THE INSIDER'S GUIDE TO WORKING WITH RFID

SUZANNE SMILEY

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Preface

This book is a collection of RFID eBooks, guides, and articles that were first published on atlasRFIDstore's Resources page or atlasRFIDstore's blog, RFID Insider. We've taken our most popular and informative content and combined them into an easy-to-read RFID guide. The chapters and concepts we've selected range from RFID basics to intermediate topics, from RFID concepts to frequently asked questions. We've arranged the topics in an order that makes sense for readers new to the technology, but, they don't have to be read in any certain order.

This guide does not cover every aspect of RFID technology, but instead is intended to walk you through RFID basics and key concepts. At the end of each chapter, a worksheet is included to test reading comprehension and RFID knowledge.

For more information about RFID and related technologies, please contact us or check out our educational resources.

Contents

Introduction to RFID

Radio Frequency Identification (RFID) is the wireless non-contact use of radio frequency waves to transfer data. Tagging items with RFID tags allows users to automatically and uniquely identify and track inventory and assets. RFID takes auto-ID technology to the next level by allowing tags to be read without line of sight and, depending on the type of RFID, having a read range between a few centimeters to over 20+ meters.

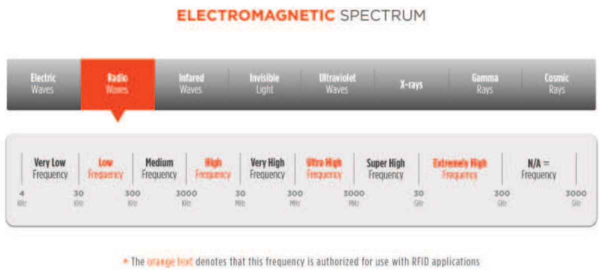
RFID has come a long way from its first application of identifying airplanes as friend or foe in World War II. Not only does the technology continue to improve year over year, but the cost of implementing and using an RFID system continues to decrease, making RFID more cost-effective and efficient.

The ability to identify and track individual items, as well as crates of items, without line of sight can be an advantage for many companies across almost any vertical. For example, if a company has 5,000 identical plastic crates, an RFID tag can be placed on each one in order to recognize crate 1,948 from crate 3,097 without requiring line of sight. Identifying these crates can be crucial to the company's bottom line when one is carrying valuable merchandise or a customer's order. That company needs to not only keep track of that merchandise or order, but also potentially the crate itself, if it is one of the company's assets. RFID can be used to locate and track these assets. Below are some additional benefits of using RFID:

- RFID doesn't need line of sight
- RFID tags are able to be rewritten and reused
- RFID tags can be extremely durable against impact and environmental factors
- RFID tag data is encrypted and can also be locked for extra security
- RFID tags can hold more data than other types of tags or labels
- RFID readers can read hundreds of tags within seconds
- RFID tags can have information printed on them like instructions, barcodes, or company names
- RFID systems can be integrated with other internal systems or processes

Electromagnetic Spectrum

The electromagnetic spectrum is composed of various frequencies of waves that are produced using electromagnetic energy. A radio wave is essentially a disturbance through space that carries energy from one place to another. Radio waves oscillate, in that, while traveling the energy continuously rises and falls in intensity. This oscillation is what is typically depicted as a wave pattern consisting of peaks (highs) and troughs (lows). The path from trough to trough, or peak to peak, is considered a full wave cycle, and the number of cycles that take place in one second is known as the wave's rate of oscillation.



Radio Waves

Radio waves are characterized by frequency and wavelength. Frequency is measured in Hertz, and one Hertz is equal to one full wave cycle per second; so, frequency is dependent upon the wave's oscillation rate.

Equation for a wave's oscillation rate:

Frequency = 865 MHz

Constant: 1 Megahertz = 1,000,000 Hertz

865 MHz is equal to 865,000,000 Hertz which means the oscillation rate is 865,000,000 cycles per second.

Wavelength is measure in meters and is found using the formula below.

Frequency = 865 MHz

Constant: 1 Megahertz = 1,000,000 Hertz

Speed of Light: 299,792,458 Meters/Second

Wavelength = Speed of Light (m/s) / Frequency in Hertz

299,792,458 / 865,000,000 = .3468 Meters = 34.68 Centimeters

For quick calculations, most round like below:

300/865 = .3468 Meters = 34.68 Centimeters

Wavelength

Within the radio wave subset of the RF spectrum, there are eight designated frequency bands:

- Very low frequency
- Low frequency
- Medium frequency
- High frequency
- Very high frequency
- Ultra-high frequency
- Super high frequency
- Extremely high frequency

Starting at the left side of the spectrum and moving right, the wavelength gradually decreases. Very low frequency (VLF), the first frequency range on the left side of the spectrum, has an average wavelength of around 55,000 meters. That means that a VLF wave, from one peak to another (or one trough to another), has an average distance of 55,000 meters, or around 500 U.S. football fields stacked together. Because radio wavelengths correlate with the speed of data transmission (i.e. the longer the wavelength, the slower the data transmission and vice-versa), VLF waves result in very low read rates; therefore, VLF is not used commonly for RFID applications.

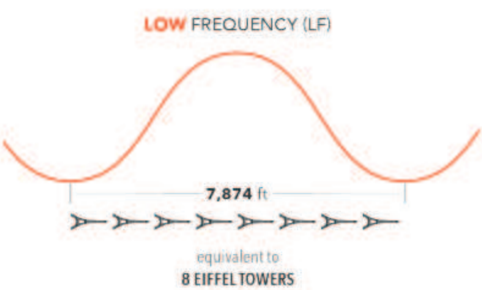
Of the eight frequencies on the radio wave band, there are three that are typically used for RFID applications:

- Low frequency (LF)
- High frequency (HF)
- Ultra-high frequency (UHF)

Main Types of RFID

Low Frequency

The Low Frequency, or LF band, is between 30 kHz and 300 kHz with long wavelengths of around 2,400 meters. Because there are multiple types of signals communicating on this band, LF RFID systems are only allowed to use the small range between 125 – 134 kHz. The large wave size allows LF waves to penetrate metal and water which is unique to this frequency band.



Although LF RFID has a long wavelength, the read range is shorter than both HF and UHF RFID – only extending from a couple centimeters, up to about 50 centimeters in ideal conditions. The short read range is due to dependence on magnetic coupling.

LF tags are generally more expensive than HF and UHF RFID tags, but vary in cost depending on the type and the application. Usually, they cost anywhere from $0.70 - $20.00 per tag, and are powered solely via magnetic coupling – meaning they could last indefinitely depending on the wear and tear of the application. They come in a variety of shapes and sizes, but all tags use the same type of magnetic coupling for power and communication. These tags also have relatively slow read rates because the data rate of transmission is very low and it takes longer for the reader to receive and decode the tag's signal.

LF antenna/RFID reader combinations are available depending on the application, and generally cost anywhere from a couple hundred dollars up to a thousand dollars (USD). Unlike other RFID tags, LF tags do not have security standards, so they are not recommended for applications where encrypted communication is a requirement.

Low Frequency Applications & Facts

LF RFID systems are used most often for animal tracking applications (e.g. pet tagging and livestock identification), but are also used in some access control applications. LF tags are ideal for animal tracking applications because they are easily read through the animal's body (containing water).

General Frequency Range: 30 - 300 kHz

Primary Frequency Range: 125 - 134 kHz

Read Range: Contact - 10 Centimeters

Average Cost Per Tag: $0.75 - $5.00

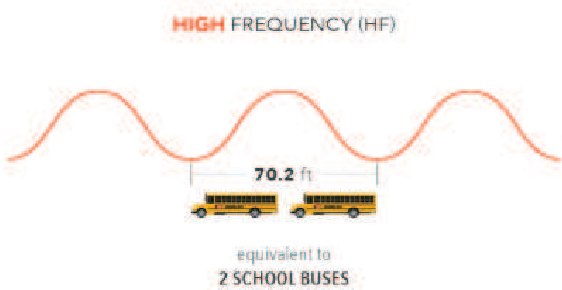
Applications: Animal Tracking, Access Control, Car Key-Fob, Applications with High Volumes of Liquids and Metals

Pros: Works well near Liquids & Metals, Global Standards

Cons: Very Short Read Range, Limited Quantity of Memory, Low Data Transmission Rate, High Production Cost

High Frequency & Near-Field Communication

The high frequency (HF) band on the RF spectrum extends from 3 MHz to 30 MHz. The wavelength of a high frequency wave is much shorter than an LF wave – only around 22 meters, or a little less than 2 school buses in length. High frequency, like low frequency, uses magnetic coupling to communicate between the tags and the RFID reader/antenna. HF waves can pass through most materials except for water and dense metals. Thin metals, like aluminum, can still be tagged with HF tags and function normally.



HF RFID tags usually have a general read range of a few centimeters up to about a meter in length depending on the setup of the system.

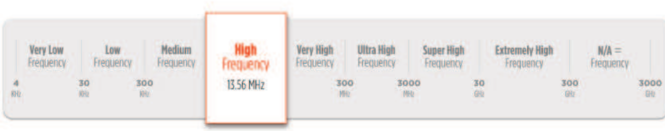
Within the high frequency band of the RF spectrum, near-field communication, or NFC, is a communication protocol approved by the International Organization of Standardization, or ISO (ISO 14443 & ISO 18000-3). Because NFC is a global communication standard, and therefore regulated, it operates on a single frequency - 13.56 MHz. Being approved as a global communication standard and operating only on one frequency makes NFC easily adaptable for hundreds of applications.

HF and NFC tags are relatively inexpensive but can range in cost depending on the size and form factor from about $0.35 - $10.00 per tag. The tags are usually delivered as labels, cards, or plastic encased tags and are generally small in size so that they can be applied to many different types of items. HF tags rely on magnetic coupling as their power source so they tend to last the lifespan of the application unless damaged by wear and tear to the tag.

HF RFID readers are used with HF tags and are relatively low in cost, generally not more than a few hundred USD. NFC tags can be read with the same HF readers, including any smartphones that contain HF/NFC readers. The ability to be read by smartphones give HF/ NFC tags the ability to gain widespread popularity in countless applications.

High Frequency Applications & Facts

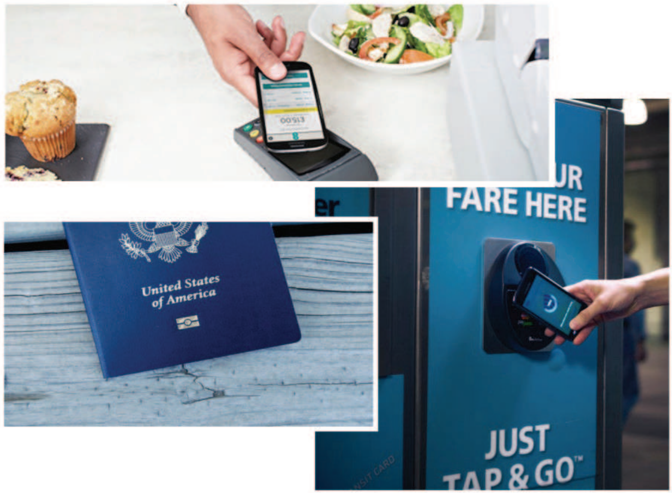
HF and NFC RFID applications are continuously emerging from numerous companies looking to solve business problems using RFID technology. NFC is particularly popular in marketing applications like advertising posters, smart items, and brand/item interactive experiences. The most used applications for HF RFID are access control applications, data transfer applications, and some ticketing applications.



HF RFID tags are also used in passports across the world in countries like the United States, Norway, Japan, Australia, India, and more. There has been criticism in the past about the security of these tags in passports which was later addressed by adding both a metal lining to lower the read range, and a password that has to be keyed into the RFID reader to read the tag.

Primary Frequency Range: 13.56 MHz

Read Range: Near Contact - 30 Centimeters



Average Cost Per Tag: \$0.20 - \$10.00

Applications: DVD Kiosks, Library Books, Personal ID Cards, Poker/Gaming Chips, NFC Applications

Pros: NFC Global Protocols, Larger Memory Options, Global Standards

Cons: Short Read Range, Low Data Transmission Rate

Ultra-High Frequency

Passive

The defining quality of passive UHF RFID systems (when compared to active UHF RFID systems) is the way in which the RFID tags function. Passive UHF RFID tags rely on passive backscatter modulation to function and have no additional power source. In short, this means that the RFID reader sends its energy through the antenna as RF waves to the UHF RFID tags in order for them to become energized and respond back to the reader. The response is called backscatter because the tag scatters back a portion of the energy that it receives from the reader. Because there is no additional power available to the tag other than what is provided by the reader, these systems have a maximum read range of around 30 meters.

UHF RFID passive tags have some of the lowest costs due to widespread adoption. Volume quantities of UHF RFID tags can dip as low as $0.10 cents a tag while maintaining an average read range of 2-5 meters. UHF RFID passive tags have decreased in cost substantially over the years allowing companies and individuals to use low-cost, label tags as disposable asset identifiers.

Passive UHF tags are very sensitive to both liquids and metal. This is because the UHF waves reflect off, refract within, or absorb into non-RF-friendly materials. Though performance degradation in the presence of liquids and metals may be difficult to overcome, interference can be mitigated by analyzing the application environment and employing techniques to overcome obstacles, such as installing RF shielding and/or using metal-mount RFID tags.

Passive UHF tags come in many form factors and are usually subdivided into categories like rugged, high-temperature, label tags, high memory, etc. The tags tend to last the lifespan of the application unless damaged by wear and tear, and because they do not have batteries, their lifespan is not dependent on a power source.

The hardware for UHF RFID system requires a more significant investment than HF and LF system equipment. Readers range between $450 for a low-cost reader up to over $2,500 for a rugged handheld RFID reader.

UHF Passive Applications & Facts

UHF Passive UHF RFID systems are used in hundreds of different applications such as tool tracking , IT asset tracking, race timing, and laundry management. New applications for these tags are being discovered frequently due primarily to the tags' long read range and low cost. Examples of applications that benefit from RFID are endless. Applications extend from broad areas like inventory tracking to supply chain management and can become more specialized depending on the company or industry. Types of RFID applications can span from IT asset tracking to textile tracking and even into specifics like rental item tracking.

What sets a potential RFID application apart from applications that can use other types of systems is the need to uniquely identify individual items quickly and more efficiently where traditional systems fall short. Below are a few applications that are successfully using RFID technology.

- Race Timing
- Supply Chain Management
- Pharmaceutical Tracking
- Inventory Tracking
- IT Asset Tracking
- Laundry & Textile Tracking
- File Tracking
- Returnable Transit Item (RTI) Tracking
- Event & Attendee Tracking
- Access Control
- Vehicle Tracking
- Tolling
- Hospital Infant Tracking
- Animal Tracking
- Tool Tracking
- Jewelry Tracking
- Retail Inventory Tracking
- Pipe and Spool Tracking
- Logistics Tracking (Materials Management)
- DVD Kiosks

- Library Materials Tracking
- Marketing Campaigns
- Real-Time Location Systems

Facts

Primary Frequency Ranges: 860 - 960 MHz

Read Range: Near Contact - 25 Meters

Average Cost Per Tag: $0.09 - $20.00

Applications: Supply Chain Tracking, Manufacturing, Pharmaceuticals, Electronic Tolling, Inventory Tracking, Race Timing, Asset Tracking

Pros: Long Read Range, Low Cost Per Tag, Wide Variety of Tag Sizes and Shapes, Global Standards, High Data Transmission Rates

Cons: High Equipment Costs, Moderate Memory Capacity, High Interference from Metal and Liquids

Primary Subsets of Passive RFID

The relatively wide range of 860 - 960 MHz is recognized as the 'Global Standard' for UHF Passive RFID; however, its late adoption led to the range being further divided into two primarily subsets – 865 – 868 MHz and 902 - 928 MHz.

865 - 868 MHz - ETSI

The European Telecommunications Standards Institute (ETSI) is the governing body in Europe that sets and upholds country-wide standards for communicating via multiple channels, including Radio Waves. By ETSI's regulations, RFID equipment and tags are only allowed to communicate on the smaller frequency range of 865 - 868 MHz because other types of radio communications are allocated to subsets of the larger range of 860 - 960 MHz.

Because ETSI sets the standards for Europe, but when purchasing tags and equipment, the standard can be called either ETSI or EU denoting Europe.

902 - 928 MHz - FCC

The Federal Communications Commission (FCC) is the governing body in the United States that sets and upholds country-wide standards for communicating via multiple channels including Radio Waves. The FCC regulations state that RFID tags and equipment can only operate between 902 - 928 MHz, because, like Europe, other communication types are allocated to the remaining portions of the larger range of 860 - 960 MHz.

RFID Equipment or Tags that are FCC certified or on the North American Frequency Range, or NA, can be used throughout North America.

Other

Because both ETSI and FCC were the first major standards to be approved, many countries either adopted one or the other, or created their own standards* within a subset of either frequency range. For example, Argentina chose to adopt the FCC range of 902 – 928 MHz, while Armenia chose to implement its own, smaller band of 865.6 – 867.6 MHz within the ETSI range.

Although regional regulations like FCC and ETSI are typically discussed using frequency ranges, there are other specifics that each country regulates such as the amount of radiated power (ERP or EIRP). Certain countries are stricter and regulate where RFID can be used, the amount of frequency "hopping" that must be used, or that a license is required to use RFID. For more information on each country's regulations – read " How to Conform to Regional Regulations when using RFID".

Active UHF RFID

Active UHF RFID systems do not rely on passive backscatter to function; instead, they use an internal battery as a power source. Because these tags contain a battery, they do not need to be energized by an RFID reader; instead, they proactively beacon at predetermined intervals. These beacons announce the presence of the tag to any readers that are within range of the tag. Active RFID readers detect the beacons from the tags and pass them on to a host system for processing.

Active UHF RFID tags can have a very long read range due to the internal battery, with beacons that can be detected by readers over 100 meters away. The signal boosting power received from the internal battery also helps these tags to overcome any materials that usually hinder RF waves like metal and water. Certain active RFID tags are engineered to withstand harsh environments like extremely low temperatures and rugged applications, including being able to continue beaconing while being buried in snow or dirt.

Active RFID tags are relatively expensive because they contain an internal battery and other electronics components. Depending on their features (e.g. Wi-Fi, Bluetooth, GPS), these tags cost $20 per tag and up. One drawback of active tags is their limited lifespan. Because they rely on a battery for power, these tags (like their batteries) can only last about 3-5 years (depending on beacon rate). While that timeframe works well for some applications, other applications may require the tags to be replaced.

Active UHF Applications & Facts

Active UHF RFID applications are frequently used in industries like oil and gas, transportation, and vehicle tracking. Because active tags beacon, they are easier to read while moving and are ideal for tracking cargo containers and vehicles. Additionally, tracking items like pipes and construction equipment is one of the more popular uses for active RFID because laydown yards encompass very large areas. Active tags can be installed on materials and large assets outdoors and read by handheld or vehicle mounted readers in order to obtain their location information.

Primary Frequency Range: 433 MHz, (Can use 2.45 GHz - under the Extremely High Frequency Range)

Read Range: 30 - 100+ Meters

Average Cost Per Tag: $25.00 - $50.00

Applications: Vehicle Tracking, Auto Manufacturing, Mining, Construction, Asset Tracking

Pros: Very Long Read Range, Lower Infrastructure Cost (vs. Passive RFID), Large Memory Capacity, High Data Transmission Rates

Cons: High Per Tag Cost, Shipping Restrictions (due to batteries), Complex Software may be Required, High Interference from Metal and Liquids; Few Global Standards

Types of RFID Worksheet

1. RFID stands for:

    a. Radio Frequency Identifying Detail
    b. Radio Frequency Intricate Deployment
    c. Radio Frequency Identification
    d. Radio Frequency Interrogation and Deployment

2. What is an advantage of RFID over barcodes?

    a. No need for line of sight
    b. Read many tags per second
    c. Increased data storage capacity
    d. Data can be encrypted
    e. All the above

3. The three frequencies most commonly used for RFID are:

    a. Low Frequency (LF)
    b. High Frequency (HF)
    c. Super High Frequency (SHF)
    d. Ultra-High Frequency (UHF)
    e. A, B, and D
    f. A, B, and C

4. Low Frequency is:

    a. Between 30 kHz and 300 kHz
    b. Able to penetrate most metals and water
    c. Frequently used in Animal Tracking and Access Control
    d. Known for a very long read range
    e. A, B, and C
    f. All the above

5. High Frequency RFID is commonly used for:
    a. Access Control
    b. Animal Tracking
    c. Race Timing
    d. Railway Management

6. NFC is a global communication standard that operates on a frequency of ________ within the __________ range.
    a. 13.56 MHz; High Frequency
    b. 13.00 MHz; High Frequency
    c. 13.40 kHz; Low Frequency
    d. 130.8 kHz; Low Frequency

7. Match each Frequency Range with its typical Read Range:

a. LF	d. Near Contact to 30 Centimeters
b. HF	e. Near Contact to 25+ Meters
c. UHF	f. Contact to 10 Centimeters

8. Which of these are typical UHF applications?
    a. Asset Tracking
    b. Race Timing
    c. Laundry Management
    d. Inventory Tracking
    e. All the above

9. What is the **main** difference between Passive and Active RFID?
    a. They operate on different frequency ranges
    b. Active tags have batteries and passive tags do not

c. Active tags include Bluetooth and Passive tags do not
d. Passive tags have a longer read range than Active tags

10. Which of the following Frequency Ranges is best for tracking steel pipes outside in a 40-acre area?
    a. LF RFID
    b. HF RFID
    c. Passive UHF RFID
    d. Active UHF RFID

Answers: 1) C; 2) E; 3) E; 4) E; 5) A; 6) A; 7) A&F, B&D, C&E; 8) E; 9) B; 10) D

RFID Tags

What are RFID tags and how do they work?

RFID tags are placed on items to identify or track those items over time or throughout their lifecycle. RFID tags can be used to track all types of objects in industries like healthcare, retail, and manufacturing, to keep track of assets or inventory. This guide covers the main aspects to consider before deciding on or purchasing an RFID tag. Each tag may vary significantly from another, which makes choosing one that has been designed to work in environments and applications similar to your application essential in order to achieve the best results.

RFID tags communicate with RFID readers and antennas via electromagnetic waves. The reader/ antenna combination directs electromagnetic radio waves to the RFID tags in the vicinity. The energy from the waves, harnessed by the RFID tag's antenna, forms a current moving towards the center of the tag energizing the integrated circuit (IC). The IC turns on, modulates the energy with data from its memory banks, and directs a signal back out through the tag's antenna. The remaining, modulated energy that replies to the reader/ antenna is known as "backscatter".

