also powered 'active' tags that include a battery and more complex electronic circuitry; active tags detect the presence of a reader and can transmit their coded message in response, providing much longer detection and read distances. However, because of their much higher cost, on the order of $25.00 each, they are not used for applications such as those in this paper.

Standards

There are several standards in place that specify operating frequencies and other aspects of RFID operation – that is why there can be many manufacturers producing compatible products. Differences remain, however, between countries and so some tags that work in France, for example, will not work in Japan because the allocated frequency ranges are different.

Figure 4: Common RFID tag styles.

Within North America, common frequency bands for RFID are mostly those reserved for "ISM" frequencies. ISM stands for "Industrial, Scientific and Medical" and are set aside in most countries for purposes other than telecommunications and military. (They include the frequency ranges of microwave ovens, for example.) By setting these frequencies aside, uses such as RFID

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won't interfere with communications (or reheating food). Note that the various frequency bands used in RFID systems affect their performance, and in particular, the expected read distances that are achievable with passive tags. The system design for any particular application needs to take these differences into account.

Common Frequency Ranges Used for RFID in North America

Band	Regulation	Max Read Distance	Typical Tag Cost
120-150 kHz (LF)	Unregulated	10 cm	$1
13.56MHz (HF)	ISM Band	10 cm to 1 meter	$0.50 - $5
902-928 (UHF)	ISM Band	1 to 12 meters	$0.15

RFID-Equipped Systems

System Design Depends on the Objectives

As was mentioned in the system element sections above, RFID systems must be designed with the application in mind for optimal performance. The effectiveness of the reader depends strongly on the antenna design, for example. Tailoring the selection of the operating frequency range, the type, size, and design of the antenna, and the selection of compatible tags all affect the ability of the reader to detect and read the tags at the distance and orientation that the tags are presented.

In a broader sense, the overall performance of an RFID system depends strongly on the objectives of the system and how those objectives are translated into the engineering design. For example, an RFID system for card access control can be designed to require users to hold the card close to the reader. This matches the application well because the users can be trained for that operation and it would be undesirable for such a reader to detect the cards at a greater distance – for example, when a user was passing by and not intending to enter the controlled door. In contrast, a system designed for loss prevention at a retail store exit would be designed to cover the entire door area and detect any passing tags even when the person passing through is intending to conceal them.

Thus, the best results will be gained when systems are designed and implemented for specific applications.

RFID Applications

The most powerful solutions integrate RFID systems with application-specific software to create fully automated systems that support business and organizational objectives. Good examples include automated highway toll collection systems, time keeping and access control systems, and retail loss prevention systems. In each of these cases, the RFID tags and readers were selected and designed to reliably and cost-effectively support the overall objectives, and are controlled by application software that provides the tracking, inventory, and billing functions for the system. As an example, let's see how RFID might support an asset management system

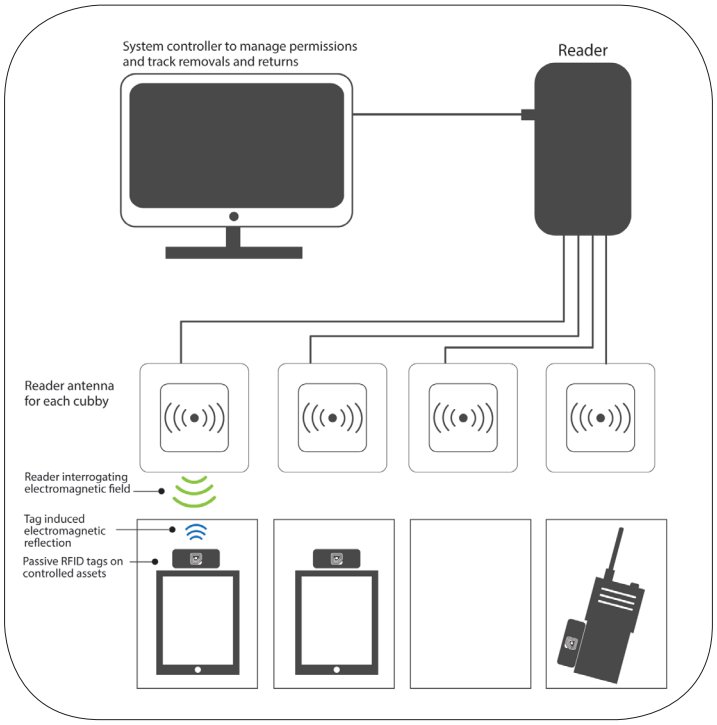

Figure 5: Elements of an Asset Management System

In an **asset management** system, for example, it might be desirable to automatically detect whether a particular asset was returned at the end of a work shift. Such an asset might be a security radio set, or a tool used in manufacturing, and it might

have a specific place where it should be returned. An RFID system can be implemented to support this need. As covered above, the solution needs to be an integrated system that includes a reader, a reader antenna, tags, and tracking software. Here are some of the elements of a solution:

1. One of the earliest considerations is the intended read distance. This is important because it may eliminate some frequency bands from consideration. In this example, a short reading range is not just acceptable, it's desirable – we don't just want to know that the radio or tool is in the vicinity, we want to know that it was put back in its place.

2. If the radio should be returned into a charging station that holds 5 radios, a single antenna that covers the 5 stations will be fine – one reader can detect and read multiple tags within range. On the other hand, if it is important that each tool is returned to a specific separate cubby, then each cubby will require its own antenna. If the range of each antenna goes beyond the size of the cubby, then shielding between cubbies may be necessary to achieve the desired specificity.

3. The other early consideration is how the assets will be tagged. As described previously, there are many styles of tags available, but the selected styles must be compatible with the selected frequency range of the readers. Depending on the nature of the asset, adhesive labels, adhesive tags, or attached fobs or button styles can be used.

4. The reader can then be integrated with appropriate management software to track the assets, detecting when they are removed and when they are returned. Management reports might show the current status of which items are currently in use, how often they were used, and similar metrics.

5. For an increased level of control, staff ID badges can also be equipped with RFID tags and the management software can record who took each asset and who returned them. More sophisticated systems might be used to control access to the assets, managing staff permission levels to control who has access to which assets, and when.

Conclusion

RFID technology is a powerful, flexible tool that lends itself to many useful system management solutions. As the cost for the system elements, and the cost of computers and communications, has dropped, RFID has become even more practical and is being implemented in an ever-growing set of applications.

One ideal application for RFID is asset management. With the variety of tag styles now available, and the power and flexibility of integrated management software, it is easy to see how RFID enables and improves automated systems to strengthen business information, staff empowerment and accountability. While the basic technology and operation of all RFID systems is the same, customized systems that are tailored to the specific application needs are gaining traction in many markets.