Quick Facts About UHF RFID Tags:

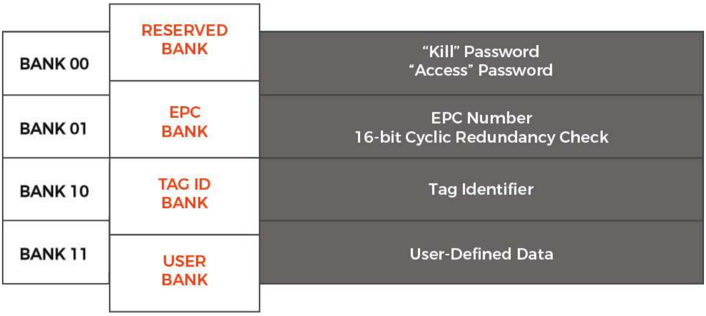
- Most do not have a battery, and are powered exclusively by electromagnetic waves.
- Those with batteries (Battery-Assist Passive RFID Tags and Active RFID Tags) can achieve much longer read ranges.
- They do not require line of sight, unlike barcodes.
- The way that tags couple, or talk to, the RFID reader is called "backscatter".
- An algorithm on each tag called "Anti-Collision" defines the order in which to reply if multiple tags are in the read area.
- The read range can vary from inches to over 120 feet depending on the tag.
- The integrated circuit (IC) has four memory banks – EPC, TID, User, Reserved.
- Each type of tag has a uniquely shaped antenna to ensure the best reactance.

What's Inside an RFID tag?

A basic UHF RFID tag is comprised of an antenna and the IC.

Antenna – A tag's antenna is unique to that specific type of tag and its job is to receive RF waves, energize the IC, and then backscatter the modulated energy to the RFID antenna.

Integrated Circuit (IC)/Chip – the integrated circuit, also called the chip, contains four memory banks, processing information, send and receive information, and anti-collision protocols. Each IC type is unique, and there are only a handful of manufacturers. The main variation between ICs is the number of bits in the respective memory banks.



The Four Memory Banks are as Follows:

EPC Memory Bank – contains the Electronic Product Code which can vary in length from 96 to 496 bits. Some manufacturers use a randomized, unique number, while others use random repeating numbers.

User Memory Bank – the User memory bank can range from 32 bits to over 64k bits and is not included on every IC. If the tag does possess a User memory bank, it can be used for user defined data about the item. This could be information like item type, last service date, or serial number.

Reserved Memory Bank – the Reserved memory bank contains the access and lock passwords which enable the tag memory to be locked by the user and require a password to view or edit.

TID Memory Bank – the TID memory bank contains the Tag Identifier which is a randomized, unique number that is set by the manufacturer and cannot be changed. In order for the reader to read this number instead of the EPC, the reader settings must be changed to accommodate.

Because there is a chance that a tag's EPC number is not unique, it is imperative to check before purchasing. Specifications may denote either "unique, randomized EPC number" or "Not guaranteed to be unique" (or some similar phrase). If you purchase a tag without a unique randomized EPC number, it may need to be reencoded with a new, specific number. RFID readers are not able to differentiate between two tags that share the same EPC value.

The EPC number of each tag is read to identify the tag as well as the item that is tagged. If no software is used, the tag will simply read the EPC number; but, by incorporating software, it is possible to associate that number with a name, serial number, or even a picture on a database.

Types of Tags

Labels/Inlays

Labels and Inlays are two types of RFID tags that are characterized by being paper thin and flexible. The main difference in labels vs. inlays is that inlays are typically clear and can be manufactured with or without adhesive. Labels have a paper or poly (plastic) face so that that graphics or text can be printed on them and read clearly.

Usually grouped together because of form factor and cost, labels and inlays are cost effective and can be purchased as low as $0.10 per tag when purchased in higher quantities. These tags are manufactured on rolls of a few thousand and can be run through an RFID printer to be printed and encoded.

Labels and inlays usually weigh less than a gram and vary in length and width from about less than ½ an inch to over several inches.

Hard Tags

UHF RFID hard tags are classified as such because they are rigid and thicker than the paper-thin labels/inlays. Hard tags are made from many types of materials such as polycarbonate, ceramic, ABS, steel, polystyrene, and polypropylene.

Because of the tougher exterior and larger size, these tags are more expensive than labels and inlays. Depending on special features, hard tags can range from just under $1 per tag to over $15 per tag. Just like labels and inlays, these tags can also be less expensive when purchased in higher quantities.

Hard tags vary greatly in size and weight. The smallest tags are around 0.2 grams and the largest, rugged hard tags can be over 250 grams. Shapes and sizes of hard tags vary greatly, and can range from the size of a small pencil eraser to as large as a license plate.

Positioning RFID Tags – SOAP Method

Although tag positioning sounds like something to consider after a tag purchase, it is important at both the decision-making stage, as well as the post-purchase stage.

The key to tag positioning is the acronym SOAP – which represents the four main aspects of tag positioning – Size, Orientation, Angle, and Placement. Below is information about each, how to use them to select the ideal tag, and when to consider them.

Size

The size of the tag is an important consideration when purchasing. Not only does tag size matter because it needs to fit the size of the object being tagged, but also because of the correlation between tag size and read range. In short, the larger the tag, the longer the read range.

Most Important: Pre-purchasing

Orientation

The tag's orientation, vertical or horizontal or otherwise, in relation to the RFID system's antenna is a critical factor in achieving ideal read rates. To find the orientation of the tag that produces the best read rates, rotate the tag on a flat surface and test it at different orientations. Of note, using circularly polarized antennas helps to mitigate any issues caused by tag orientation.

Most Important: Pre-purchasing, Post-purchasing, Testing

Angle

The steeper the angle of the tag, the shorter the read range. When possible, ensure that the front of the tag directly faces the antenna. Even a small angle could cause a decrease in the tag's read range. To mitigate this issue, it is best to an array of antennas to cover tags from multiple angles.

Pitch, Yaw, & Roll are three additional aspects to consider that fall under both orientation and angle. Testing to cover these positions, will ensure the best read range is received with the selected tag and system.

Most Important: Post-purchasing, Testing

Placement

Test readability in a variety of spots on the item to find the "sweet spot" that generates the best reads. On a cardboard box for example, find the side that will face the antenna/reader and then test in various places on that face to find the one that produces the best results.

Most Important: Post-purchasing, Testing

Tag Attachment Methods

Dependent on the exact tag, attachment methods can vary from common forms like adhesive to unique ways such as shrink wrap. Inlays and labels use a permanent type of adhesive in most applications, while hard tags vary depending on the tag type, weight, application, and application environment. Below is a list of commonly used attachment methods for RFID tags.

Deciding which attachment method to use will depend on the tag, item, and application. In all applications, choosing an attachment method can be just as important as choosing a tag. If an attachment method fails, the tag will fall off the item making it no longer trackable, and the application no longer accurate.

Below are a few specific aspects to think about before choosing the right attachment method for your application.

Surface Area – Just like prepping a car for a window or bumper sticker, the surface area of the item should be prepped for the attachment of the tag. Depending on the method, make sure the surface is smooth, dust and water free, and clean.

Exposure – If the tag will be exposed to prolonged UV light, moisture, vibration, pressure, or chemicals, its attachment method will be exposed as well. Certain environmental conditions like the ones listed above will need special attachment methods that have been proven reliable in similar circumstances.

Temperature – As mentioned above in the exposure section, make sure that the attachment method chosen has been tested in similar conditions as your tagging environment. Extreme temperatures will have different effects on the compound or object used for attachment than the tag, like melting and/or becoming brittle and breaking.

Application Lifespan – Choose a tag as well as attachment method that will hold up the length of time that the item needs to be tagged. Some attachment methods will slowly degrade over time, depending on the chemical makeup. Evaluate the attachment method chosen to ensure it can last the amount of time the tag needs to stay on the item.

Application Surface Materials

The surface of the item to be tagged will greatly influence tag selection, and, if there is more than one item surface type, a different tag should be chosen for each. For example, if an application is taking inventory of assets and one asset is metal and another is plastic, then those two items will likely need to be tagged with two different RFID tags.

An object's surface material is important because most tags have been tuned by the manufacturer to perform better when used on certain materials. The tag's antenna is very sensitive to the type of material it is placed on because of the way it sends and receives signals. Attaching a tag to an incompatible type of surface material could result in a lower read range, lower read rate, or no reading at all.

The most well-known surface material for crippling read range when tagged with the wrong type of RFID tag is metal. Metal causes problems with RFID for two reasons – first, metal reflects RFID waves and, second, RFID tags are manufactured to perform on low-dielectric surfaces (plastic, wood, cardboard) not high-dielectric surfaces like metal. There are two easy ways to solve this issue, either purchase a metal-mount tag that has a built-in, low-dielectric backing or is tuned accordingly, or purchase a tag and place a low-dielectric material such as foam, in between the tag and the metal object.

Tag Special Features

Nearly all UHF RFID tags have special features that make them attractive to certain applications or environments. Most of the time, these special features will help narrow down the search for the ideal tag.

While labels/inlays only have a few feature options, hard tags have quite a few, which usually explains their higher cost. Below are special features that can be found on labels/inlays or hard tags, and information about how they are used.

Resistance to extreme temperatures – Tags with this ability can be used for tagging items in freezers or cold temperature environments (as low as -50° C), or with high-temperature environments (up to 250° C).

Availability: Hard Tags

Metal-mountable – A few label/inlays exist that are metal-mountable, but the majority of metal-mount RFID tags are hard tags. These tags are tuned to work well on metal and must be used when tagging metal items unless a spacer is used to separate the metal object from the non-metal mountable tag. Of note, tags made specifically for on-metal applications tend to get better read range than those with spacers added post-manufacturing.

Availability: Hard Tags, All-Surface Label Tags

Printability – The ability to print directly onto a tag's face is a unique feature of inlays/labels, which allows the tags to be identified visually, or support marketing/branding purposes. Most RFID inlays/labels can be run through an RFID printer which is very convenient for large scale operations. Of note, while it isn't possible to print directly onto hard RFID tags, most still are able to support a manually applied label or sticker.

Availability: Labels/Inlays

Embeddability – The ability to be embedded within an item is very useful in some rugged applications where the tag could potentially get knocked off or be in the way of the item's use. Most embeddable applications involve wood or metal. The key to embedding tags in metal is to make sure that only three sides of the tag are covered with metal while one side is left open to allow for reader/tag communication. Epoxy can be used to cover the open side to seal the tag in place.

Availability: Hard Tags

Impact resistance – Some rugged application environments, like construction yards, need tags that can withstand impact from other objects. Non-impact resistant hard tags will not be able to withstand much shock before the enclosure breaks and the tag stops functioning.

Availability: Hard Tags

Vibration resistance – The vibration in vehicles, trains, and certain types of machinery can be problematic for not only RFID readers, but tags as well. Intense, constant vibrations need to be mitigated by using a tag that can stand up to that type of repetitive, high-intensity motion.

Availability: Hard Tags

Customizable – Most labels/inlays can be customized with graphics, text, or colors, but other labels can be customized to a specific shape and form factor, material type, or given a specialty adhesive depending on the item being tagged. Some hard tags can also be given a specialty adhesive, have labels manually applied, or be produced in certain colors. A minimum order quantity usually exists, but truly customizable tags can be designed and shaped according to the application's needs.

Availability: Labels/Inlays, Hard Tags

Autoclavable – The autoclave is a piece of machinery that is used often in the healthcare field to sterilize instruments after use. Normal RFID tags cannot withstand the heat of the sterilization process, so it is necessary to choose a tag that is autoclavable for these applications.

Availability: Hard Tags

UV resistance – In applications where the tagged item will spend a significant time subjected to UV (or Ultra-Violet) waves, if the tag contains printed information on its face, the chosen tag will need to be resistant to the UV exposure. This includes printed tags that will be unprotected from sunlight (through a window or door) for long periods of time.

Availability: Hard Tags, Label Tags

ATEX certified – ATEX certification means that the RFID tags are approved for use in environments with an explosive atmosphere. These tags are used for applications in environments like mines or workplaces with activities that release flammable gases or vapors.

Availability: Hard Tags

Chemical Resistance – Chemical resistance is a feature that is used in the presence of airborne and water-based chemicals so that the tag does not breakdown or corrode from exposure.

Availability: Hard Tags

Ingress Protection – For applications around dust/dirt or water, ingress protection ratings (or IP ratings) are incredibly important to check before selecting a tag. The first digit of the IP rating will be 0 - 6 and indicates the protection against solids like dirt and dust. The second digit of the IP rating will be 0 – 9 and is the level of protection against liquids, like water. The highest IP ratings for tags would be a rating of 67, 68, or 69 depending on direct or indirect contact with liquids.

Availability: Hard Tags

High Memory – Tags that are available with a higher User or EPC memory can be used to store increased data on the tag, such as service dates and complete item identification. While high memory is good for some applications, most RFID systems associate the tag ID in a database containing the same information by way of software. This frees up the memory on the tag and allows the tag to be read quicker.

Availability: Hard Tags, Inlays/Labels

The Relationship Between Tag Read Range and Size

One of the biggest misconceptions about UHF RFID tags is that all tags get about the same read range regardless of the size, materials, or tagged items. In truth, all those factors combine to determine a tag's general read range, but the tag's size is the most influential component.

Because of how small antennas must be to fit within small tags, they can only send and receive data at just a fraction of the distance of typical large tags. Some of the smallest UHF tags can only be read from a few inches away. Generally speaking, read range increases as the size of the tag increases, with some of the biggest passive tags being able to read over 35 meters (115 feet).

The correlation between read range and size suggests that, for each application, there must be a compromise between the two in order to find the ideal tag. In some applications, such as tool tracking, the objects to be tagged can be so small, that size isn't negotiable; therefore, tags for that application will have only a short read distance. When tracking items that are more accommodating with regard to surface area – a medium to long range tag can be chosen and provide a better balance between size and read range.

Tag Customization Options

Contrary to off-the-shelf RFID tags, custom RFID tags can be created with unique features for an application such as a special adhesive backing, specific data printed and encoded on the tag, as well as a custom size and shape. Custom RFID tags can be an advantage especially for applications that require a large number of tags because the additional cost per tag for customization can be offset by volume pricing. When purchasing RFID tags, there are three levels of customization available:

High Customization

Constructed from scratch to fit a specific application, these tags have unique variables for almost all the options defined below.

Semi-Customization

A semi-custom tag is usually an off-the-shelf tag that has an increased level of customization from one or all of the following: custom printing, encoding, or specific backings or attachment methods.

Low to No Customization

An off-the-shelf tag is basically a ready-to-go tag with the possibility of some custom printing and encoding specific to the application.

Customizable Features

Detailed next are some of the options available for the varying customization levels for RFID tags.

Attachment Methods

Many RFID applications require unique attachment methods to best fit the item to be tracked. While many off-the-shelf RFID tags come standard with adhesive, customizable tags can be created or purchased with attachment methods such as extra strength adhesive, epoxy, or holes for mounting with zip ties, or even screws.

Backings/Encasement

The material or substrate that makes up the back of an RFID tag usually determines the ruggedness of an RFID tag. Most inlays and labels have a PET or plastic backing followed by a layer of adhesive. Because hard tags typically have an external layer of encasement around them, a durable plastic, or sometimes metal, makes up the backing in order to hold up to more rugged applications.

Other backings can be used to create a special effect on how the RFID tags behave. Metal-mount tags are affixed with a special backing that provides separation from the metal surface, absorbs RF energy, and then uses the metal surface as a backplane to amplify the RF waves, thus enabling the tag to work better on or in metal.

Another example is foam-backed RFID tags used for mounting on metal or items with a large water content, such as the human body. The foam spacer in between the tag's antenna and the mounting surface helps to minimize effects usually present when mounting on these RF-unfriendly materials.

Face Stock

For inlays and labels, there are a few different types of material that make up the front of the tag, or the tag's face. The most often used materials are clear PET (polyethylene terephthalate, a type of plastic), white PET, and paper. Clear and white PET can stand up to a few more environmental factors than paper, and PET also keeps the printed text from fading quicker than paper. However, paper is generally a cheaper face stock than PET and is great for short-term applications like race timing.

When printing data onto the inlays or labels, the chosen face stock will affect the printer ribbon as well. While paper face stocks can accommodate a more economical wax or wax-resin blend ribbon, PET face stocks require a more costly (and more durable) full resin ribbon.

Data – Encoded

Customizing the encoded information on each tag is one of the biggest advantages of using customizable tags. Off-the-shelf tags are usually shipped from production pre-encoded with either a random repeating number or random unique number, but custom encoding can ensure that the data on the tag is relevant to a specific application.

Data – Printed

Printing custom information on an RFID tag, like human readable text, 1D or 2D barcodes, or logos can be a great way to visually customize tags for ease of use, additional functionality, or marketing purposes. Printed data on tags is a great way to quickly tell the difference between two tags or visually gather information about the item that is tagged.

Memory

The memory size affects the amount of data that can be stored on the RFID tag. Memory is expensive and most applications don't require extended memory, so most RFID tags have similar memory sizes. However, it is possible to customize the amount of memory on RFID tags – either by re-allocating specific bits to certain memory banks (depending on the tag's integrated circuit, or IC), or by customizing a tag with a high-memory IC.

Size & Shape

Most often, tags are designed with a simple shape and size to match the internal antenna; however, different sizes and shapes can be created in order to best suit the intended application and asset to be tagged. An example of a tag with a customized size and shape (and attachment method) to make it an ideal tag for a specific application is the RFID hang tag.

Encoding RFID Tags

All UHF RFID tags are delivered from each manufacturer with a string of characters already encoded to the EPC memory bank. However, just because the EPC memory for each tag is delivered encoded, that doesn't mean the tag's memory shouldn't be rewritten when the tag is being deployed. In fact, in many applications, the EPC memory needs to be rewritten as tags are deployed.

The Importance of Encoding

Some UHF RFID tags are delivered from the manufacturer with a unique, randomized number on the EPC memory bank; however, many shipments are delivered where each tag has the exact same EPC number.

RFID is used to uniquely identify items; so, when a tag is assigned to an asset, person, or item, each tag ID should be unique. For example, if two identical red cars are on a lot (i.e. only the VINs are different), each must have a tag with unique EPC number so they be differentiated from one another. If there is no guarantee that a EPC number is unique from the manufacturer, the tag must be encoded with a unique number before deploying it.

Whether the EPC memory bank is delivered encoded with a unique, or serialized, number depends on the tag's integrated circuit (IC), or chip.

Tags that ARE encoded with a unique, randomized EPC number can potentially be used without re-encoding them because the chances of repeating that number are slim to none. For example, the EPC number on an Alien tag is created by using a combination of the IC's wafer ID, wafer position, as well as a portion of the latter 35 bits of the TID number. Together, these elements create a unique 32-bit serialization factor at the end of the EPC number.

Tags that are NOT encoded with a unique, randomized EPC number must be re-encoded before use. Some tags are sold with every tag on the roll having identical EPC numbers; others have purely randomized EPCs that are not guaranteed unique.

To Do:

Determine if your tags have a unique, randomized, or serialized EPC number. This can be done by checking the IC specifications of the tag.

What to Encode

Regardless if the tag has a unique EPC or not, there are a few reasons to re-encode the EPC number with unique information. Below are a few common scenarios.

Encode the EPC number as an item's serial number or unique product number

Working with an item's serial number or unique product number helps to cut down the complexity of associating two, seemingly random numbers. This is commonly done in race timing applications by encoding the runner's bib number as the EPC number, or, in inventory applications, by encoding the item's unique serial number.

Generate an EPC number per one of the specifications devised by GS1

GS1 devised specifications called Identification Schemes in order for UHF RFID to be universally compatible for global trade. These schemes explain how to encode the EPC number depending on the item and use of the item. Each scheme defines the number of bits overall, and within a specific section of the string. Different segments that form the EPC number include the Header, Filter Value, the GS1 Company

Prefix, Item Reference, Partition, and Serial Number. The most commonly used Identification Scheme is SGTIN-96 which stands for Serialized Global Trade Item Number, 96-bits.

Encode the EPC incrementing from "…1"

Incorporating header numbers and/or leading zeros and incrementing "from one" (or some beginning number) can be advantageous in many applications where other numbering schemes don't fit. This encoding scheme is common for applications that don't require specific numbers or product information available on each RFID tag.

To Do:

Determine which of the above encoding styles will best fit your application

Conversions – Bits > Hex > ASCII

Bits

Bits are basic units of information and are what is being transmitted between the reader and the tag. Bits are coded in strings of 4, using only ones or zeros. Overall, using strings of bits to communicate data is referred to as Binary Coding. Below is a string of bits.

0010 1101 0100 1001 0100

When a tag's specifications indicate that its EPC memory bank has 96 available bits, it means that a combination of 96 ones and zeros are backscattered to the reader. Below is an example of a 96-bit string.

0100 1111 0100 0010 0010 0010 0111 0101 0011 0011 0100

1000 0011 0101 0100 0010 0011 11110101 0011 0010 1100 0011 0101

Understanding bits is the first step in learning about the two most common encoding formats for UHF RFID tags – Hexadecimal and ASCII.

Hex

Hex, or hexadecimal coding (also called base 16), is a method that utilizes only 16 types of characters – letters A-F and numbers 0-9. Each hexadecimal character represents a string of four bits. Below is the same string of 96-bits above, represented in hex.

0100 1111 0100 0010 0010 0010 0111 0101 0011 0011

4 F 4 2 2 2 7 5 3 3

0100 1000 0011 0101 0100 0010 0011 1111 0101 0011

4 8 3 5 4 2 3 F 5 3

0010 1100 0011 0101

2 C 3 5

The entire string in Hex:
"4F422275334835423F532C35"

A 32-bit memory bank can hold 8 hexadecimal characters.

A 64-bit memory bank can hold 16 hexadecimal characters.

A 96-bit memory bank can hold 24 hexadecimal characters.

A 128-bit memory bank can hold 32 hexadecimal characters.

A 256-bit memory bank can hold 64 hexadecimal characters.

ASCII

ASCII, or American Standard Code for Information Interchange, is an encoding method that uses 128 specific characters, each represented by two strings of four bits. ASCII can represent the entire alphabet (lower case and upper case), numbers 0-9, as well as some special characters, such as asterisks, question marks, and parenthesis. Below is the same string of 96-bits above, represented in ASCII.

0100 1111	**0100 0010**	**0010 0010**	**0111 0101**	**0011 0011**
O	**B**	**“**	**u**	**3**
0100 1000	**0011 0101**	**0100 0010**	**0011 1111**	**0101 0011**
H	**5**	**B**	**?**	**S**
0010 1100	**0011 0101**			
,	**5**			

The entire string in ASCII: “OB”u3H5B?S,5”

A 32-bit memory bank can hold 4 ASCII characters.

A 64-bit memory bank can hold 8 ASCII characters.

A 96-bit memory bank can hold 12 ASCII characters.

A 128-bit memory bank can hold 16 ASCII characters.

A 256-bit memory bank can hold 32 ASCII characters.*

**Of note, a tag's EPC memory is ALWAYS encoded using hexadecimal format. So, if ASCII characters are desired, an ASCII – hex conversion formula must be used when encoding to and reading back from the RFID tag.*

To Do:

Determine which encoding format is best for your application – hexadecimal or ASCII.

ASCII - Hex - Binary
Conversion Chart

ASCII	Hex	Binary	ASCII	Hex	Binary	ASCII	Hex	Binary	ASCII	Hex	Binary
NUL	00	00000000	SP	20	00100000	@	40	01000000	`	60	01100000
SOH	01	00000001	!	21	00100001	A	41	01000001	a	61	01100001
STX	02	00000010	"	22	00100010	B	42	01000010	b	62	01100010
ETX	03	00000011	#	23	00100011	C	43	01000011	c	63	01100011
EOT	04	00000100	$	24	00100100	D	44	01000100	d	64	01100100
ENQ	05	00000101	%	25	00100101	E	45	01000101	e	65	01100101
ACK	06	00000110	&	26	00100110	F	46	01000110	f	66	01100110
BEL	07	00000111	'	27	00100111	G	47	01000111	g	67	01100111
BS	08	00001000	(	28	00101000	H	48	01001000	h	68	01101000
HT	09	00001001	)	29	00101001	I	49	01001001	i	69	01101001
LF	0A	00001010	*	2A	00101010	J	4A	01001010	j	6A	01101010
VT	0B	00001011	+	2B	00101011	K	4B	01001011	k	6B	01101011
FF	0C	00001100	,	2C	00101100	L	4C	01001100	l	6C	01101100
CR	0D	00001101	-	2D	00101101	M	4D	01001101	m	6D	01101101
SO	0E	00001110	.	2E	00101110	N	4E	01001110	n	6E	01101110
SI	0F	00001111	/	2F	00101111	O	4F	01001111	o	6F	01101111
DLE	10	00010000	0	30	00110000	P	50	01010000	p	70	01110000
DC1	11	00010001	1	31	00110001	Q	51	01010001	q	71	01110001
DC2	12	00010010	2	32	00110010	R	52	01010010	r	72	01110010
DC3	13	00010011	3	33	00110011	S	53	01010011	s	73	01110011
DC4	14	00010100	4	34	00110100	T	54	01010100	t	74	01110100
NAK	15	00010101	5	35	00110101	U	55	01010101	u	75	01110101
SYN	16	00010110	6	36	00110110	V	56	01010110	v	76	01110110
ETB	17	00010111	7	37	00110111	W	57	01010111	w	77	01110111
CAN	18	00011000	8	38	00111000	X	58	01011000	x	78	01111000
EM	19	00011001	9	39	00111001	Y	59	01011001	y	79	01111001
SUB	1A	00011010	:	3A	00111010	Z	5A	01011010	z	7A	01111010
ESC	1B	00011011	;	3B	00111011	[	5B	01011011	{	7B	01111011
FS	1C	00011100	<	3C	00111100	\	5C	01011100	|	7C	01111100
GS	1D	00011101	=	3D	00111101	]	5D	01011101	}	7D	01111101
RS	1E	00011110	>	3E	00111110	^	5E	01011110	~	7E	01111110
US	1F	00011111	?	3F	00111111	_	5F	01011111	DEL	7F	01111111

RFID Tag Worksheet

1. RFID tags communicate with RFID readers and antennas via ________________ waves.

   a. Electromagnetic
   b. Refracted
   c. Active
   d. Passive

2. The energy that a UHF passive tag sends to the reader/antenna as the reply is known as:

   a. Back Coupling
   b. Backscatter
   c. Battery-Assisted
   d. Back Current

3. Which two types of tags contain batteries? (Choose 2)

   a. Passive Tags
   b. Active Tags
   c. Battery-Assisted Passive Tags

4. A basic tag is comprised of two parts - (Choose 2)

   a. An Antenna
   b. ASCII Data
   c. A Memory Bank
   d. An IC

5. Which answer choice correctly lists a tag's four memory banks?

   a. EPC, User, Registered, TID
   b. EPC, User, Registered, DIT
   c. EPC, User, Reserved, DIT
   d. EPC, User, Reserved, TID

6. The SOAP Method is very important for understanding -
    a. Tag Memory
    b. Tag Read Range
    c. Tag Attachment Methods
    d. Tag Types

7. Which one of the following answers is not important for choosing the ideal tag attachment method?
    a. Surface Area
    b. Customization
    c. Exposure
    d. Temperature
    e. Application Lifespan

8. Which surface material is known for crippling UHF Passive tag* read range? (*In this scenario, the tag has no special modifications.)
    a. Plastic
    b. Cardboard
    c. Metal
    d. Foam

9. For most applications, the larger the tag, the ___________ the read distance.
    a. Longer
    b. Shorter

10. When you purchase a tag, you should:
    a. Automatically re-encode the tag
    b. Do nothing; use the pre-encoded number
    c. Convert the encoded number to a different format

d. Check to see if the encoded number is unique and randomized
e. Any of the above, depending on your application

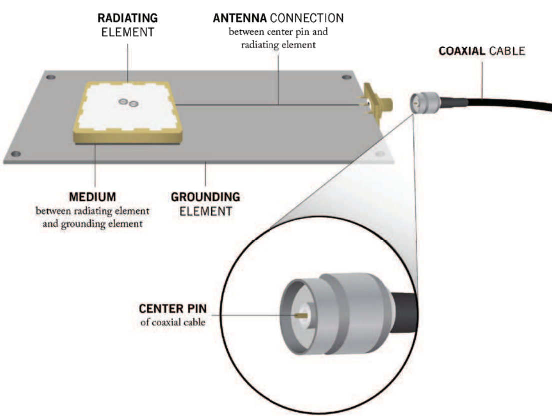
11. Which of the following is not a common encoding method?
    a. Encode the EPC the same number as on the TID Memory Bank
    b. Encode the EPC incrementing from "...1"
    c. Generate an EPC per one of the specifications devised by GS1
    d. Encode the EPC number as an item's serial number or unique product number

Answers: 1) A; 2) B; 3) B&C; 4) A&D; 5) D; 6) B; 7) B; 8) C; 9) A; 10) E; 11) A

RFID Antennas

In short, RFID Antennas take energy from an RFID reader and transmit it in the form of RF waves to RFID tags in the vicinity. If RFID Readers are the "brains" of an RFID system, RFID antennas are the arms because they actually transmit RF waves to the tags.

diagram *of a*
UHF RFID ANTENNA

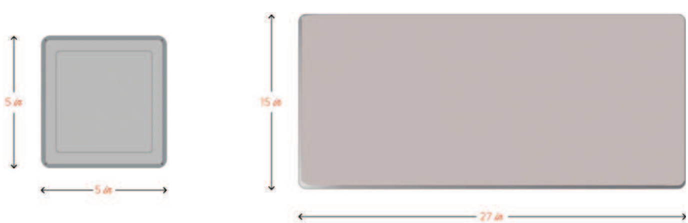


In addition to transmitting, antennas also receive the information sent from the tags so the reader can decode it. While antennas are usually described as "dumb devices" in an RFID system, there are many different types, each with distinguishing characteristics, which makes selecting the right antenna extremely important.

Before selecting an RFID antenna for a specific application, consider the information below about antenna types and options in order to make the right choice.

Size: Large or Small

RFID Antennas range in size from smaller than a standard cell phone, to as large as a TV. The difference in size is usually indicative of the read range – the bigger the antenna, the higher the gain, the longer read range and vice versa. Some antennas, however, are exceptions to the rule because they were built for a specific application; one example is the large Impinj Guardwall antenna. Built for tightly controlled read spaces, the Guardwall antenna only has a gain of 6 dBi because it is designed to be mounted across from another Guardwall to create a small, accurate read zone.



Size constraints may also factor into the decision making process because some applications do not allow for much available space in the area where the antenna will be placed. Certain environments, like retail stores, may not have the space for a bulky 15 x 15-inch antenna, nor will such an antenna fit in aesthetically. Small antennas are optimal for item level reading and writing as well as for applications that require smaller read zones like conveyor belt reading and personnel access control applications.

Key takeaway: The size of the antenna should depend on the space available in the application environment. Also remember, generally the smaller the antenna, the shorter the read range.

Ruggedness: Indoor or Outdoor

Because RFID applications can be implemented in almost any environment, each part of an RFID system must be reviewed or tested for ingress protection against water and dust. Just as most personal phones are not designed for use outside in a rain storm, most RFID technology is not either. All electronic devices are rated on ingress protection (IP) from dust and water, by the US IEC standard 60529 and the British standard EN 60529 ranging from IP 00 to IP 69.

The first digit in the IP rating can be between 0 – 6 and describes the level of protection against solids – like objects or dust. Zero specifies not protected at all against solid objects, and six specifies that the piece of equipment is completely protected from dust. The second digit in the IP rating can be between 0 – 9 and indicates the level of protection against liquids. Zero indicates not protected at all from any liquid, and 9 indicates protected from continuous immersion in liquids that the manufacturer deems safe for the product. IP69 exists and describes a product protected completely from dust and from high pressure liquid, and is the only IP rating that ends in a nine.

The antenna's operating temperature range is not just important for extreme temperature applications; it also should be checked for outdoor or non climate controlled indoor applications. All RFID equipment has an operating temperature range that should be strictly followed, otherwise the equipment could work slowly, stop working, or react negatively to temperatures outside of the specified range.

For extreme temperature applications and/or low IP-rated equipment, solutions exist as a "work around" – for example, weatherproof enclosures and temperature-controlled enclosures.

Key takeaway: Outdoor, non-climate controlled indoor, and extreme temperature applications will require an antenna with a high IP rating and/or a wide operating temperature range.

Form Factor: External or Integrated

RFID antennas can either be integrated within a reader as one device, or purchased separately as an external piece of hardware. Integrating a reader and antenna saves space and provides a more mobile system without worrying about lengthy cabling. Integrated reader antennas are also optimum for retail or desktop applications because they are usually compact, easy to use, and more visually appealing than two bulky external devices. External antennas, on the other hand, provide for many more options and flexibility within any given application.

Key takeaway: Before purchasing a reader or antenna, decide if the application is small enough or customer facing where it would benefit from an integrated reader and antenna.

Frequency Range: US, EU, or Global

Just like RFID readers and RFID tags, RFID antennas are designed for use within specific frequency ranges. Without being tuned to a specific frequency range, antennas would not be able to transmit or receive information from either the reader or the tag. Most RFID antennas fall into one of the following operating regions:

- US or FCC (902 – 928 MHz)
- EU or ETSI (865 – 868 MHz)
- Global (860 – 960 MHz)

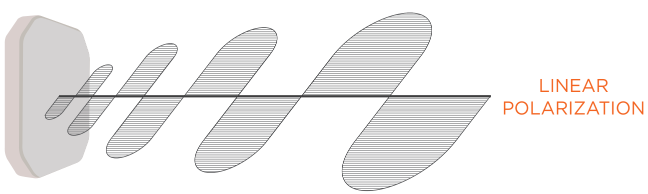
The Global operating region is a good "catch all" for applications that run in multiple countries, or for applications that will be tested in both the US and Europe. Otherwise, it is better to choose an antenna with a narrower frequency range; doing so will result in better performance and, all things being equal, a longer read range. Of note, all RFID equipment working together within any given system must be tuned to the same frequency range in order to communicate successfully.

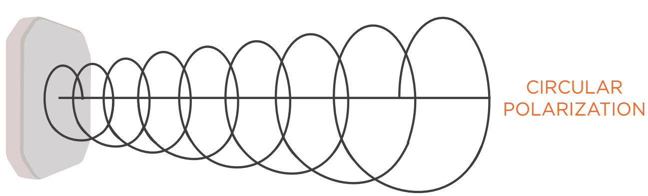
In order to decide which frequency or operating region is appropriate for an application, double check the frequency guide provided by GS1 and ensure that all parts of the RFID system (tags, reader, and antenna) are all compliant within the country they are operating.

Key takeaway: If the system will be operating somewhere other than the US or Europe, double check the frequency guide for each country's specific regulations. A global frequency range antenna is a good fall back if the exact regulations aren't specified.

Polarization: Circular or Linear

Because RFID antennas radiate and receive RF waves, polarization is an important factor to consider when choosing an RFID antenna. Polarization applies to waves and is basically the geometrical direction of the wave's oscillation. RF waves generally oscillate in a single direction which can be described as linear, or in a rotating pattern which can be described as circular. Below is an illustration that shows the difference between radiating waves linearly and radiating waves circularly.





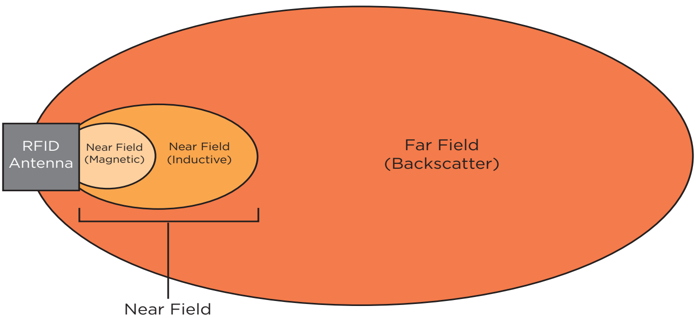
Where this is important for an RFID application is how the waves radiate and line up with an RFID tag's antenna. A circularly polarized antenna works well for applications where the tagged item's location will not be known or will be at different angles and heights. Because the field rotates, it allows for a little more positional uncertainty for the tagged items (e.g. reading tags on palletized boxes moving through a dock door portal). Linearly polarized antennas are not as flexible with tag angles and heights. If a linearly polarized antenna is radiating waves on a horizontal plane, the receiving tag should be horizontal as well and at a consistent height (e.g. reading tags on rail cars). The same idea applies for linearly polarized antennas that radiate waves on vertical planes.

Two types of circularly polarized antennas exist and are differentiated by the way that they rotate: Right-Hand Circularly Polarized (RHCP) antennas rotate counter-clock wise, and Left-Hand Circularly Polarized (LHCP) antennas rotate clockwise. The choice between LHCP and RHCP only matters when there are two RFID systems with two separate RFID readers in a small area. If two RHCP antennas are facing each other in two separate systems, the waves could collide and cause a large null zone in the middle where no tags will be read. In this case, when these are facing, it would be important to choose one LHCP and one RHCP in order to create the best RF environment.

Key takeaway: Choosing a linearly polarized antenna or a circularly polarized antenna depends on the environment of the application and how the tagged items will pass by the specific antenna. If the tags will be at a constant height and orientation, linear works well, if there is some unknown about the heights and angles, circularly polarized antennas are better. When in doubt, choose a circularly polarized antenna.

Read Range: Far-Field or Near-Field

The most important characteristic of an RFID antenna from a user's standpoint is usually the read range – i.e. how far the RF waves will radiate in a geometric field. Several factors determine the read range generated by an RFID antenna such as reader transmit power, amount of cable loss, coupling technique, antenna gain, and antenna beamwidth.



A key aspect of any RFID antenna is whether it is a far-field or near-field antenna. The difference in the two is the way in which they communicate with an RFID tag.

Near-field RFID antennas typically use magnetic or inductive coupling to communicate with the tag when it is the near vicinity. Near-field antennas usually cannot read more than a foot away at the most because their magnetic field and the tag antenna's magnetic field must be close enough to send and receive information.

Far-field antennas use backscatter to communicate. Backscatter is a communication method in which the antenna sends energy to the tag, which powers the integrated circuit (IC). The IC then modulates the information and sends it back using the remaining energy. Far-field antennas can communicate with passive RFID tags up to 30 feet or more in an optimal environment.

Long read range is not always optimal. In an application with limited space, a greater read range could cause problems due to reading too many tags at once (i.e. "stray" tag reads), instead of one specific tag or group of tags.

Key takeaway: Determine how far away the tagged items will be from the antenna in order to establish if a far field or near field antenna would be best for an application. An application requiring proximity reads will generally benefit from a near field antenna.

Strength: High or Low Gain

Antenna gain is expressed in decibels (dB) and is a logarithmic unit of measurement of the ratio of two powers. Gain can be expressed as a few different units of measure such as dB, dBi, dBd, dBm, or dBW which makes it a little more complicated to define. The difference in the unit conveyed (dB, dBi, etc.) explains which two ratios are being measured. Antenna gains cannot be adequately compared in two different units of measure.

dB–The antenna's power output measured against the power input into the antenna.

dBm–The antenna's power output measured against 1 milliwatt of power

dBW–The antenna's power output measured against 1 Watt of power.

dBi–Antenna gain expressed in dBi and is basically the measurement of the amount of power required to produce a certain field of electromagnetic waves in comparison to a "perfect" (no loss, isotropic) antenna's ability to produce the same field. (dBi = dBd + 2.15)

dBd–The antenna's power output measured against the gain of a halfwave dipole antenna.

Antenna gain is expressed in decibels (dB) and is a logarithmic unit of measurement of the ratio of two powers. Gain can be expressed as a few different units of measure such as dB, dBi, dBd, dBm, or dBW which makes it a little more complicated to define. The difference in the unit conveyed (dB, dBi, etc.) explains which two ratios are being measured. Antenna gains cannot be adequately compared in two different units of measure.

Key takeaway: Decide how much read range is required in order to fulfill your application's needs. Factor in antenna gain accordingly, and be sure to compare antenna gains with like units of measure.

Coverage: Wide or Narrow Beamwidth

Beamwidth is very closely related to gain and is exactly what the name implies – the width of the beam or RF field. Two fields exist - the azimuth and elevation fields - and they each have a beamwidth which is crucial to understanding where the RF waves will be directed. Linearly polarized antennas have a relatively small beamwidth in one field, and, depending on the gain, between 30 degrees and 360 degree beamwidth in the other. Most linear antennas' specifications note the elevation and azimuth beamwidths as the same degree due to the fact that the antenna can be physically turned 90 degrees to show the opposite beamwidth.

Generally speaking, the higher the gain, the smaller the beamwidth. most users have to decide what is more important for their application, a greater length of read with a small width, or a shorter read length and wider RF field.

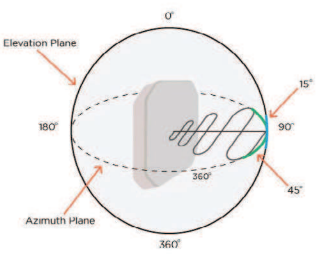
Some examples are included below.

Circular Antennas	Gain	Beamwidth
Keonn P11	3.3 dBi	100°, 100°
Laird S9026X	6 dBi	70°, 70°
Invengo XC-AF26	12 dBi	45°, 45°

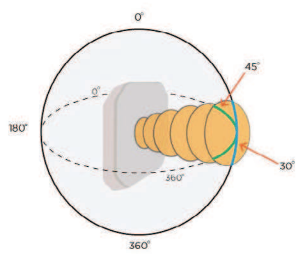
Linear Antennas	Gain	Beamwidth
Times-7 A4030L	7.5 dBi	62°, 62°
MTI MT-263003	10 dBi	50°, 50°
MTI MT-263006/N	12.5 dBi	42°, 42°

2D and 3D radiation graphs are illustrations that manufacturers provide and are a "map" of the RF field produced by the antenna. These maps are very helpful in choosing an antenna for a specific application. 2D radiation graphs will have two images – one of the horizontal or azimuth plane and one of the vertical or elevation plane. 3D radiation graphs provide a 3D mapped image of the exact beam pattern in both fields.

LINEARLY POLARIZED ANTENNA



CIRCULAR POLARIZED ANTENNA

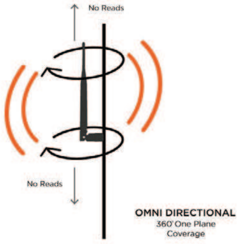


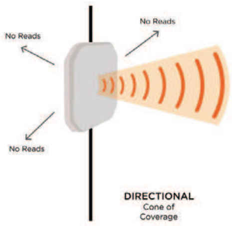
Key takeaway: An antenna with a wide beamwidth will generally have a lower gain and cover more area either vertically or horizontally (or both); while a narrow beamwidth will generally have a higher gain and read farther, but cover a smaller area.

Direction: Directional or Omni-Directional

Closely related to both gain and beamwidth, directivity is defined as the antenna's ability to focus in a particular direction to transmit or receive energy. Two different types of antennas exist in relation to directivity: directional and omni-directional. Directional antennas, like the name suggests, have a concentrated beam in one direction. Whether the beamwidth is 25 degrees or 75 degrees, directional antennas focus their gain into a specific direction to pick up tag reads.

Omni-directional antennas provide a wide range of coverage in one plane. Instead of producing a cone-like beam of coverage like directional antennas, omni-directional antennas usually cover one entire plane. Their 3D radiation patterns look similar to doughnuts because they typically have coverage of 360 degrees in one plane and around 20 to 65 degrees in the opposite field. These antennas are made for environments that will see tagged items all at the same height, but may pass the antenna at different angles. Unfortunately, because these antennas have to cover such a large plane, their gain is usually low to lower mid-range.





Key takeaway: Directional antennas read in one direction and produce a cone-like field, while omni-directional antennas read 360 degrees on one plane.

RFID Antenna Worksheet

1. RFID Antennas are the ______________ of an RFID system.

    a. Brain
    b. Arms
    c. Heart
    d. Eyes

2. When choosing an RFID Antenna, which IP rating is more protected from dust and liquids?

    a. IP 50
    b. IP 55
    c. IP 60
    d. IP 68

3. If the tagged item's location will be unknown, or at different heights and angles, it is best to use a ____________________ polarized antenna.

    a. Circularly
    b. Linearly

4. Near-field antennas use ________________ to communicate with tags, while far-field antennas use ______________________.

    a. Backscatter, RF Waves
    b. Backscatter, Coupling
    c. Coupling, Backscatter
    d. RF Waves, Backscatter

5. Which of these is not a unit of measurement for Antenna Gain?

   a. dB
   b. dBi
   c. dBd
   d. dBc

6. Generally speaking, the ________________ the gain, the ________________ the beamwidth.

   a. Higher, Narrower
   b. Higher, Wider
   c. Lower, Narrower
   d. Lower, Lower

7. Which type of antenna produces a doughnut-shaped radiation pattern?

   a. Directional
   b. High Gain
   c. Omni-Directional
   d. Low Gain

Answers: 1) B; 2) D; 3) A; 4) C;
5) D; 6) A; 7) C

RFID Readers

Types of Readers

Every year, new RFID readers hit the market with improved usability and features, so it is important to know the pros and cons of each reader as well as any additional features that could make an impact on an RFID application. Before diving into the features available on RFID readers, first it is necessary to understand the two major classes of readers recognized in the industry.

Fixed Readers

Fixed readers are generally two-port, four-port, or eight-port, high performance readers. These readers are the ‘workhorses’ in the industry because they provide high power and receive sensitivity to non-mobile applications. Integrated readers are a subset of fixed readers and are unique because they are a reader and antenna combined into one unit. Integrated readers may have one additional port, are usually non-mobile, and are medium- to high-performance readers depending on the specific unit.

Mobile Readers

The first subset of mobile readers can be classified as mobile computers, which also have an integrated antenna. No additional antenna ports are available on these readers, but there are plenty of other features, like onboard processing, that enable these readers to run various programs while maintaining high read rates. Sleds, a second subset of mobile readers, are small RFID readers that connect to a smart device through Bluetooth or an auxiliary port and use a downloaded or custom-developed mobile application in order to function.

Most RFID readers are made with certain specifications, options, and features that make them unique in comparison to other readers on the market. Below is an outline of general reader features followed by a break out of specific options and some information about each one.

Power Options

How the reader is powered is one of the first things to note when purchasing an RFID reader. In certain applications, such as mobile, manufacturing, or warehouse-based, outlets are limited or unavailable, which narrows down the power options. Four options are available when deciding how to power an RFID reader.

Power Adapter

The most common way to power an RFID reader is plugging it into an outlet via a power adapter. Before using this method, ensure that an outlet is in close proximity to where the reader will be installed.

PoE

Another popular way to power an RFID reader is PoE, or Power over Ethernet. PoE uses an Ethernet cable to both power the reader and send/receive data. After setting up a reader via PoE, cabling can be run up to 100 feet and still reliably provide power to the reader. The advantage of using

PoE (vs. a power adapter) is the elimination of the need to run AC power to a reader's location, which may add up to considerable savings in moderate to large deployments.

Battery

Generally specific to mobile readers, batteries provide power while allowing the reader to be cordless and mobile. Batteries are very convenient but they still must be charged, usually after several hours of continuous use. A best practice is to have spare batteries along with a charging station that can charge multiple batteries at once.

In-Vehicle

Applications that require an RFID reader within a vehicle (e.g. truck, forklift, etc.) should consider a reader that has been developed specifically for use in vehicles. Powering an RFID reader through a vehicle is a great solution for reading RFID tags while driving around large areas like laydown yards or for reading pallets as a forklift picks them up. Not many readers on the market have been designed specifically for such use, but the ones that have are ruggedized and contain loose wires that can be connected directly to the vehicle's wiring.

Interconnectivity

RFID readers connect to host computers or networks and communicate data in a variety of ways. Connecting to a network allows readers more flexibility than being connected directly to a computer; instead, they are able to communicate with other programs and readers to create a connected and resolute system.

Wi-Fi

Connecting to a network or a host computer can be done via Wi-Fi for applications in a setting with a strong Wi-Fi connection. Wi-Fi connectivity provides a cordless, flexible option for RFID solutions. Wi-Fi and LAN ports are generally the only options if the application needs to be connected to a network. An additional advantage to an RFID reader on a network is the ability to connect a printer or other smart device to the reader.

Bluetooth

Bluetooth allows the reader to connect to a host computer while remaining wireless. Bluetooth options are generally available on handhelds - especially sleds - for connecting to smart devices like phones and tablets.

LAN

A LAN, or Local Area Network, connection uses an Ethernet cable to join a network. Once on the network, the reader can interact with programs and other connected devices. If an application's needs change and a Wi-Fi connection is required with a reader that is not Wi-Fi enabled, an Ethernet cable can be used to connect the reader to a wireless bridge, allowing the reader to have a Wi-Fi connection.

Serial

Serial ports use either a 9 pin serial or USB cable to connect directly to a host computer. A serial connection is optimal for simple applications with one reader and host computer and no need for additional network capabilities.

Auxiliary Port

Some handheld sleds have the ability to connect either by Bluetooth connection or by using the audio port (or auxiliary port) on smart phones and tablets. Using the auxiliary port to connect to the smart device frees up the Bluetooth connection for the host device in case it needs to be used to connect to another device.

Antenna Ports

When choosing a reader for an application, the user should always check the amount of available antenna ports. Typically, readers are available with two-ports, four-ports, and eight-ports (without any additional devices, such as multiplexers). Antenna hubs, or multiplexers, are available that can connect up to 32 antennas to a single reader. When determining the amount of antenna ports (or antennas) that an application requires, first decide upon the number of read zones required, and, within each read zone, determine how much coverage is needed in order to achieve the desired read rates.

Fixed Readers

Fixed readers usually come with two-ports, four-ports, or eight-ports, depending on the reader. These readers can be set up to cover one read zone or a few different ones, depending on the speed and amount of tagged items.

Integrated Readers

Integrated readers are ideal for applications with a small read zone and are usually more aesthetically pleasing so they can be used in applications like retail or file tracking. These readers usually have one integrated antenna and one open antenna port for connecting an additional antenna if needed.

Mobile/Handheld Readers

Typical mobile/handheld readers have one integrated antenna and no additional antenna ports.

Multiplexers – Multiplexers, also called antenna hubs, can be used in conjunction with RFID readers to increase the amount of antennas able to connect to a single reader. With certain configurations, a single four-port fixed reader can connect to up to 32 antennas. Of note, most multiplexers are only designated for use with very specific RFID readers.

GPIO Options

General Purpose Input/Output connections on RFID readers are used for optional devices like light stacks and motion detectors. Generally, readers read and write tags, but with the addition of an auxiliary device connected through a GPIO port, certain tag reads (or lack thereof) can be programmed to trigger an event. These events, like turning on a green light when a tag is read, provide audio or visual cues that can help an application run smoothly and effectively. When deciding to add an auxiliary device, it is important to understand the amount of voltage it will need in order to perform effectively. Some devices use much more voltage than the reader is able to supply; in those cases, a GPIO box is required to provide the extra power to the auxiliary device.

Inputs

GPI devices or General Purpose Input devices are connected through the GPIO port and include items like motion detectors and light-break sensors. GPI devices use electrical signals to communicate with the reader. If the device sends a signal to the reader, software commands the reader to perform a function specific to the application.

Outputs

GPO devices or General Purpose Output devices are connected through the GPIO port and include items like light stacks and annunciators. For example, if a reader reads a certain tag, software can then tell the reader to send an electrical signal telling the auxiliary device to perform a specific function, such as turning on a light.

Additional Utilities

On some RFID readers, additional ports or utilities are added in order to provide new functionality that can either simplify or enhance the current system. Below are a few common examples of additional features on RFID readers and how they can be used.

HDMI

One of the newest features on RFID readers is the addition of an HDMI port. HDMI ports allow a display or monitor to be directly plugged into the reader.

USB

USB ports are multifunctional on RFID readers and their exact functionality is explained within each individual reader's specifications. While the USB port may function differently on each reader, it can be used for data storage, data transfer, powering, or for additional ancillary capabilities such as adding a Wi-Fi dongle.

GPS

A mobile RFID reader with GPS capabilities is very useful in large deployments, especially those spanning hundreds of meters. GPS coordinates can be associated with the tag read, allowing users to note a defined location of the asset.

Camera

In some applications, especially in remote areas, it is convenient to have a camera outfitted in a mobile reader in order to document a tagged item's status. This is especially helpful if the handheld also has GPS capabilities that may enable the tag read, photo, and GPS coordinates to be associated (geo-tagged) and sent back for analysis. Pictures of tags can also be stored for any needed inspection recording purposes.

1D/2D Barcode

The most common addition to a traditional mobile reader, 1D and 2D barcode readers, are used in conjunction with the tag read typically in applications like supply chain management. They can be used in conjunction with RFID tags or, if a part of the supply chain does not use RFID, the barcodes can be used in lieu of RFID in small shipments.

Cellular Capabilities

Mobile RFID readers with cellular capabilities are used frequently in remote sites that do not have access to Wi-Fi or other connection alternatives. A cellular connection provides an alternative method to transport tag reads or locations when other connections aren't readily available.

Onboard Processing

Onboard processing is typically associated with mobile computing RFID readers, but is also available on many fixed readers. A reader with a processor can run applications on the reader instead of running them on a computer. This reduces the need for a host computer in networked applications. Readers with onboard processing typically have their memory capacity outlined in the specifications, which is important to note when developing an application. If the RFID reader does not have the memory capacity to handle all the added programs, SD card slots are featured on some readers for expansion purposes.

Applications can take up most of an RFID reader's memory, but memory can also be used to store read data on the reader itself. The ability to store and buffer tag read data is a great benefit when a network connection is not available. By storing tag reads, the data can later be uploaded to a network or host computer when available.

API Options

An API, or Application Program Interface, is an important facet to consider before purchasing an RFID reader, especially before developing software. A carefully selected API allows for more seamless communication between the hardware and software/middleware.

Each manufacturer has its own API, so it is important to investigate which API may be the best fit for a specific development environment.

Reader Modules

Unlike finished RFID readers that can be deployed right out of the box, reader modules are associated with a product development cycle. This document is intended to guide you through the development cycle and to help you understand how finished readers differ from RFID reader modules.

Differences Between Finished Readers and Reader Modules

At the most basic level, a finished RFID reader will include a processor, memory, power supply, antenna connectors, and a durable case built around an RFID reader module. Out of the box, a finished RFID reader is ready for deployment and, when paired with an RFID antenna, is capable of reading RFID tags.

Reader modules are components of custom developed RFID readers (requiring custom engineering) that must be paired with a motherboard, provided with a power source, as well as be connected to an antenna in order to read RFID tags.

Ideal Customer Profile for RFID Reader Modules

Where the ideal customer for a finished reader is an individual who may lack either significant hardware engineering experience or the time to spend on product design and development, module customers have both hardware engineering experience AND a financial incentive to develop from the modular level up. Most module customers fall into one of two categories:

RFID enabling an existing product - Some customers already have an electronic device (or a product that contains an electronic device) into which they want to integrate RFID technology. Examples might include a tablet, a smart cabinet, or a thermal transfer printer.

Developing a new product with RFID capability - Some customers are creating an entirely new product into which they want to design RFID capability.

Advantages of RFID Reader Modules

For both of the customers mentioned above, reader modules provide several advantages:

Price - Because the customer only pays for the hardware that the application requires, mass scale implementations are often much more cost-effective when the project leverages RFID reader modules. In this case, the customer can avoid readers that are otherwise "over-engineered" for the application in question.

Flexibility - when developing using RFID reader modules, the customer has greater flexibility to specify the module's frequency ranges, sensor options (Bluetooth/WiFi/GPS/PoE), and processing power instead of being limited to a finished reader's existing design.

Form Factor - Where finished reader come with an existing case, RFID modules enable customers to tailor fit the RFID reader's finished dimensions based on the application's needs.

Product Development Cycle for UHF Reader Modules

ThingMagic recommends a three-step process as customers move from proof-of-concept to full scale deployment using RFID reader modules.

1. **Module Development Kit (Software):** The first step for customers is to interact with the Development Kit. Customers can use the basic module, chassis, and power adapter to attach antennas and begin reading tags in about an hour. The Mercury API is ready for download to enable a developer to begin writing code and interfacing with the reader module. The module development kit is ideal for:

- Testing different antennas without breaking delicate ports
- Connecting to a PC and run URA (Universal Reader Assistant) to test in various environments
- Technical Support - 60 days of tech support is provided as standard.

2. **Sensor Hub (Hardware):** Once the software is developed, it is ready to be loaded onto the sensor hub. The Mercury xPRESS Sensor Hub's ARM Processor allows for compiled code to be tested in a demo or proof-of-concept environment. The xPRESS Sensor Hub comes with the appropriate engineering files that may be needed to select appropriate form features. The xPRESS Sensor Hub is ideal for:

- Sensor Hub Hardware: Microcontroller based motherboard with any of the optional modules – Bluetooth, Wi-Fi, PoE, GPS – as well as pre-screening for regulatory compliance
- Loading Compiled Software Code: Developed software – for demonstrations or ready-for-customer use – can be compiled and loaded onto the sensor hub

- Documentation and Design: Quick-start guide, access to reference design H/W S/W files, schematics, layout files, and Gerber files/BOM component data sheets are accessible in order to provide printed circuit board manufacturers with detailed specifications

3. **Modules at Scale (Mass Production):** The xPRESS Sensor Hub allows the end user to design an appropriate printed circuit board that can replace the Sensor Hub inside the finished product. At this point, customers would begin purchasing reader modules themselves in volume.

RFID Reader Worksheet

1. Without the addition of an antenna multiplexer, most RFID readers can have -

    a. Two antenna ports
    b. Four antenna ports
    c. Ten antenna ports
    d. Eight antenna ports
    e. A, B, & C
    f. A, B, & D

2. Mobile readers can be broken up into two different categories -

    a. Mobile Computers and Integrated Readers
    b. Mobile Computers and Fixed Readers
    c. Mobile Computers and Sleds
    d. Integrated Readers and Fixed Readers

3. PoE is a common way to ____________________ a reader.

    a. Integrate
    b. Provide power and connectivity to
    c. Connect an antenna to
    d. Expand the memory of

4. Connecting an RFID reader to a network instead of directly to a computer allows readers:

    a. More flexibility
    b. More antenna ports
    c. More tag options
    d. More read range

5. What is an antenna multiplexer?
    a. A device that allows a reader to connect to more than one computer
    b. A device that allows a reader to connect to another reader
    c. A device that allows a reader to connect to up to 32 antennas
    d. A device that allows a reader to connect to up to 10 auxiliary devices

6. What is another name for auxiliary devices like light stacks, motion detectors, and annunciators?
    a. Multiplexers
    b. GPIO devices
    c. API devices
    d. Reader modules

7. Which of the following is not an additional port or utility available on select RFID readers?
    a. HDMI Port
    b. GPS Capabilities
    c. 1D/2D Barcode Scanning
    d. Cellular Capabilities
    e. Vibration Sensors

8. Reader Modules are ideal for -
    a. Enabling RFID capabilities in an existing product
    b. Developing a new product with RFID capabilities
    c. Adding additional power to a finished reader
    d. A & B
    e. A & C

9. API stands for -
    a. Applicable Programming Interference
    b. Applicable Programming Interface
    c. Application Programming Interface
    d. Application Programming Interference

10. True or False. Reader Modules are generally cheaper, more flexible, and smaller than Finished Readers.

Answers: 1) F; 2) C; 3) B; 4) A; 5) C; 6) B; 7) E; 8) D; 9) C; 10) True

RFID Cables, Connectors, & Adapters

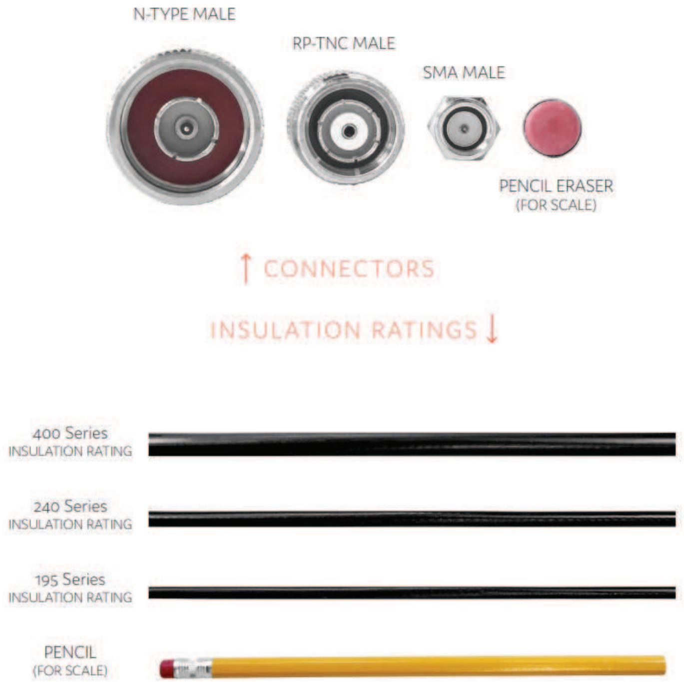
Coaxial cables provide the essential link between an RFID reader and an antenna. They can also be used to connect auxiliary devices like antenna hubs and multiplexers in certain applications. Coaxial cables are energy conductors consisting of a copper core that is insulated by both metal and rubber. The energy generated by the RFID reader is sent via the antenna port of the reader, into the first connector, through the cable, out the other connector, and into the antenna. The better insulated the cable is, the less energy lost during the process.

Antenna cables terminate at both ends in a connector; but, connectors, as well as adapters, can also be sold separately.

Components of Coaxial Cables

Cables have one job – to transfer energy; but, just as important, cables must be properly built to combat potential energy loss. Energy loss happens in every system; the key here is to understand how it is lost from a cable in order to fight it.

Three components make up a coaxial cable, and are important to understand in order to select the correct cable for an application.



Length – The longer the cable, the farther the energy has to travel. No antenna cable is perfectly insulated; so, the farther the energy travels, the more energy it will lose. In some applications, the reader is farther from the antenna due to the nature of the application. If a long cable must be used, it is important to use the appropriate level of insulation required to combat loss.

Insulation Rating – The higher the insulation rating, the thicker and more protected the cable. The most common ratings used with UHF coaxial cables are 195 series, 240 series, and 400 series. The downside to a thicker, more insulated cable is that the cable is less pliable and could be difficult to position in a tight space.

Connectors – Connectors are located at both ends of a cable, and their type is determined by the connectors on the reader and antenna being used in the application. Later, this guide will walk through what types of connectors are compatible with each other.

Cable Loss

Cable loss is the amount of power lost from the cable and is determined by the insulation rating and length of the cable. For applications that need a system running at maximum power to provide long read range or for tracking at high speeds - the reader's transmit power, cable loss, and antenna gain will play key roles. Below is a chart documenting cable loss by length for each insulation rating. This chart shows the correlation between the two so that, if the cable must be lengthened, a higher insulation rating can be used to offset the loss.

Cable	LMR-195	LMR-240	LMR-400	LMR-600
Loss per 100 ft in dB @ 900 Mhz	11.1	7.6	3.9	2.5
Cable Length				
0	0.0	0.0	0.0	0.0
5	0.6	0.4	0.2	0.1
10	1.1	0.8	0.4	0.3
15	1.7	1.1	0.6	0.4
20	2.2	1.5	0.8	0.5
25	2.8	1.9	1.0	0.6
30	3.3	2.3	1.2	0.8
35	3.9	2.7	1.4	0.9
40	4.4	3.0	1.6	1.0
45	5.0	3.4	1.8	1.1
50	5.6	3.8	2.0	1.3
55	6.1	4.2	2.1	1.4
60	6.7	4.6	2.3	1.5
65	7.2	4.9	2.5	1.6
70	7.8	5.3	2.7	1.8
75	8.3	5.7	2.9	1.9
80	8.9	6.1	3.1	2.0

80	8.9	6.1	3.1	2.0
85	9.4	6.5	3.3	2.1
90	10.0	6.8	3.5	2.3
95	10.5	7.2	3.7	2.4
100	11.1	7.6	3.9	2.5
105	11.7	8.0	4.1	2.6
110	12.2	8.4	4.3	2.8
115	12.8	8.7	4.5	2.9
120	13.3	9.1	4.7	3.0
125	13.9	9.5	4.9	3.1
130	14.4	9.9	5.1	3.3
135	15.0	10.3	5.3	3.4
140	15.5	10.6	5.5	3.5
145	16.1	11.0	5.7	3.6
150	16.7	11.4	5.9	3.8
155	17.2	11.8	6.0	3.9
160	17.8	12.2	6.2	4.0
165	18.3	12.5	6.4	4.1
170	18.9	12.9	6.6	4.3
175	19.4	13.3	6.8	4.4
180	20.0	13.7	7.0	4.5

**Of note, because power is being measured on the decibel scale, for every 3 dB reduction, the power is cut in half. A reduction of 6 dB would be only 25% of the original power setting, and so on. Likewise, for every 3 dB increase, the transmitted power doubles.*

If an application isn't getting the desired read range, transmit power on the reader and cable loss can easily be calculated and adjusted. If the application is losing too much energy from the cable, consider decreasing the length and/or increasing the insulation rating to ensure more energy is received by the antenna.

To easily calculate the amount of power that the RFID antenna is receiving, see the equation below.

Transmit Power (dBm) - Cable Loss (dB) = Antenna Input

Additionally, if the power entering the antenna isn't quite enough, a higher gain antenna can be used. To calculate the total system output of power at the antenna, the following equation can be used:

Transmit Power (dBm) - Cable Loss (dB) + Antenna Gain (dB) = System Output

30 dBm - 3 dB + 6 dB = 33 dBm

Please note that most regions limit the total power output from the point of the antenna. For example, FCC regulations limit the total power output to 4 watts or 36 dBm. Be sure to check the regulations for your region to ensure your system is in compliance.

Determining the Correct Connector

Types of Connectors

Connecting a cable from the antenna to the reader in an RFID system isn't difficult – but purchasing the correct cable that will join the hardware together can be a tedious task. Quite a few types of cable connectors can be used, and each one is dictated by the connectors on the hardware. The chart below walks through the most popular types of coaxial connectors with a little information about each.

RP-TNC – A derivative of a TNC connector, the RP-TNC connector is one of the most frequently used cable connectors for a UHF RFID system.

SMA – SMA connectors are known for their small size in comparison to other typical UHF connectors, and are about the size of a pencil eraser.

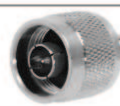
N-Type – N-Type connectors are almost twice as big as an

RP-TNC connector, so they are the largest connectors commonly used in UHF RFID systems.

TNC – A relative of RP-TNC, the TNC connector is the normal polarity version.

RP-SMA – A derivative of an SMA connector, an RP-SMA is simply an SMA connector with the polarity reversed.

BNC – BNC is a less commonly used connector in UHF RFID systems but is similar in size to a TNC connector. BNC connectors allow for quicker attachment than most others, but they are more likely to loosen over time.

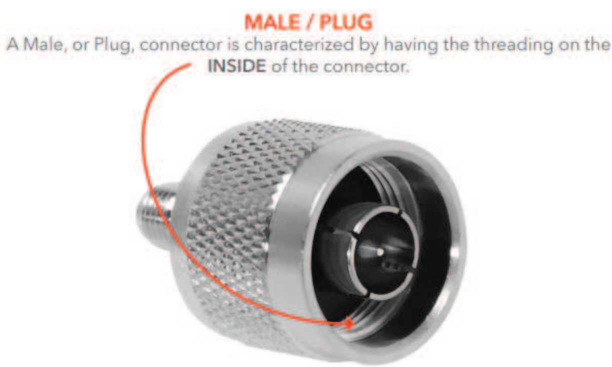
COAXIAL CONNECTOR	IMAGE
RP-TNC A derivative of a TNC connector, the RP-TNC connector is one of the most frequently used cable connectors for a UHF RFID system	 RP-TNC MALE
SMA SMA connectors are known for their small size in comparison to other typical UHF connectors, and are about the size of a pencil eraser	 SMA MALE
N-TYPE N-TYPE connectors are almost twice as big as an RP-TNC connector, so they are the largest connectors commonly used in UHF RFID systems	 N-TYPE MALE
TNC A relative of the RP-TNC, the TNC connector is the normal polarity version	 TNC MALE
RP-SMA A derivative of an SMA connector, an RP-SMA is simply an SMA connector with the polarity reversed	 RP-SMA MALE
BNC BNC is a less commonly used connector in UHF RFID systems, but is similar in size to a TNC connector. BNC connectors allow for quicker attachment than most others, but they also are more likely to loosen over time	 BNC MALE

The Threading

On a coaxial cable connector or adapter, the threading is either on the outside of the connector in plain view, or on the inside of the connector. Two terms are used for each of these types of connectors.

Female/Jack – A Female, or Jack, connector is characterized by having the threading on the OUTSIDE of the connector

Male/Plug – A Male, or Plug, connector is characterized by having the threading on the INSIDE of the connector.



The Center Pin

The center pin of a coaxial connector is the component that conducts the RF energy and is one key to identifying what type it is and with what it is compatible. There are two options when it comes to the center pin of a connector, normal polarity or reverse polarity.

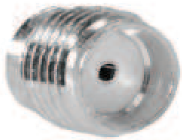
Normal Polarity

Examples include: TNC, SMA, N-TYPE, BNC

Female/Jack - A normal female/jack connector has the threading on the outside and a hole in the center to receive the male/plug's center pin.

Male/Plug - A male/plug connector has the threading on the inside and a metal center pin to insert into a female/jack connector.

Key takeaway: Normal polarity = center pin is in the MALE connector.



Normal Polarity FEMALE
Outside Threading
Hole for Center Pin

Normal Polarity MALE
Inside Threading
Center Pin

Reversed (RP) Polarity

Examples include: RP-TNC, RP-SMA

Female/Jack - A reverse-polarity female/jack connector still has the threading on the outside, but, because the polarity has been reversed, the center pin is on the inside of this connector.

Male/Plug - A reverse-polarity male/plug connector still has the threading on the inside, but because the polarity as been reversed, the hole is on the inside of this connector.

Key takeaway: Reverse polarity = center pin is in the FEMALE connector.

Reversed Polarity (RP) FEMALE
Outside Threading
Center Pin

Reversed Polarity (RP) MALE
Inside Threading
Hole for Center Pin

Connections

Ensuring two connectors will properly join and work as expected can sometimes be a confusing and tedious task. For example, if an RFID reader has an RP-TNC Female connector, should it connect to a RP-TNC Male, a TNC Female, or a TNC Male? These four types have similar names and sizes, and ordering the incorrect type can add several days' worth of delay to a project. Below are a few rules to go by, for matching up the correct connectors.

Rule #1 – Similar types connect.

Example: TNC connects to a TNC; SMA

Rule #2 – Similar polarities connect.

Example: RP-SMA connects to an RP-SMA; RP-TNC connects to an RP-TNC

Rule #3 – Opposite genders/threading types connect.

Example: SMA Male connects to an SMA Female, RP-TNC Male connects to an RP-TNC Female

MALES	FEMALES
TNC MALE	TNC FEMALE
RP-TNC MALE	RP-TNC FEMALE
SMA MALE	SMA FEMALE
RP-SMA MALE	RP-SMA FEMALE
N-TYPE MALE	N-TYPE FEMALE
BNC MALE	BNC FEMALE

Adapters vs. Cables

An adapter is used to join any two coaxial connectors that would otherwise be incompatible. There are two scenarios where a coaxial adapter may be required:

1. If one or both connectors on a cable is incompatible with the RFID reader or antenna.

Purchasing a cable with the incorrect connectors can happen easily; not only are some of them similarly named, but they appear similar in pictures as well.

2. To save money when experimenting with different antennas and readers.

If an application is still in the testing phase, several different antennas and/or readers can be purchased for experimentation. Instead of purchasing several cables with different connectors to match each reader/antenna combination, one cable and a few different adapters can be purchased instead. This can save time and money during testing.

RFID Cable Worksheet

1. What is the difference between a connector and an adapter?
   a. A connector is at the end of a cable and an adapter is a standalone piece with two sides.
   b. An adapter is at the end of a cable and a connector is a standalone piece with two sides.
   c. An adapter connects the cable to a reader and a con nector connects the cable to an antenna.
   d. A connector connects the cable to a reader and an adapter connects the cable to an antenna.

2. What are the three components that make up a coaxial cable?
   a. Length, Flexibility, Connectors
   b. Length, Flexibility, Adapters
   c. Length, Insulation Rating, Connectors
   d. Length, Insulating Rating, Adapters

3. Cable loss is the amount of power lost from the cable and is determined by the ____________________ and ______________________ of the cable.
   a. Insulation Rating, Length
   b. Flexibility, Length
   c. Length, Connectors
   d. Length, Adapters

4. If a connector type, like TNC, is preceded by "RP", what does that mean?
   a. Regular Polarity
   b. Reverse Polarity

c. Regulated Polarity
d. Renewed Polarity

5. Which of the following is not a type of cable connector?
   a. BNC
   b. SMA
   c. N-Type
   d. RP-TNC
   e. RP-ICA

6. If the connector is TNC, and the threading is on the inside of the connector, what does that indicate?
   a. The connector is Female
   b. The connector is a Jack
   c. The connector is Male
   d. The connector is a Jill

7. If the connector is TNC, and the threading is on the outside of the connector, what does that indicate?
   a. The connector is Female
   b. The connector is a Plug
   c. The connector is Male
   d. The connector is a Jill

8. If the connector is SMA, and does not have a center pin, what does that indicate?
   a. The connector is Female
   b. The connector is a Plug
   c. The connector is Male
   d. The connector is a Jill

9. If the connector is SMA, and does have a center pin, what does that indicate?
    a. The connector is Female
    b. The connector is a Jack
    c. The connector is Male
    d. The connector is a Jill

10. If the connector is SMA with threading on the outside and no center pin, what is the connector's identity?
    a. SMA Male
    b. SMA Female
    c. RP-SMA Male
    d. RP-SMA Female

11. If the connector is SMA with threading on the outside and has a center pin, what is the connector's identity?
    a. SMA Male
    b. SMA Female
    c. RP-SMA Male
    d. RP-SMA Female

12. If a reader terminates in an RP-TNC Female, what connector should your cable terminate in?
    a. RP-TNC Male
    b. TNC Male
    c. RP-TNC Female
    d. TNC Female

Answers: 1) A; 2) C; 3) A; 4) B; 5) E; 6) C; 7) A; 8) A; 9) C; 10) B; 11) D; 12) A

RFID Printers

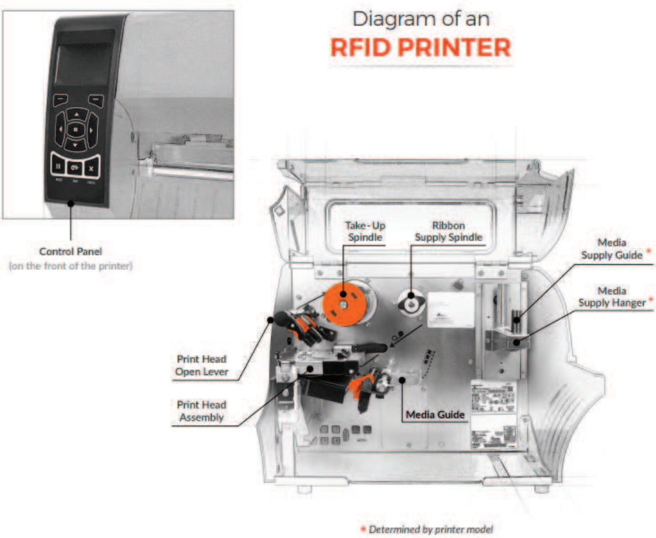
RFID Printers are devices that simultaneously print and encode information on RFID inlays or labels. These devices are the only way to print on labels, and they also save time by automating the manual process of encoding each tag. RFID Printers have the ability to print not only human readable numbers and information, but graphics and 1D and 2D barcodes as well.

Even for applications that do not require printing , RFID Printers can add value by saving time on encoding. Industrial printers, for example, can print up to 14 inches per second in certain operations, which would be a little over 6 tags per second for 2-inch tags (including breaks).

When to Invest in an RFID Printer

RFID printers are not for everyone, especially since the cost can be relatively high. In order to decide if and when it is time to buy an RFID printer, you must first determine whether it would be a good return on investment.

If you are getting to the point where you are spending too much time (because time is money), or you are paying someone too much to hand-encode tags, you should consider the benefits of an RFID printer.



An RFID printer can quickly encode tags as well as print a human readable number, logo, or barcode on the face of the tag. Also, It's much more accurate than hand-encoding tags as it removes the element of human error.

If you assign a value to each hour devoted to manually encoding tags, then add up the value of the hours over a year's period, as well as errors made, you can then determine if it is worth investing in an RFID printer. If the manual encoding costs are higher than the cost of the RFID printer, it may be time to invest in an RFID printer.

In the event that you are buying tags pre-encoded, the situation is a little different. To calculate the ROI in this case, you must take the difference between the cost of pre-encoded tags and unencoded tags. In low volumes, it typically pays to NOT invest in an RFID printer; however, in higher volumes, investing in an RFID printer is usually the wise choice.

As with the manual encoding process, you should calculate the difference in cost across an entire year in order to obtain a worthwhile figure. If the difference is higher than the cost of the RFID printer, then it may be time to invest in an RFID printer.

Types of RFID Printers

There are several different ways to breakout and differentiate types of RFID printers. The most common is by the usage of the printer. Under printer usage there are three main categories: Industrial, Desktop, and Mobile. Another common way that RFID printers are categorized is according to RFID tag compatibility, usually by tag frequency or, sometimes, specialized tag types.

Printer Usage

Industrial (10,000+ tags per day)

Industrial printers are manufactured to be durable and able to be used in most application environments. Industrial printers stand out because of the sheer volume of labels they can print in a day, week, or month. For demanding applications with a large volume of labels, an industrial printer is the best-suited option.

Desktop (500+ tags per day)

As the name implies, Desktop printers are designed to be used in office-like environments. Typically, desktop printers are used to print a low-volume of labels a day and keep up with a mid-level quantity of items to be tagged. Desktop printers are also designed to be aesthetically pleasing, so they can be used in customer-facing applications.

Mobile (200+ tags per day)

Mobile RFID printers are not as common as Desktop and Industrial printers, but they can be very convenient, especially in large spanning applications such as warehouses or shipping yards. The availability of using a mobile printer when covering a large space is much more convenient than relying on a printer in a central location. Due to their compact size, mobile printers typically require specialized media.

Tag Type

Frequency

The most common type of RFID printer is a UHF Passive RFID printer. UHF Passive RFID printers have an encoder that operates at the 860-960 MHz frequency range. However, there are also NFC and HF printers available. These printers often look visually identical to their UHF Passive counterparts, but they have an encoder that operates at the 13.56 MHz frequency range.

Specialized Printers

Another tag-based printer option is a specialized printer for tags like RFID cards and badges, foam backed tags, and all-surface labels that have a metal backing. RFID cards and badges generally aren't on a roll, but sold individually; so, normal RFID printers will not be able to read, write, or print on these. Instead, a specialized card printer is required along with specialized ribbon to print on the thick, plastic cardstock. Because the industry is growing and new types of tags are being made, new specialized printers and printer settings are being released to keep up with demand (e.g. printers designed for foam-backed and metal-mount tags).

Types of Printing – Direct vs. Thermal Transfer

Direct Thermal

Direct Thermal printing is the standard in many industries that need to consistently print text or images, the best example being printing receipts. The Direct Thermal process involves two steps: heating up the printhead, and the printhead coming into contact with the heat-sensitive paper. The paper type is the key in this process because, if the paper is not chemically-coated to be heat sensitive, the printhead will not be able to produce the color change that occurs when the paper is in contact with heat.

Direct Thermal printers are more expensive when compared to generic ink or LaserJet printers; however, because direct thermal printers do not require a regular ink supply the investment over the long term is typically much lower. The downside to direct thermal printing is that the paper used is very sensitive to light, heat, and abrasion, so if the label is exposed to any of those elements for too long, the printed information may become unreadable.

Direct thermal printing is also not recommended for items that need to be labeled for a long-time period because the text will begin to fade over time.

Barcodes on shipping labels, receipts, parking tickets, and some logistics applications use direct thermal printing because the labels do not need to have a long lifespan. Mobile printers typically use direct thermal as well, because of the transient nature of the barcode printed labels.

Thermal Transfer

Thermal Transfer printing is typically used in RFID label printing because of its general resistance to environmental elements and longer lifespan. Thermal Transfer printing requires purchasing a thermal transfer ribbon which is an added cost associated with this type of printing (in comparison to direct thermal). Thermal transfer involves the process of heating up the printhead and pressing it to the back of the thermal ribbon. The heated printhead melts the ribbon and transfers the color to the front of the label, which creates the printed text or image.

The pros of thermal transfer printing are long ink lifespan and little reactance to heat, light, or abrasions. Another positive aspect of this printing process is that there is a ribbon in between the printhead and label, which acts as a buffer for foreign items like dust and dirt. The ribbon helps keeps these impurities out of the printed text or image as well as expands the lifespan of the printhead. A negative aspect of printing via thermal transfer is the reoccurring ribbon cost.

Due to the heavy use of Thermal Transfer printer with RFID tags, the remainder of this guide will focus solely on Thermal Transfer printing.

Printer Ribbon

For Thermal Transfer printing, the printer must be equipped with a ribbon. Three groupings of ribbon are available for printing on RFID labels: Wax Ribbon, Wax-Resin Ribbon, and Resin Ribbon. Each of these ribbon types has its pros and cons as outlined below.

Wax vs. Resin vs. Wax Resin

Facts about Wax Ribbon

- Low melting point
- Most commonly used ribbon

- Should be used on paper labels, coated or non-coated
- Produces softer images
- Inexpensive
- Susceptible to smudges, scratches, and abrasions
- Printed images have a shorter lifespan

Facts about Wax-Resin Ribbon

- Mid-level melting point
- Should be used on coated paper labels like, glossy, smooth surfaces, and synthetic labels
- Clear, sharp image
- Mid-level price point
- Resistant to certain chemicals, abrasions, smudges, and scratches
- Printed images have a long lifespan

Facts about Resin Ribbon

- High melting point
- Should be used on synthetic labels and garment labels
- Clear, sharp images
- High price point
- Highest resistance against chemicals, abrasions, smudges, and scratches
- Printed images have a very long lifespan

Performance & Resistance Levels

After choosing what type of ribbon will work best for your media and application, there are still a few more choices to make before purchasing. Within each category (Wax, Wax-Resin, Resin), an array of different ribbons can be selected depending on application specifics. In order to decide the best within the class of ribbon, it is important to read each ribbon's qualities front to back. If you are unsure which ribbon is right for your application, contact us and we'll be happy to assist.

Card Printer Ribbon

Card Printer ribbon is a separate type of ribbon that is shaped and spooled differently than ribbon for typical label printers. These ribbons are available in solid black, monochrome, and color varieties and can be purchased in the form of a cartridge for ease-of-use.

Media

Media Types

As a general rule, there are two types of RFID tags: inlays/labels and hard tags.

Hard tags can be encoded, but, because they are not on a roll and generally thick, hard tags are usually encoded manually (one of the main exceptions is cards/badges.)

Wet inlays and RFID labels can be run through an RFID printer for encoding and printing purposes. The specifications relating to media size and roll size are imperative to take into consideration when purchasing a printer, as well as when purchasing tags for that printer. Most printer data sheets have a Media section that specifies the different sizes that can be used with the printer. Below are a few facts about each.

Media Size

Width

Most printers use media width as one of the key features of the printer. The media widths usually vary between 4 and 6 inches, depending on the printer.

Length

In printer data sheets, some manufacturers display the maximum label length and others denote the minimum label length. Generally, labels should be a minimum of 0.35” and a maximum of 157” long; but, the specific range depends on the exact printer and the printer's dots-per-inch, or DPI (a measurement of the printer's image resolution).

Thickness

Most labels will be in between 0.002" and 0.010" thick. For thicker labels, an exact printer configuration or special type of printer will be required. Tags/labels with special backing like foam or metal for metal-mount tags are prime examples of tags that cannot be printed with a typical printer or printer setting (see image on page 11).

Media Separation

Because tags are manufactured on a single long liner, back-to-back, manufacturers created a way for RFID printers to determine where one tag ends and the other begins. There are a few of these separation indicators, and the one that is used varies depending on manufacturer and tag type. The three most common are called continuous, notch, and black-mark. Before an RFID printer starts encoding/printing, it must know what the separation indicator is in order to know when to encode/ print.

Continuous

Like it sounds, continuous means that there is no separation between each tag. For this type, the only way that the printer knows one tag from the other is pre-entered tag measurements during calibration.

Notch

Notch, or gap, separation is fairly common on tag rolls and simply means there is a small area between each tag that the printer uses to identify one tag from another. The printer can tell from the reduction in thickness that no tag is in the space between tags.

Black-Mark Separation

Black-Mark separation means that there is a black line that varies in thickness indicating the area between two tags. The printer identifies the color change and is able to use that as the indicator that there is no tag in that space. (These black-marks used for separation indicators between tags should not be confused with black marks that some manufacturers use to denote bad RFID tags.)

Special Media Indicators

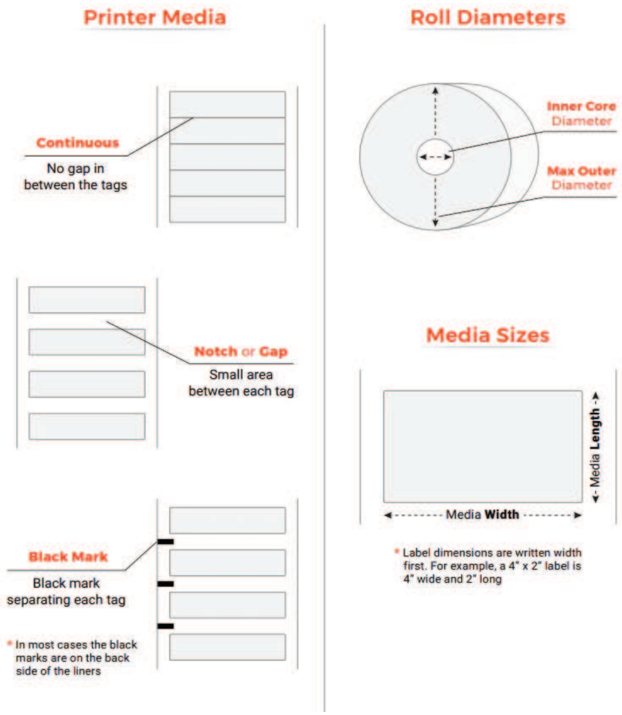
Tags can have identifiers for various reasons that can be important to the printer during the calibration process. The most common special tag identifiers are die-cut tags and liner-less tags.

Die-cut indicates that the tag was cut with a "cookie-cutter" type instrument and is most easily recognized when tags are cut in special shapes or have rounded-edges. Liner-less indicates that the tag has no paper on the back or "liner", meaning there is no waste during the printing process.

Outer Roll & Inner Core Diameter

A common problem that occurs when printing with RFID printers is purchasing a roll of tags that is physically too large to fit in the printer. While tags are usually cheaper purchased in bulk, the diameter of the roll can be too big to fit into the printer enclosure. Each printer has specifications for roll size in order to minimize the risk of purchasing a roll that cannot be used. Another issue is the roll of tags might have a too large or too small diameter core that doesn't fit, or doesn't fit properly, on the printer arm.

Tag roll cores vary in size depending on the type of tag, amount of tags, and tag manufacturer. If the core diameter is too large or small to fit on a printer arm, the best idea is to re-roll the tags on a different size core. Both the outer roll and inner core diameter specifications are available on most printer data sheets.



**These different media types are important to understand in order to properly calibrate a printer for a specific roll of RFID tags. If a printer is not properly calibrated, it could print in-between tags and not properly encode the tags resulting in a waste of resources. For more information on printer calibration, see Printer Maintenance.*

Printer Specs to Know (And Why They Matter)

Printer specifications are the best tools for choosing the ideal printer for an application.

Operating Frequency

RFID printers have an RFID reader inside of them, so it is imperative to check which operating frequency the printer uses. Most printers are set to the Global standard of 865 – 960 MHz, while others can be set to the US (902 – 928 MHz) range, the EU (865 – 868 MHz) range, or even set to print and encode HF and NFC tags (13.56 MHz).

Data Interface

Data Interface explains how the printer connects to a computer or network. The most common data interfaces are Wi-Fi, USB, RS-232, Ethernet, and Bluetooth.

For placing a printer on a network so that more than one computer can print to it, you can use Wi-Fi, Bluetooth, or Ethernet connections. To connect a printer with a single computer directly, USB, RS232 (Serial Connection), Ethernet, and Bluetooth can be used.

Power Source

Most RFID printers are powered by an AC cord, but mobile printers are powered using rechargeable batteries that must be charged every few hours depending on the size and type of battery, as well as printer usage. For battery-operated printers, it is useful to purchase additional batteries and a charging cradle so that the application is not interrupted due to a drained battery.

Operating Temperature

If the application is outside, or in a non-temperature controlled environment, the printer's operating temperature will be important to consider. Most printers have similar operating temperature ranges as RFID readers, unless the printer specifically states that it can withstand harsh environments and extreme temperatures. Printers, like RFID readers, can overheat and shut down if they are not stored properly according to their operating temperature specifications.

Host API

Application Programming Interface, or API, is a set of protocols and tools on a device that allow a programmer to build software to interact with that device. Manufacturers create APIs in specific programming languages such as C#, Java, or their own, unique programming language. The programming language in which the API is available can be a significant advantage for a software programmer that is proficient in that language. For users looking to create a custom software for their RFID printer application, the Host (or manufacturer's) API programming language could be the deciding factor between two or more devices.

Printer Options That Affect Pricing

Resolution/DPI

The resolution, or clarity of the text or image printed on the RFID tag, can be important in certain applications, especially when printing barcodes that will be scanned with a 1D or 2D barcode scanner. If the resolution is not clear, the barcode scanner may not retrieve the correct information for the user's application. On RFID printers, the resolution is described as DPI, or Dots Per Inch. The higher the DPI value, the clearer resolution of the printed text or image. Printers with higher options of DPI cost more because of the more sophisticated printhead required to produce enhanced clarity.

Print Width

Most printers are available with either a 4 or 6-inch maximum print width, which is important to note to ensure that the tag isn't too wide to be encoded and printed with the selected RFID printer. If the tag width is smaller than 4 inches, it can be used with any supported printer. Printers that have a 6-inch print width will generally be more expensive than printers with a 4-inch print width and allow more flexibility when choosing media.

Cutter/Rewinder/Peeler/Auto-applicator

Some printer manufacturers can provide optional, user-friendly capabilities that can be purchased on, or in addition to, the printer. Below is a list of some of the more common options.

Cutter – a cutter is positioned on the front of the RFID printer at the bottom of the opening where the tags are expelled. The cutter is used to cut the tags for you, instead of having to use scissors or additional equipment.

Rewinder – a rewinder is a separate element that is very useful when printing hundreds of tags because it carefully winds the printed and encoded tags coming from the printer, onto a new roll for ease-of-use.

Peeler – a peeler peels the tags off the liner as they come out of the printer for more automated applications and ease-of-use.

Auto-applicator – an auto-applicator is used in peel and stick applications on conveyor belts, usually in conjunction with a cutter and peeler, to replace the human element in the labeling process.

Printer Software

A few different boxed printer software options are available to use with an RFID printer. Printer software allows a computer to interface with an RFID Printer in order to create and send data for printing and encoding tags. Without out-of-the-box software, tags can be printed and encoded by creating a script in the printer's programming language and sending it to the RFID printer. Creating a script requires knowledge of programming in the printer's native language.

In order to print and encode tags without programming knowledge, printer software can be purchased making communication between the computer and printer seamless. Each boxed printer software is different, but the basic functionalities include creating or importing encoding data as well as the data to be printed on the tag face. Boxed printer software is designed to be easy to use, but can vary in price depending on features and the number of printers licensed to use the software.

Another option for interfacing with RFID Printers is to design a custom software using the printer's Host API and programming language. Custom software is a good option for companies that want to automate their printing or create a piece of software with additional capabilities like communication with other pieces of software or databases.

Printer Maintenance

Calibration

Because different RFID tags are used with RFID printers, the printer must be calibrated for a specific piece of media. Calibrating is basically configuring the printer settings to operate with a specific tag. There are two different types of calibrating when talking about RFID Printers – RFID Calibration and Media Calibration.

RFID Calibration refers to when the printer reads the tag and determines the best antenna position and read/write power for encoding to that particular tag.

Media Calibration refers to when the printer prints a few tags in order to adjust settings to accommodate for the tag's size and the gap in between each tag.

Both types of calibration must be completed each time a new tag/piece of media is placed inside the printer to be printed and encoded. Typically, each printer is shipped with either a booklet or loaded information about all the tags that can be printed on that printer and their calibration settings.

Cleaning

Cleaning is an important part of upkeep with an RFID printer. Printers in environments that produce a lot of dust, ash, or dirt will start to slow down or stop working due to an accumulation of debris inside the unit. For printers in this type of environment, it's important to clean the unit every couple of weeks to a month depending on the accumulation. Once every few months, even printers in cleaner environments will need to be cleaned so that dust does not affect printing speed or quality.

Cleaning a printer can be done carefully like any other piece of equipment using cleaning cloths and/ or dusters. Alternatively, a specialized cleaning kit can be purchased for supported printers.S

Recurring Costs

Besides the obvious recurring costs of tags and ribbons, printers may have a few maintenance or equipment replacement costs. In addition to the cost of printer cleaning supplies, printheads may sometimes need to be replaced (although this is rare). Today's printers are built with high-quality materials and are made to last.

RFID Printer Worksheet

1. Typical RFID Printers print and encode which types of RFID tags?
   a. Hard tags and inlays
   b. Labels and inlays
   c. Cards and labels
   d. Inlays and Badges

2. What are the three most common types of RFID Printers?
   a. Industrial, Commercial, Business
   b. Industrial, Commercial, Desktop
   c. Industrial, Business, Desktop
   d. Industrial, Desktop, Mobile

3. What is the difference between Direct Thermal and Thermal Transfer printing?
   a. Direct Thermal involves printing on heat-sensitive paper, while Thermal Transfer melts ribbon which transfers color on a regular label.
   b. Thermal Transfer involves printing on head-sensitive paper, while Direct Thermal melts ribbon which transfers color on a regular label.
   c. Direct Thermal involves melting ribbon on heat-sensitive paper, while Thermal Transfer involves heat-sensitive ink on a regular label.
   d. Thermal Transfer involves melting ribbon on heat-sensitive paper, while Direct Thermal involves heat-sensitive ink on a regular label.

4. Which type of Ribbon is the most commonly used and why?

   a. Wax-Resin Ribbon because it has a mid-level melting point and price point
   b. Resin Ribbon because of the clear, sharp images and high chemical resistance
   c. Wax Ribbon because of its low price point and ability to be used on coated and non-coated paper labels
   d. None of the above

5. Which of the following is not considered a method of separation between tags on a roll?

   a. Continuous
   b. Notch
   c. Dip
   d. Black Mark Separation

6. Which types of inlays must be printed using a specialized RFID printer?

   a. Foam Backed Inlays
   b. Dry Inlays
   c. Wet Inlays
   d. Round Inlays

7. The higher the DPI, which stands for ____________________, the ____________________ the resolution of the printed text.

   a. Digits per Inch, straighter
   b. Dots per Inch, clearer
   c. Decibels per inch, straighter
   d. Definition per inch, clearer

8. True or False. A single printer can print and encode tags in any RFID frequency.

9. Which RFID Printer components will contribute the most to your recurring costs if you're consistently printing tags?
    a. Tags and Ribbon
    b. Ink Cartridges and Tags
    c. Printer Heads and Tags
    d. Data Plans and Tags

10. True or False. A printer calibration must be completed each time a new tag or piece of media is placed inside an RFID printer.

Answers: 1) B; 2) D; 3) A; 4) C; 5) C; 6) A; 7) B; 8) False; 9) A; 10) True

RFID Software

Software, Firmware, Middleware

A few different types of software are common components of most RFID systems – firmware, middleware, and application software. Though all of these components are technically software, their individual functions differentiate them into one of the aforementioned three categories.

Application Software

By definition, software is any set of machine-readable instructions that directs a computer's processor to perform specific operations. Thousands of software applications are accessed daily by end-users, ranging from apps on our phones, to some more specialized applications such as software built for accessing and analyzing data collected by RFID systems. Speedway Connect Software is an example of a software application that provides a graphical user interface which allows users to interact directly with RFID hardware. Generally speaking, application software gives you the ability to get the data that you are looking for, how and when you need it.

Firmware

Software that resides specifically on a hardware component is called firmware. Firmware controls the operation of the device on which it is hosted and does not typically initiate communication with external devices, such as PCs. Device firmware may be upgraded periodically to fix bugs and to add new functionality to the hardware component. An example of firmware is the Astra-Ex v4.19.2 for the ThingMagic Astra-Ex reader. This particular firmware version contained no new features; instead, its focus was on fixing bugs and improving stability.

Middleware

Middleware is a piece of software that usually runs in the background. It essentially is the "glue" that holds two other pieces of software together and allows them to effectively communicate. A common use of RFID middleware is a service that communicates with and controls RFID readers in order to gather data, which then may be analyzed and stored in a database for consumption by a different user-facing application.

RFID Software Worksheet

1. Software that resides on a hardware component is called -
   a. Application Software
   b. Firmware
   c. Middleware
   d. API

2. Speedway Connect Software is an example of -
   a. Application Software
   b. Firmware
   c. Middleware
   d. API

3. The type of software that acts as "glue" that holds together two pieces of software is called -
   a. Application Software
   b. Firmware
   c. Middleware
   d. API

4. An error has occurred in my RFID system and it seems like there may be a bug. Regarding software, what is usually the first thing to check when troubleshooting?
   a. Check for a Software Update
   b. Check for a Firmware Update
   c. Check for a Middleware Malfunction
   d. Unplug all antennas from your device

Answers: 1) B; 2) A; 3) C; 4) B

Important RFID Concepts

Regional Regulations

Regional regulations are rules put in place by individual countries to regulate the transmit frequency and output power of RFID systems. In any country, these regulations are important to know and abide by when purchasing and deploying an RFID system.
Here are the most common questions and the relevant answers about RFID power regulations.

In terms of RFID, what is regulated?

- Frequency or frequency range of transmissions
- Power levels of RF Emissions
- RFID Readers, Active Tags, and Certain Passive Tags

Why are regulations put in place?

Most governments have regulating bodies, or commissions that create and oversee regulations involving country-wide standards relating to radio communications. For the RFID portion of this, these commissions oversee RF frequency, power emissions, and ensure that the RFID equipment manufactured or imported in the country is certified for use.

The Federal Communications Commission or the FCC, is the governing body that oversees these standards for the United States in accordance with the Federal Communications Act. The European Telecommunications Standards Institute better known as ETSI, sets the standards for the European Union for all Information and Communication Technologies which includes RFID.

Frequency or Frequency Range of Transmissions

Frequency ranges are regulated because each country allocates specific frequency bands to certain types of communication. If communication types are fixed to one specific range and monitored, it reduces interference. Radiating RF waves on the wrong frequency range in a country produces interference with other channels that could be allocated to more critical communications like military transmissions, aviation transmissions, or satellite communications.

Power levels of RF Emissions

Regulations on reader emissions are put in place to ensure the power output from the RFID reader does not exceed a predefined level that can interfere with other radio waves in the vicinity. If an RF system is in close proximity to another while exceeding the maximum permitted power level, it most likely will interfere with the other system causing missed reads, lost reader to tag or tag to reader communication, or application failure, and also may cause unintended operation in the other system.

RFID Readers, Active Tags, and Certain Passive Tags

Most devices that radiate RF waves must be certified by each country's government in order for it to be used, manufactured, or imported into that country. Certifications enable countries to enforce communication standards, especially for validating that the reader or tag cannot output more power than the country allows.

Certain passive tags are also subjected to federal certification in order to be sold for and used in hazardous environments or to pass unique, application-based specifications.

How do regulations differ from country to country?

Frequency

Countless variables go into approving a frequency range and a maximum output power for each country, which is why it can vary greatly between countries.

Speaking strictly in terms of frequency ranges, it would be incredibly difficult to have a set, universal frequency band for UHF RFID. This is mostly due to the late adoption of UHF RFID and the limited amount of space still available in the mid-range of the Electromagnetic Spectrum. One example of this is that North America uses 902-928 MHz, but Europe already uses parts of that frequency range for military communications, meaning that it had to determine another frequency range for RFID.

Most countries choose and adopt one of the two common, pre-existing ranges – either 865 – 868 MHz or 902 – 928 MHz, and enable the use of that range country-wide. However, there are a few countries that have more distinct regulations that must be followed, below are the two most common outliers.

1. A common frequency outlier in some countries is to have two specific smaller bands allocated for UHF RFID. Generally, like above, this is due to another communication channel being allocated in the middle of a larger band such as 902 – 928 MHz.

2. Some countries allow for UHF RFID systems to be used,

but only after obtaining a license through the government. More commonly, countries only require licenses for certain bands in the frequency range or for using a certain frequency band at or over a specific output power. If an UHF RFID user does not get a license before going forward, they could be subjected to large fines or company shut downs.

Output Power

Power output in dBm or watts varies per country and just depends on what the government has decided works best with their country's pre-existing standards. Power in watts is usually either 2 watts ERP or 4 watts EIRP.

How do I know if I am within regional regulations?

First and foremost, check GS1's UHF frequency regulations to determine your country's exact specifications. Their document contains a list of each country that has adopted GS1 regulations and documents each country's allocated frequency range, output power, and any other specifics that might be needed to set up an RFID system in that country.

Frequency range will be easy to determine because the reader or receipt from the purchase of any RFID equipment should denote the frequency range. Most often, readers cannot be sent to countries that they are not certified in, but it is still important to double check that you are using the correct frequency for your country.

When it comes to output power, once you have determined what the regulations are in your country, the next step is to calculate your system's output power.

Principle to Know

Effective Radiated Power (ERP) vs. Effective Isotropic Radiated Power (EIRP)

The technical difference in the two is that ERP refers to the gain in relation to a half-wave dipole antenna and EIRP refers to the gain in relation to an ideal isotropic antenna. Some countries provide output power in ERP and some provide it in EIRP, and there is a big difference between them in terms of how they are calculated.

Below is the relation between ERP and EIRP in terms of Watts, and dBm.

EIRP (W) = 1.64 * ERP (W)

EIRP (dBm) = ERP (dBm) + 2.15

Calculating Output Power

To calculate output power, you need the following information:

<u>Reader Transmit Power in Watts, mW, or dBm</u>

Radiated power can be expressed multiple ways, but for RFID, the most common ways are Watts, milliwatts (mW), and dB referenced to one milliwatt (dBm).

<u>Cable Loss in dB</u>

To calculate output power in ERP or EIRP the cable loss in dB is required. To learn more about cable loss check out this article.

<u>Antenna Gain in dBd or dBi</u>

Antenna gain can be expressed in a few different ways depending on the antenna and the manufacturer. The most common ways to express gain are dBi, dBic, dBd, and dbiL.

Use the following equations to calculate the EIRP or ERP of your system. Decide which to calculate (ERP or EIRP) by checking your country's frequency regulations, as noted above.

_____ dBm – _____ dB + _____ dBi = _____ dBm EIRP

_____ dBm – _____ dB + _____ dBd = _____ dBm ERP

Below is an example of calculating EIRP and ERP.

Transmit Power = 31.5 Cable Loss = 3 dB
Antenna Gain = 6 dBi

31.5 dBm – 3 dB + 6 dBi = 34.5 dBm = 2.82 W EIRP

31.5 dBm – 3 dB + (6 dBi – 2.15 dB = 3.85 dBd) =
32.35 dBm = 1.78 W ERP

How can I make sure to stay within regulations? What if I'm over?

If you use the calculations above to determine output power and it is higher than what is allowed in your country/area, there are a few different ways you can adjust your system to stay within regulations. The first, and easiest, way is to simply reduce the transmit power on your RFID reader. Turning down the transmit power, depending on how far over regulations the system currently is, can keep your system from violating the ERP or EIRP maximum.

Two other ways to reduce the output power are:

1. Use a lower gain antenna
2. Use a cable with appropriate attenuation loss to compensate for the power level.

Exceeding a country's regulations can cause problems with other RF systems in the area and call government attention to your system. If you are exceeding the regulated power output, you or your company could be fined or the application could be shut down depending on the country.

Remember to check and see if your country has any further instructions on using RFID in that area, like special licenses.

Frequency Hopping

There are many issues that can arise during the testing phase of an RFID system. One of the most common issues people face is called reader collision. Reader collision occurs when two readers transmit the same frequency at the same time, causing interference in one another's read zones. RFID readers utilize "Dense Reader Mode" to coordinate with other readers so no two readers interfere with each other. Dense Reader Mode uses a technique known as "Frequency Hopping" in order to achieve this. This is extremely useful for environments that have multiple readers located closely within a facility.

Frequency Hopping Spread Spectrum (FHSS) is a method used to rapidly switch transmitting radio signals among several frequency channels.

The FCC has certain regulations in place with which RFID readers must comply in order to transmit 1 W of output power. The FCC allows high output power if the system:

- Uses FHSS
- Supports hopping across 50 channels (500 kHz wide) between the operating frequencies of 902 - 928 MHz
- Transmits no longer than 0.4 seconds per channel

Frequency hopping is a technique mainly used to keep two or more RFID readers from interfering with each other while reading RFID tags in the same area. Each reader initiates its operating program, and, once it receives a frequency hop trigger signal, a frequency hopping sequence is then selected from the available operating frequencies. The reader then prompts the RF module to switch to a frequency channel described in the hopping sequence and stays there for 0.4

seconds. Once completed, the reader will stop transmitting and store the channel it was using. The reader will then continue to use the same sequence if a new trigger signal arrives in less than 30 seconds. Because of this rapid hopping among various frequencies, multiple readers and tags are allowed to communicate with one another with minimal, if any, reader collision.

The nature of this technique allows for very minimal interference since the probability of two readers transmitting at the exact same frequency is very low. This comes in handy when using multiple readers that have overlapping read zones. The technique can be better illustrated in Figure 1 shown below, where three readers are able to transmit signals within a certain range of frequencies without any reader collision.

UHF Security Measures

Class 1 Gen 2 UHF RFID Tags. The gaps in usage of UHF tags were even more pronounced before the release of Class 1 Gen 2 in 2004, because previous versions such as Class 1 Gen 1 contained virtually no security features.

Called "Gen 2" for short, the Class 1 Gen 2 protocol was released in order to create a single global standard for interoperability. Because the standard was created primarily to unify tag and hardware manufacturers under one global standard, security measures were auxiliary in production, but still managed to answer to newly emerging issues. A burst of security and authentication problems arose some pre- but mostly post-2004, forcing EPCglobal and ISO to respond with increased security measures on UHF tags in both the Gen 2 standard and the newly released G2V2 standard.

Security Breaches

Security breaches started as low-scale threats like hackers reading tags and obtaining private information, but they have grown into seven large global threats to UHF RFID security. To be addressed in a later post, these seven threats include hacking events like spoofing, reverse engineering, and eavesdropping.

Current Gen 2 tags do not have the capability to thwart all threats, but two security measures in particular were developed and applied to UHF Gen 2 tags in order to provide the first layer of protection against hackers – serialized TID numbers and passwords.

TID Numbers

When the Gen 2 standard was released, it introduced serialized Transponder ID (TID) numbers for identification purposes. While initially the concept of serialized TID numbers was intended for identification purposes (manufacturer's codes, etc.), the TID became widely used for the purpose of authentication once cloning tags became achievable. TID numbers, unlike EPC numbers, are locked after being written at the factory and as a general rule cannot be tampered with. Generally, to authenticate a tag that is suspected to be fake, read the EPC memory bank and the TID memory bank and record both numbers.

Passwords

Two password functionalities are currently available on Class 1 Gen 2 tags: the access password and the kill password. Both passwords are stored on the reserved memory block and come pre-encoded with zeros, which do not function as an access or kill code.

Access Code

The access code on UHF Gen 2 tags must be written in order to be used. Once written, the access code is stored on the reserved memory bank along with the kill code and prevents anyone from changing the 'lock' state without first sending the 32-bit code. Four lock states exist on each memory bank:

- Unlocked
- Perma-unlocked (can never be locked)
- Locked
- Perma-locked (can never be unlocked)

The access code can also prevent readers from reading the reserved memory bank if it is locked. "Locking" the memory bank enables it only to be read when the reader interrogates it first with the access code, and is the first layer of security generally used with UHF tags. After the access code has been written and the selected memory bank has been locked, the next step is to lock the access password so that users cannot simply re-write it. It is important to note that a small piece of software is usually required in order for the reader to interrogate the tag using the access password. For specifics on locking RFID tags, read Locking Memory on EPC Gen2 RFID Tags.

Kill Code

The kill code is used primarily for applications that require tags to change state (or phase) to indicate a specific event has occurred. Applications like retail benefit from the kill code because once an item is purchased the tag can be killed, making it permanently unreadable. If this method is used, a reader is generally set up at the register to send the kill code after checkout. Using this state change, retailers are able to know if an item was actually purchased versus stolen if it is returned.

The Future – G2V2

Ever since the first details were released about the new G2V2 standard, the idea of security with UHF RFID tags has changed drastically. The new standard takes UHF tags into the 21st century - from two small security measures on Gen 2 tags, to intricate anti-counterfeiting measures and security privileges on G2V2. EPCglobal and ISO were able to step up security and anti-counterfeiting for this new standard by using encryption and cryptologic keys.

While enhanced security measures along with the other three new features are revolutionary, these features are not required on all G2V2 tags. The chips will be customizable based on which features the application needs. For example, if a manufacturing application needed enhanced user memory on tags in order to store increased information but did not need cryptographic authentication, EAS functionality, or the ability to be untraceable, the users can purchase the tag with that one feature alone. Allowing these tags to be customizable (16 combinations) enables them to be cheaper because one-feature chips will be cheaper than chips with all four features.

Even though allowing the chips to be customizable is cost-effective, it adds a huge barrier in the production timeline and availability. Because manufacturers cannot predict which combination will produce the biggest return-on-investment, virtually no G2V2 chips have been put into production as of mid-2016. Back in 2014, it was estimated these chips would be put into production and available in different tag formats for purchase by early 2016; but until the demand grows and large companies place significant orders, these tags will not likely be available in the near future.

Custom Protocols & Interfaces

Protocols

Protocols are a certain set of rules that govern the exchange of data through a communication connection. Most widely used protocols define small data exchanges that occur millions of times a day like the Hypertext Transfer Protocol (HTTP) or File Transfer Protocol (FTP). It is fair to say that most people use protocols on a daily basis. Because RFID is built on communication exchange, there are multiple protocols specific to RFID systems. Some higher-level, complex protocols are constructed of component protocols; a common example of that is the EPC Gen2 protocol.

The EPC Gen2 protocol is comprised of other protocols like anti-collision protocols, air interface protocols, and authorization protocols – just to name a few. Each exchange of data must be defined in a protocol in order to not only comply with rules set by the FCC and other regulatory bodies, but also to gain widespread acceptance and usage. Protocols can be created by a company a manufacturer, or a committee, but must be approved by a governing body to be used.

Industry Specific Protocols

Because the popularity of RFID tracking is becoming more widespread, industries as a whole are starting to use RFID and are invested in creating standards and protocols specific to their use cases. They also have broad applications which will foster easier data exchange between diverse entities who do business with each other. Two common examples of this are the ATA protocol created for the transportation industry, and the AAR protocol created for the railway industry.

The ATA protocol was created for the transportation industry; it was set by the American Trucking Association or (ATA) who created a standard to define and set protocols for using RFID in the industry. The ATA protocol defines the way that the communication will take place between tag and reader, while the standard defines items like memory allocation and security methods.

Industries like these create standards and protocols in order to create specifications to work toward universal adoption. This allows users from all across the industry to read RFID tags and find tracking information in the same uniform way, and, in this case, there is the added benefit of cost competition between RFID vendors.

Added Benefit: Ease of use, and Potential Widespread Adoption

TransCore's eGo & SeGo Protocols

TransCore, an RFID manufacturer that specializes in Automatic Vehicle Identification (AVI) and tolling applications, owns two specific protocols that can provide benefits to automotive applications. eGo and SeGo are two protocols under ISO 18000-6B that are currently used in applications like access control, tolling, and AVI. SeGo – also known as "SuperEgoTM", differs from eGo in that it has higher tag-to-reader data exchange rates.

Both of these protocols provide advanced security procedures to customers that ensure a tag's authenticity while preventing data corruption and/or alteration. In addition, tag cloning, spoofing, copying, or duplicating is prevented1. Because vehicles are high-cost assets, these advanced security techniques are valued in AVI applications. In addition, these tags offer 3x the amount of read/write memory than standard RFID tags – up to 2048 bits.

Added Benefit: Advanced Security Measures, and Increased Memory

Wiegand Protocol

The Wiegand Protocol is another example of a custom protocol that can be used for added benefits. Wiegand is built upon the Wiegand effect, discovered by John R. Wiegand, which uses wires and magnetic properties to encode and decode cards. Because this can be used with RFID, and not just magnetic key cards – a protocol was created to describe the communication between tag and reader with Wiegand capabilities. The most common use for a Wiegand system is in electronic access systems to enter gates or buildings.

In order to setup an electronic access system using RFID with doors, locks, and gates, the readers most likely will need to have Wiegand output capabilities. Wiegand output capabilities on RFID readers are similar to GPIO abilities in that they provide information to other Weigand protocol compatible accessories like control systems for gates or magnetic locks for door entry. The RFID tags used in the system will also have to be programmed with Wiegand specific coding.

Added Benefit: Enable Use with Wiegand systems/devices

Reader Interfaces

Reader manufacturers usually offer software Application Program Interfaces (APIs) for RFID readers so that custom software can be developed by end users to integrate the reader into their business processes. Reader manufacturers may also provide Software Development Kits (SDKs) which provide sample code examples and other helpful documentation to speed up the development and integration process of RFID readers into their environment.

Two Gen2 interfaces exist that can help users integrate directly with RFID readers and start reading and writing as well as building custom applications.

API – Application programming interfaces are provided by reader manufacturers and the functions of each may vary.

The primary disadvantage to using an API to build custom software is if the application changes to a reader made by another manufacturer. If this occurs, then the code will need to be modified using the new manufacturer's API commands.

ALE – Application level events specifies an interface that is basically a starting point for creating and writing custom software. It gives users filtered and consolidated data capture information for physical events and other related data.

Other custom interfaces exist on the market that provide added benefits, such as Kathrein's KRAI Interface.

Kathrein's KRAI Interface

Kathrein is one of the few companies that created an interface that works through the reader to manipulate connected, smart RFID antennas. The KRAI, or Kathrein RFID Antenna Interface, is a selectable option when purchasing certain Kathrein manufactured antennas and readers. The KRAI interface actually takes the place of choosing a polarization – whether RHCP, LHCP, or linear polarization that can be horizontal or vertical.

This configurable reader deployment is due to the innovative way that the reader and antenna modules communicate. Working together, a KRAI reader and antenna toggle between the four different polarization methods and then choose (through internal testing) which is best suited for the read area. This unique feature allows for the optimum antenna polarization and changes depending on the site performance requirements.

On one specific KRAI antenna, the Wide Range UHF RFID Antenna, the interface allows the antenna to switch between three read fields in order to enable coverage in specific areas. This antenna is typically used for logistics, AVI, and general portal applications. This vendor specific interface provides abilities that can greatly increase the success of an application.

Added Benefits: Optimized Antenna Polarization / Optimized Read Field

Factoring in the Environment

Deploying an RFID application without consideration of the environment can potentially lead to thousands of dollars spent with less than stellar read rates. If positive results cannot be provided within the required timeframe, the project may be abandoned and the organization deprived of potential time and cost savings.

Whether the RF waves are absorbed (as with liquids) or reflected (as with metals), any source of interference in the environment may cause problems unless properly mitigated.

Liquids and RFID

Liquids absorb RF energy.

What's the Problem?

Tagging Liquid-Filled Containers

In the past, it was nearly impossible to tag liquid-filled containers because the absorption of RF energy by the liquid would leave little RF energy for the RFID tag to receive, much less to backscatter in reply to the RFID reader. Now, there are quite a few options for tagging liquid-filled containers.

How can you mitigate it?

Option: Use Low Frequency (LF) RFID instead of High or Ultra-High Frequency. LF RFID does not have the issues with water that higher frequencies struggle with, so it can be used for animal tracking or water-filled items. The downside is slower data transmission speeds and shorter read ranges relative to the higher frequencies.

Option: Use UHF labels approved specifically for use on water-filled containers like the Omni-ID IQ 600 Labels and the Confidex Silverline.

Option: Use UHF Near-Field tags approved for use on water-filled containers like the Alien SIT tag and the SMARTRAC Trap.

Option: Use regular UHF inlays or labels and place a spacer between the liquid and the tag made from foam, silicon, or another thick material (e.g. the Foam-Backed ShortDipole).

What's the Problem?

Tagging Items in Liquids

Impossible with UHF until a few years ago, tagging items in liquids can now be done thanks to the better tag construction and design.

How can you mitigate it?

Option: Use Low Frequency (LF) RFID instead of High or Ultra-High Frequency. LF RFID does not have the issues with water that higher frequencies struggle with, so it can be used for animal tracking or water-filled items. Again, the downside is slower data transmission speeds and shorter read ranges relative to the higher frequencies.

Option: Use UHF Near-Field tags approved for use in water-filled containers like the Alien SIT tag. The read range will be very short, but these tags will still read. NOTE: there is no guarantee that this will work consistently for an application; testing is always key.

What's the Problem?

Liquid in the Environment

Whether the application is outdoors near lakes or ponds, or indoors around water tanks or water-filled machinery, liquid can play a role in an RFID application because it absorbs RF energy.

How can you mitigate it?

Option: Use Low Frequency (LF) RFID instead of High or Ultra-High Frequency. LF RFID does not have the issues with water that higher frequencies struggle with, so it can be used for animal tracking or water-filled items. Again, the downside is slower data transmission speeds and shorter read ranges relative to the higher frequencies.

Option: Set up the RFID system with extra hardware to ensure that the necessary RF energy gets to the tagged objects and not significantly absorbed by the liquid. RFID Power Mappers are a great tool for measuring UHF RF energy in any given area and determining if enough energy is reaching the designated read zone.

Metals and RFID

Metal reflects RF waves.

What's the Problem?

Tagging Metal Objects

How can you mitigate it?

Option: Use metal-mount RFID tags which are produced specifically for tagging metal surfaces. Examples of metal-mount tags are the Omni-ID Exo 750, Xerafy Micro XII, and the Vulcan Custom Universal Asset Tag.

Option: Place an embeddable, metal-mount tag into a drilled or pre-made hole in the object. In some applications, embedding works even better than adhering on the object (such as in rugged environments). When embedding an RFID tag, always leave one side with no metal covering and protect it with epoxy or something similar to ensure it can be read. (NOTE: an RFID tag completely encased in metal cannot be read).

What's the Problem?

Metal in the Environment

Metal in the environment reflects RF waves, potentially creating null zones where the RFID tag cannot be detected. More metal in an environment will lead to an increased number reflections, ultimately causing multiple null zones.

How can you mitigate it?

Option: Place RF absorbing materials in front of metal objects to absorb the RF waves instead of reflecting them back into the environment. RF absorbing materials can be substances like carbon-loaded foam and polyurethane foam.

Option: Set up the system with extra hardware to ensure that the necessary RF energy gets to the tagged objects. RFID Power Mappers are a great tool for measuring UHF RF energy in any given area and determining if enough energy is reaching the designated read zone.

Fluorescent Lighting and RFID

Fluorescent lights can reflect RF waves, but only when the lights are on.

What's the Problem?

Fluorescent Lighting in the Environment

Fluorescent lights can, in some instances, reflect RF waves causing null zones. Fluorescent lights become more of a problem the closer they are to the RFID system or tagged object.

How can you mitigate it?

Option: Using RF absorbing materials, such as carbon-loaded foam, between the fluorescent lights and the RFID system will allow the RF waves from the lights to be absorbed effectively negating interference.

Option: Because fluorescent lights only affect an RFID system in close proximity, the lighting could be moved or replaced with LED or incandescent lighting (if possible).

Option: Set up the system with extra hardware to ensure that the necessary RF energy gets to the tagged objects. RFID Power Mappers are a great tool for measuring UHF RF energy in any given area and determining if enough energy is reaching the designated read zone.

RF Waves and RFID

Additional RF waves can cause reflection and null zones.

What's the Problem?

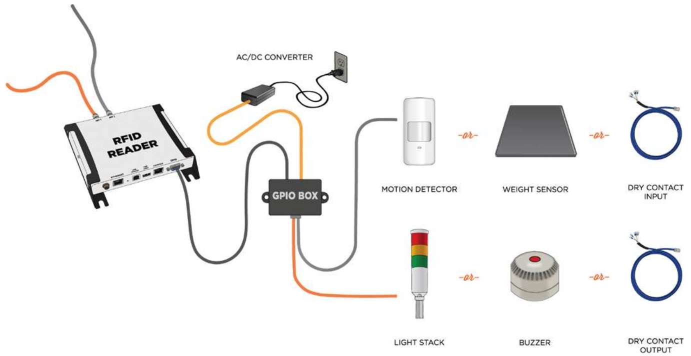
Additional RF waves in the environment
Other RFID applications or machinery that emit electromagnetic waves can create additional RF waves in the environment that create null zones and difficulty reading RFID tags.

How can you mitigate it?

Option: RF shielding or absorbing material like carbon-loaded foam can be used to separate the waves from the two systems so that there is little to no interference. To find out if there are existing UHF electromagnetic waves in the application environment, try using an RF Power Mapper that detects RF energy and then map out where exactly it is. Then shielding can be installed to keep the waves from interfering with the RFID system.

GPIO Capabilities

Most fixed RFID readers have a GPIO port, or General Purpose Input / Output port, that enables additional functionality, such as visual or audio signals. Unlike other ports on RFID readers, the GPIO port has only two settings – high (i.e. "on"), or nothing. The high signal acts as a trigger for GPO devices because it sends voltage through the port to trigger them to perform a certain action; likewise, an incoming high signal from a GPI device can act as a trigger the reader uses to perform a predetermined action.



RFID SYSTEM *with* GPIO DEVICES

What is a GPIO device?

A GPIO device is a device that performs actions based upon triggers sent by the RFID reader, providing additional functionality like audio or visual signals. Most fixed RFID readers have GPIO ports that allocate certain voltage levels to input and output electric signals. Within each GPIO port are several pins and each pin either outputs or inputs a trigger signal.

The number of pins in a GPIO port varies with the RFID reader, and it is important to note how many pins exist because most GPIO devices require 3, 4, or more pins in order to operate. It is also crucial to understand the amount of voltage each pin will provide to the GPIO device. Some readers' GPIO ports do not allocate enough voltage to power a GPIO device. In those cases, even though the reader has a GPIO port, a GPIO box is necessary to power to the device.

When to use GPIO Devices and GPIO Boxes

GPIO boxes provide convenient access and power from a reader's GPIO port to a GPO, or General Purpose Output device. Like a GPIO device, the GPIO box wires directly into the GPIO port on an RFID reader, the GPIO box itself does not provide any additional functionality. GPIO boxes provide AC/DC power if the RFID reader does not provide enough voltage to power the allotted GPO device and it provides the user an easier way to hardwire the GPIO device. Unless the GPO device is small and uses minimal voltage such as a small LED light, an RFID system using GPO devices will likely need a GPIO box.

GPI devices, or General Purpose Input devices may not require a GPIO box because they utilize a different source of AC/DC power to operate. Because these devices perform an action before the reader is involved, they must be powered by a source other than a reader or GPIO box. However, some RFID systems might use a GPIO box for GPI devices for the ease of access that GPIO boxes provide for wiring.

Why use a GPIO device?

As mentioned above, GPIO devices provide additional functionality that can improve an application. Many different types of devices can be added to an RFID system by way of a GPIO port such as stack lights, motion detectors, buzzers, and indicators. Below are examples of where an application could benefit from a GPIO device.

Stack Lights – GPO, Output - Because there are a variety of available colors in most stack lights, these devices can often be seen in a security or access control application. In a high security area, the ability to have one light turn green when the reader detects a valid RFID tag/card and one light turn red if it doesn't, adds easy visibility for staff.

Motion Detectors – GPI, Input – For RFID systems in manufacturing or warehousing applications, a motion detector can be used to send an input signal to tell the reader when to begin transmitting in order to read RFID tags. Such functionality works well in applications with randomly timed tagged objects moving through a certain area like a dock door.

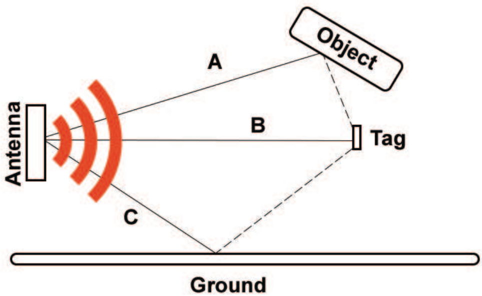
Who uses a GPIO device?

Anyone that uses an RFID system that would benefit from alerts or indicators no matter the application can use a GPIO device. If additional voltage is needed to drive a device, or a user would like an easier way to work with device wiring, external GPIO boxes are available.

Multipath

If you currently have an RFID system, or are thinking about purchasing one, there are a few terms that should be in the back of your mind when you start setting up your system.

The RF energy that your reader generates is sent out in electromagnetic (EM) waves and like any wave, their propagation is impacted greatly by their surroundings. Some travel in direct lines, and some move out at different angles from the bore sight (or center of the antenna). In order to better anticipate the paths RF waves travel in your system, you need to have a deeper understanding of EM waves.



EM waves, just like light waves, water waves, and sound waves react very differently in diverse settings. Below are a few reactions that these waves have with specific objects and materials which could drastically impact the performance of your RFID system.

Common Wave Reactions

Reflection

Like all waves, EM waves reflect off of specific materials at the same angle (angle of reflection) that they approached the material (angle of incidence). EM waves are reflected from metallic surfaces, as well as dielectric surfaces such as dirt, wood, ice, asphalt, cardboard, paper, glass and concrete. Wet surfaces also provide better reflection such as pools, oceans, lakes, or even pitchers of water. Reflection can be avoided by blocking any metallic or dielectric surfaces, or adjusting your read range sensitivity on your reader.

Refraction

Not as big of a concern as reflection in RFID systems, refraction is when the EM waves pass through a specific material at an angle and changes angles when it passes through. A typical example of refraction is when light waves pass through water and propagates at a different angle through the water. Water and other dielectric materials between the tag and antenna can refract the EM wave.

Diffraction

When RF waves seem to bend around objects instead of passing through them, it is called diffraction. Metal poles, corners of buildings, and other corners of metallic objects are where this is seen the most.

Absorption

When an EM wave is absorbed by the object that it is sent toward it is called absorption. Specialized absorbent material like carbon loaded foam for example work well to absorb EM waves. Water and most materials absorb RF waves to an extent as well as refracting, reflecting or diffracting.

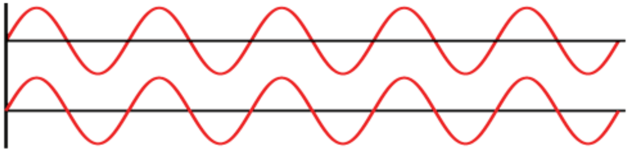
Multipath

The definition of multipath is "when two or more favorable radio paths exist between the reader antenna and the tag." When the reader sends a signal to the antenna to 'ping the tag' the antenna doesn't just send one beam of RF waves straight forward. The reader antenna sends waves on several different paths in order to pick up the tag's signal. This is where reflection, refraction diffraction and absorption come into play.

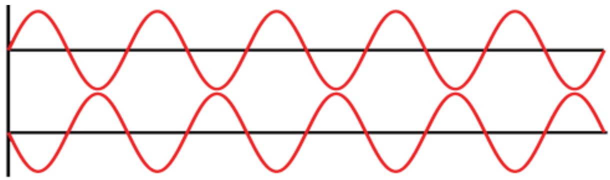
Each path besides the direct path is at a small angle from the center and has a high probability of experiencing reflection, refraction, diffraction or absorption depending on the materials or objects in the vicinity. That poses a problem when you have more than one tag in the read field, and you only want to read a specific subset of tags. One way to mitigate this problem would be creating a tunnel type of enclosure with RF shielding materials. For example, if you were using a conveyor belt RFID system to read tagged boxes on the warehouse floor, but only want to read the specific set of tags coming through the conveyor belt, installing the reader antennas in a contained tunnel will create a boundary from the effects of multipath.

Another problem area with multipath is if the direct RF wave intersects with another RF wave with a different phase, it will create a null spot in your read field. Null spots can occur multiple times in your read zone. In a null spot, your RFID tag will not be read by the antenna because the out of phase waves will cancel each other out.

The phase of a wave is defined as the distance between the first zero-crossing and the point in space defined as the origin. That basically states that if the waves have the same frequency and do not intersect each other, the waves are 'in phase'. If you have two waves that either have two different frequencies or do intersect each other, these waves are called 'out of phase'. See the drawing below for more information.

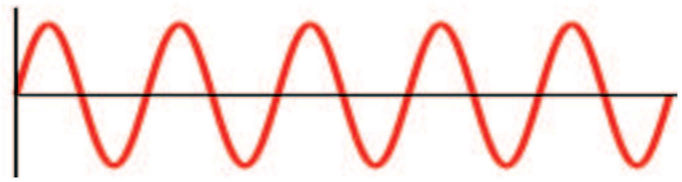


The waves above are 'in phase' waves



The waves above are 'out of phase' waves

In-phase waves will intersect in the same phase, thus creating constructive interference. You can see below that constructive interference strengthens the wavelength making it possible to read well outside the normal read range of that antenna. An example of that would be if your antenna typically reads around 6 feet, in one area where two RF waves come together at the same phase, your antenna would be able to read a few feet more.



Above: Constructive interference of 'in phase' waves, increasing read range

Below: Destructive interference of 'out of phase' waves, causing a null area in the read zone

Determining the exact area that is a null zone or an extended read zone is not a trivial process. In order to determine these areas, you would have to move the tag around on the x, y, and z axis.

All of the information about EM waves and multipath above can help you to anticipate how to get the most out of your RFID system. If you effectively design the area surrounding your system, you can avoid the different effects of multipath.

Testing

Testing is key to launching a successful RFID implementation. While RFID works well in a wide variety of environments, testing is necessary to find the optimum RFID tags, readers, and antennas for your application and environment.

Testing is a simple, low-cost, and effective way to see if your idea for your business can improve your operations without having to make a major purchase decision.

Testing is extremely important because there are many factors that can affect the ability to read RFID tags consistently – the environment in which the tag is being read, the orientation of the tag on the object, the antenna gain, and reader settings are just a few of the factors that can affect your ability to capture reads.

There is not one RFID tag, reader, or antenna that works best for every situation. Most products have been created to fit a specific need because every business situation will be unique in some way. For example, if you are tagging a cardboard box, you'll use a very different tag than if you are tagging a steel beam.

So, before assuming RFID is right for you and spending a lot of money on readers, tags, antennas, and the software necessary to bring it all together, start small.

Customizable RFID tag sample packs and development kits are a great place to begin. Tag sample packs can be customized specifically for your application – combining an assortment of tags that should perform well in your situation. During your testing, a customized sample pack will make it easier to select the tag that works best with your operation.

An RFID development kit is a low-cost and effective way of testing your idea before you make a major purchase decision. Each development kit is a little different, but all development kits include:

- An RFID reader
- An antenna (which is sometimes integrated directly into the device)
- An antenna cable (if the antenna isn't directly integrated)
- Tag samples, and
- Access to the testing software you will need to get started.

The four major categories of RFID Development Kits are 4-port reader development kits, integrated reader development kits, USB reader development kits, and handheld reader development kits. Each type of development kit has its own pros & cons and some fit certain applications better than others.

The four-port reader is great for applications where you will need lots of coverage. The four ports allow users to attach multiple antennas to a single reader (depending on the reader and setup, the number can range from 4 to 32 antennas). With the ability to attach additional antennas, users can cover more ground and have the added flexibility of being able to choose from a wide array of antenna options. Depending on the kit selected, you have options for Wi-Fi and Power-over-Ethernet.

The integrated reader is a lower-cost option than the four-port reader. It has an antenna integrated inside of it, as well as an additional antenna port which gives users the option to add another antenna if needed. If you only need one or two antennas, this may be the best option for you. Like the four-port readers, you also have Wi-Fi and Power over Ethernet options.

The USB reader is the least expensive of the RFID readers and is a great fit for desktop and close proximity applications. It is also a great fit if you are just getting into RFID and want to start with an inexpensive option. Because of its size and power output, its read range is much less than any other reader. Additionally, due to having a serial connection, USB readers must be connected to a host computer and cannot be placed on a network like other RFID readers.

The handheld reader is a mobile RFID reader with an integrated antenna. It is great for applications where you are on the move, and don't want to be restricted to a single point for reading tags. Most handheld readers also have the ability to read various types of barcodes. Because many units are also full-fledge mobile computers, they are typically the most expense type of RFID reader you can buy.

As I mentioned earlier, a development kit is great for testing because it allows users to try out different approaches to various applications. With the ability to test multiple types of antennas and tags, an RFID Development kit can help you asses your business idea to see if RFID can improve your operation without spending a tremendous amount of money.

Challenges

Facing challenges when installing a new system or procedure is expected, but it helps to consider potential problems before installation. Large and small companies, as well as individuals, thinking about installing an RFID system have numerous things to consider before making a purchase. If the potential user prepares thoroughly and completes enough due diligence up front, it should reduce unplanned issues mid and post-installation. Unfortunately, even the most prepared organization might run into a few issues during installation due to the unpredictable nature of RFID when implemented in a new environment.

Deploying an RFID system can present many challenges; below are the four most common challenges (and ways to mitigate them).

1. When your business problem is non-existent

One of the most important things to consider when thinking about RFID is – be realistic when it comes to the problem that needs to be solved. When considering automating a process, the first step is to take time to understand what the business problem is currently and how the business would be affected if a part of the process, or the entire process, were automated. Would it save time, money, or both, and what would those savings mean in terms of a return?

Other important factors to consider are the advantages that RFID has to offer and if RFID technology is necessary for the application to accomplish its goals. One of RFID's most important characteristics is that the technology uniquely identifies items (or crates of items) without requiring line of sight, making it exceptionally productive in applications like inventory and asset tracking. For example, finding a particular wrench, or group of wrenches, in a truck filled with hundreds of tools can be invaluable.

Understanding that a process is in need of automation is step one, but step two is asking the question "Do I need to uniquely identify items in my application, or is item 100006 any different from item 1555562?"

While problems can start out as small and grow until they reach a substantial size, generally speaking, small problems usually do not receive the return on investment (ROI) needed to offset the initial (and potentially ongoing) cost of installing an RFID system. Sometimes, automating a personal (i.e. non-business related) problem may lead to a very lucrative product or process, but because RFID systems are still relatively expensive, careful analysis should be undertaken in order to ensure RFID will produce a significant ROI.

2. When you are working in an extremely non-RF-friendly environment

The most common dilemma with RFID is environmental issues – whether that be non-RF-friendly substances like metal or water, or a generally unconducive environment. Environmental considerations can impose many limitations when discussing an RFID system deployment, but these considerations don't necessarily erase any chance of RFID success. Depending on the specific environmental concerns, there are usually a few ways to mitigate the problems and ensure a successful RFID application.

Mitigating Metal – Metal reflecting RF waves is one of the most common sources of interference experienced with RFID. The interference occurs because of the movement and reaction of electromagnetic waves with other surfaces, also called multipath. In other words, RF waves sent from the reader/antenna to the tag collide with objects or other RF waves causing refraction, diffraction, absorption, null zones, or extended read zones.

If a long read range isn't necessary, Low-Frequency (LF) or High Frequency (HF) RFID may be a solution instead of Ultra-High Frequency (UHF) RFID because these two frequency ranges perform better around metal (this is especially true with LF RFID). If longer read ranges are necessary, incorporating metal-mount tags onto metal items and introducing RF blocking materials or shielding are two ways to improve the functionality of an RFID system.

Mitigating Water – Mitigating problems with water-filled items is less complex than mitigating RFID applications that are exposed to water. Tracking items that are filled with liquid including bottles, barrels, and even the human body can be done if the right precautions are taken. For example, adding a small piece of foam between the tag and the water-filled item can usually improve read range significantly.

RFID tags and equipment that are exposed to water pose an entirely different problem. Hardware exposed to water will typically need a higher IP rating and, if an RFID reader is involved, sheltered from direct water exposure. This can be accomplished with the use of antennas and cables rated for outdoor use and, for readers, weatherproof enclosures. Additionally, RFID tags exist that are rugged enough to be exposed to water, like rain and snow, without a problem, but they are more expensive than inlays or paper RFID tags.

Underwater RFID applications are few and far between. The only type of RFID tag that can be read through water is a tag that uses magnetic coupling to communicate with the reader, such as LF technology. Even then, the read range will not exceed more than a few centimeters and should be thoroughly tested before implementation.

Besides water and metal, other factors, such as magnetic fields, may also play a major role in affecting an RFID system. The best way to determine how much read range an RFID system will receive is through thorough testing. It is also a smart idea to map out the area to get a better understanding of where RF waves might reflect, refract, or absorb.

3. When your budget is below a certain threshold

RFID is a technology that has the ability to change the way that people interact with items, but it comes with a cost. Over the years, RFID tags and hardware have gone down in price and have become more accessible to consumers; however, the technology is still not inexpensive enough to justify buying a system without first calculating the potential return on investment.

Most RFID systems are different and can include an array of hardware options, from a couple of fixed readers, antennas, and GPIO adapters, to one handheld reader with a built-in antenna. Before purchasing any system, it is important to understand the general cost breakdown for an RFID system.

Start-up (i.e. near-term) costs and recurring (i.e. long-term) costs are both very important to consider. Start-up costs are described as the amount spent to get an RFID system up and running as well as integrated with current systems. Start-up costs include readers, tags, software, and other hardware equipment. Recurring costs such as software contracts, and consumables are costs that reoccur monthly or yearly that keep an RFID system up and running.

Development kits and sample packs of tags are a good way to get started with RFID before investing too much money. Purchasing a development kit and sample pack is a cost-effective way to see if an RFID system could be the solution to the business problem at hand.

4. When the new system needed to be installed yesterday

Unfortunately, RFID is not exactly a "setup and go" technology; so, if an organization determines that RFID is a good fit, then it needs to plan ahead. Failing to plan ahead will usually lead to project delays and increased costs. In the worst case, the project could be 'scrapped' altogether if expectations aren't met quickly enough.

In order to properly implement RFID, consumers must choose the best fit equipment and tags and then test thoroughly. As a best practice, time should be spent before purchasing to fully vet the hardware and tag options available in order to learn about potential pros and cons. After readers and antennas are selected, purchasing a few different types of tags for testing is strongly recommended. Ordering various types in small quantities allows for flexibility during the testing process.

Rushing through purchasing and testing could lead to larger problems down the road. Sometimes the installation and testing can take several weeks or months, but that extra time will pay dividends later.

RFID Concepts Worksheet

1. In terms of RFID, what is regulated?
    a. Frequency range of transmissions
    b. Power levels of emissions
    c. Antenna Gain
    d. RFID Readers, Active Tags, and Certain Passive Tags
    e. A, B, & C
    f. A, B, & D

2. Which of the following frequencies within the UHF RFID range is certified for use in North America?
    a. 865 - 960 MHz
    b. 865 - 868 MHz
    c. 902 - 928 MHz
    d. 956 - 965 MHz

3. What is the difference between Effective Radiated Power (ERP) and Effective Isotropic Radiated Power (EIRP)?
    a. ERP refers to gain in relation to a half-wave dipole and EIRP refers to gain in relation to an ideal isotropic antenna
    b. EIRP refers to gain in relation to a half-wave dipole and EIRP refers to gain in relation to an ideal isotropic antenna
    c. ERP refers to gain in relation to a full-wave dipole and EIRP refers to gain in relation to an ideal isotropic antenna
    d. ERP and EIRP are pretty much the same thing

4. Why is it important to calculate output power?
    a. To ensure that you are getting the right read range

b. To ensure that you are on the right frequency
c. To ensure that you are receiving backscatter from the tag
d. To ensure that you are not violating regional regulations

5. If your system's output power is too high, you can reduce it by:

   a. Using a longer and less insulated cable
   b. Using a smaller tag
   c. Using a reader with less antenna ports
   d. Using an antenna with a lower gain
   e. A & C
   f. A & D

6. How do you avoid Reader Collision?

   a. Frequency Interaction
   b. Frequency Hopping
   c. Reverse Engineering
   d. Increase Security Measures

7. What is Gen2 short for?

   a. Class 2 Generation 2
   b. Class 2 Generation 1
   c. Class 1 Generation 2
   d. None of the above

8. Which of the following is not a security feature on Gen2 Tags?

   a. Serialized TID numbers
   b. Serialized EPC numbers
   c. Access Code
   d. Kill Code

9. Which of the following is the correct order of steps for locking Gen2 tags?

    a. Lock the selected memory bank, Write the access password, Lock the access password
    b. Write the access code, Perma-lock the access code, Lock the kill code
    c. Write the access code, Read the access code, Lock the selected memory banks
    d. Write the access code, Lock both the kill and access codes, Try to read the tag

10. ______________________ are a certain set of rules that govern the exchange of data through a communication connection.

    a. Readers
    b. Reader Interfaces
    c. Proprietary Interfaces
    d. Protocols

11. What is the difference between an API and an ALE?

    a. API's are interfaces while ALE's are events and other related data
    b. API's are integrations while ALE's are events and other related data
    c. API's occur within ALE's and basically jump start the coding process
    d. API's occur within ALE's and filter out repeated data

12. Which four environmental elements cause problems with UHF RFID?

    a. Liquids, Metals, All Lights, and Additional RF Waves
    b. Liquids, Metals, Fluorescent Lights, and Additional

RF Waves

c. Liquids, Metals, UV Lights, and Additional RF Waves
d. Liquids, Metals, Halogen Lights, and Additional RF Waves

13. Which of these is not a reason to use a GPIO Box and/or Device?

    a. Provide additional functionality
    b. Provide additional power
    c. Provide additional visibility
    d. All the above are valid reasons
    e. None of the above are reasons

14. How does Multipath affect an RFID System?

    a. By creating multiple paths of resistance between the reader and antenna
    b. By creating multiple paths of resistance between two readers
    c. Waves propagate between the reader and the tag in multiple paths, reacting to their surroundings and causing a variety of consequences.

15. Which one of the following is not a result of multipath?

    a. Destructive Interference
    b. Constructive Interference
    c. Angle of Incidence
    d. Null Zones

16. What is the most important part of launching a successful RFID implementation?

    a. Testing
    b. Using UHF RFID

c. Accounting for Cable Loss
d. Staying under budge

17. What are the four most commonly faced problems when deploying an RFID system?

    a. Being Unrealistic, Wasting Time & Products, the Environment, Testing Procedures
    b. Being Unrealistic, the Environment, Budget Restrictions, Testing Procedures
    c. Being Unrealistic, the Environment, Budget Restrictions, Lack of Proper Planning
    d. Being Unrealistic, Saving Time, the Environment, Lack of Advanced RFID Knowledge

18. Is RFID necessary for every business problem?

    a. No, RFID cannot solve all problems and have a return on investment
    b. No, RFID cannot solve all problems without an additional integrated technology
    c. Yes, automation is the future
    d. Yes, RFID varies in cost - small systems for small problems

19. Which of the following is a way to mitigate environmental issues?

    a. Using a different type of RFID
    b. Incorporating specialty tags
    c. Introducing shielding and RF block materials
    d. All the above
    e. None of the above

20. What two items are a good way to get started with RFID before investing too much money?

    a. Readers & Antennas
    b. USB Reader & Sample Tags
    c. Development Kits & Sample Tags
    d. An Integrated Reader & Sample Tags

Answers: 1) F; 2) C; 3) A; 4) D; 5) F; 6) B; 7) C; 8) B; 9) A; 10) D; 11) A; 12) B; 13) D; 14) C; 15) C; 16) A; 17) C; 18) A; 19) D; 20) C

Deploying RFID: 20 Questions & Answers

How do I know if RFID is right for my application?

There are several steps required to answer this question.

1.) Define the Business Problem

Before considering RFID as a potential solution, a company should first seek to understand its business problem. The problem may be as simple as "I can't find my items when I need them"; however, pinpointing the root of the problem and considering all the various associated pain points is a critical first step. A well-defined problem leads to a well-defined solution, including any goals a company is looking to achieve. Properly defined problems are easier to scope and solve, which leads to saving time, money, and resources, and allows for determining if RFID will be a necessary part of the solution (or not).

2.) Complete Internal RFID Testing (or hire an RFID expert to complete a site survey)

All facilities are different, especially when considering the environmental factors which play an important role in the success of an RFID system. Through individual testing or consulting with an RFID expert to conduct a site survey, each potential read zone in a facility should be examined in order to determine:

- Which challenges exist that would never need to be overcome if an RFID system were to be deployed?
- Which specific types of readers, tags, and antennas would be required in order to achieve a company's goals?
- Which process changes (if any) would be required in order to ensure RFID tags can successfully be read?

3.) Establish a Business Case (i.e. determine the cost of an RFID solution and complete an ROI assessment)

After defining the business problem to be solved, setting related goals, and thorough testing or site survey analysis, a company should have enough information in order to estimate how much a system should roughly cost. Whether borne internally or purchased externally from a third party, estimated costs should cover all necessary hardware, software, installation, and support, as well as any ancillary services that may be required to get a system up and running (e.g. running network and power drops, installing bollards to protect equipment, etc.). Special attention should be paid to initial system setup costs vs. potential on-going costs (e.g. consumable RFID tags, annual support) when calculating all costs for an ROI analysis. From there, a company should complete an ROI assessment, effectively weighing the costs of implementing a system vs. the expected return on investment (assuming the given system will achieve the predefined goals).

4.) Determine Feasibility

There are two main reasons that RFID might not be suitable for a specific application:

1. **Application Feasibility** – from an environmental or pure physics standpoint, it may not be possible to deploy an RFID system that is able to capture RFID tags reads with enough success to meet a company's goals.

2. **Cost/ROI Feasibility** – RFID might work well for the application, but the ROI isn't significant enough to justify implementation of the technology.

Is there a chance RFID won't work for me?

Yes, RFID is not the answer for every application. The application itself must be feasible from an environmental perspective as well as a cost perspective. For example, if there are temperature or pressure extremes that could destroy RFID tags, or if an RFID system's costs outweigh the value added, then RFID shouldn't be implemented. Ideally, such aspects would be determined during the business definition and scoping process.

How much will an RFID system cost?

Because RFID systems can differ greatly in size from one handheld reader and a few tags to hundreds of readers and antennas and thousands of tags, there isn't a particular cost (or range of costs) that can be determined without some sort of analysis. In order to get an estimate for a specific system, it is important to consider both near-term and long-term costs.

There are two different classifications of costs for just about any RFID system – start-up (i.e. near-term) costs and recurring (i.e. long-term) costs. Start-up costs can be defined as the amount of money spent in order to get an RFID system up and running and integrated with any other current systems. Recurring costs are ongoing costs that are needed in order to keep a system functional; these costs can recur weekly, monthly, or yearly.

Some examples of start-up costs might include:

- RFID Hardware - Readers, antennas, cables, etc.
- RFID Tags - Reusable tags for fixed assets or tags for one-time purchase
- Software - Custom development costs and/or initial license cost
- Services - Installation and testing/tuning
- A few examples of recurring costs could include:
- Support Contract - For additional support for a defined period of time for the system
- Software - Annual maintenance fees
- Consumable Supplies - RFID tags (if they can't be reused), printer ribbon, etc.)

Can I try RFID before investing in a full system?

Yes, RFID development kits and RFID tag sample packs are an ideal way to test RFID and see if it will work well for a specific application. Complete RFID solutions can be expensive, so starting small and thoroughly testing is a best practice before investing a lot of time or money.

Development kits include all the basic RFID equipment needed in order to set-up and test an RFID system. Most RFID development kits come with a reader, one or more antennas, some sample tags, a sample program for reading, encoding, and testing RFID tags, as well as access to the reader's SDK (i.e. software development kit –documentation, API access, and code samples).

RFID tag sample packs provide a cost-effective way to test different RFID tags and find the ideal one for each application. Testing multiple tag types and sizes is an important and necessary task to ensure optimum performance from the RFID system.

What do I need for a full system?

Most RFID systems consist of the same basic elements:

- Readers - An RFID reader is the "brain" of the RFID system and necessary for any system to function. Readers, also called interrogators, are devices that transmit and receive radio waves in order to communicate with RFID tags.
- Antennas - RFID Antennas are a necessary element in any RFID system; however, they are "dumb devices" which use power from the reader to generate an RF field allowing the reader to transmit and receive signals from the RFID tags.
- Tags - An RFID tag, in its most simplistic form, is comprised of two parts – an antenna for transmitting and receiving signals, and an RFID chip (or integrated circuit) which stores the tag's ID and other information.
- Software - Software is essential to all RFID systems. Software allows the reader to operate and communicate with RFID tags, the data collected from tag reads to shown, sent, stored, etc. so that users can make informed decisions and take actions, or can trigger other systems to take preprogrammed actions. Ultimately, software can be as simple or complex as required by the application.

In addition to the basic elements, some systems may also require ancillary devices, such as stack lights, motion sensors, and other GPIO devices. The total amount of hardware and software required will ultimately depend upon the system requirements.

How do I choose my RFID hardware?

A large selection of RFID hardware is available and specific types of RFID equipment are better suited for certain environments; so, choosing the right hardware for any given application can be a tedious process. In any situation, once a selection is made, rigorous testing is key to ensure success.

How do I choose my RFID tags?

There are hundreds of passive RFID tags on the market, so choosing the right tag (or set of tags) for any given application can seem like a daunting task. Similar to choosing RFID hardware, selecting the right RFID tag can be accomplished by narrowing down options using certain criteria. Once a set of tags is selected, thorough testing is necessary to ensure success.

Can I get RFID Tags pre-printed and pre-encoded?

Yes, most RFID tags can be pre-printed and pre-encoded, which saves a company time and money. Printing and encoding RFID tags is a custom process and usually adds additional lead time to an order.

What sort of software will I need for my RFID system?

Few off-the-shelf (OTS) software packages specifically geared towards RFID solutions are available for purchase. As the market matures, more OTS software options will become available for various RFID applications. Until then, most companies will likely need a software solution customized to meet their needs.

Custom software can be as simple or complex as the company desires. In many cases, it makes sense to start small with the basic necessary functionality, while architecting the software to accommodate for future expansion of all desired features and functionality. As the RFID application matures, so can the software. This crawl-walk-run methodology allows a company time to become familiar with the ins and outs of its application and better determine exactly what features and functionality will be of most use.

Can I setup an RFID system without software?

In short, no. Even on a small scale, software must be incorporated in some fashion. For example, basic functions such as reading and writing tags will require software; otherwise the reader will not know which tags to write, or which tag reads to report to the system.

Software can be as simple or as complex as needed. As part of the initial project scoping process, defining software requirements should be one of the top priorities. Depending on requirements, some commercially available off-the-shelf software (such as the Impinj Speedway Connect Software) may be all that is needed. Other times, the project may require custom software development to meet all specifications.

Do I need a software engineer on staff?

Every company looking to implement RFID does not necessarily need a software engineer on staff. If a company has defined its business problem and successfully defined the project scope (including software requirements), it can begin to look into commercially available software options.

If requirements are not met by commercially available software, utilizing a software engineer may be the next best step. Whether allocating an existing internal resource or hiring an outside resource, a company will need to employ a software engineer (or engineers) to develop a custom software solution for its RFID system.

Who installs the RFID system?

If the purchasing company has a technical team with RFID experience (or, at least, superior technical abilities with the time and ability to learn about RFID), that team should be capable of testing and installing an RFID system. Without sufficient RFID experience or superior technical knowledge and ability, there is a strong likelihood that an RFID system could be setup incorrectly and not provide the desired results.

If a company isn't 100% confident in its ability to provide the necessary RFID implementation team, then that company should partner with an RFID professional (or team of professionals) in order to ensure the RFID installation is a success.

Is there a recommended way to set up RFID hardware and get started?

Because every facility is different, there isn't a specific way to set up an RFID system and guarantee that it will provide the desired results. A best practice when setting up each and every read zone is to spend time testing and tuning until:

a.) 100% (or near 100%) of RFID tags are read when they should be read.

b.) Stray reads are avoided (i.e. unintended tag reads from another area being captured in the zone being tested).

Defining the ideal read zone for any given application is dependent upon many factors including reader settings, antenna gain, and RFID tag selection. Learn more by reading about the 6 factors that affect read range.

Because even small changes in an environment can have large effects on an RFID system, there is no guarantee that a particular zone (once tuned) can simply be replicated throughout a facility. Ideally, the settings for a well-tuned read zone setup can act as a starting point from which each additional read zone can be tested and tuned.

In short, no – there is no ideal recommended way to setup RFID hardware. Each case is different and requires thorough testing. Below are a few helpful tips when setting up an RFID system for the first time.

- Keep the RFID reader and antenna(s) as close as possible in order to reduce the length of antenna cabled needed and, thus, cut down on cable loss.
- When mounting RFID antennas, test different locations and antenna angles in order to get the best results. Also, testing different types of antennas may be beneficial. During tag selection, do not simply settle for a tag that works. Test different types in order to find the ideal RFID tag (or tags) for your application.
- Test different settings on the reader (e.g. transmit power, search modes/sessions, etc.) in order to ensure best results.

How many read zones are needed and where will they be located?

In short, an RFID read zone should be located at every point it is necessary to gather data (i.e. every point where reading RFID tags is required).

In some cases, a portal-type setup at a dock door to read items going in and out may be the appropriate solution; in another, a single handheld RFID reader may be the best fit in order to scan items within an inventory closet. Moreover, installing read zones at various stages of a manufacturing process allows a user to know exactly where any given (tagged) item is on the facility floor. Some companies may only be interested in knowing if an item is in the facility. In these cases, read zones would only be necessary at the facility's entrances/exits.

Ultimately, the amount of read zones required and where those zones should be located depends on the type of application as well as the amount of data needed to achieve the desired results.

There are items in my facility that contain liquids/metals; does that mean RFID will not work for me?

As with any RFID application, thorough testing is key. There are certain methods and measures that can be put in place to mitigate potential interference caused by metal and water (as well as other interference causing elements).

If a company has limitations within the facility, environment, or items being tagged, it should not discount RFID as the solution entirely. Instead, limitations should be noted and thorough testing should be executed in order to see if such obstacles can be overcome using specific equipment or techniques. Each type of item to be tagged will have different specifications that should be noted when choosing the ideal tag. Some applications might require the use of several different types of RFID tags in order to get the best results.

What if I want to use RFID in my facility for more than one application? Should I have separate RFID systems?

The answer ultimately depends on the business case at hand.

If it makes more sense (from a business perspective – data access, user access, etc.) for the systems to be combined, then they should be combined. If the business case dictates that the systems should be separate or standalone, then they should be separate. The answer to whether a new RFID system should be combined with an existing one or a separate standalone system should be created, should be determined during the business problem definition and scoping phase of the project.

How long does a typical RFID system take to deploy?

The timeline for an RFID deployment can vary greatly based upon the type and complexity of an RFID application. A commercially available all-in-one RFID hardware and software solution could potentially be purchased and deployed within a few weeks. A custom RFID solution that addresses complex business problems and requires much testing and custom software development may take 6 to 12 months to fully deploy.

Below are the typical stages when deploying an RFID system:

- Define the business problem
- Establish the Business Case
  - » Project Scoping
    - Understand the potential and limitations of RFID technology
    - Define the project objectives
- Analysis of the Existing System
  - » Collect information
  - » Information analysis
- Develop a Project Road Map
- System Design
  - » Requirement analysis
  - Hardware/software selection

    - Develop a new process
- Proof of Concept
    - » Prototype Testing
        - Debug
        - System Adaptation
- Pilot Implementation
- Full Implementation
    - » System deployment
    - » Training
- Continuous Improvement
    - » Monitoring
    - » Collect feedback from users

How do I train my employees on RFID?

If a company decides to implement RFID within a facility, key employees should be trained on the basics of RFID – what it is, how it works, key limitations, etc. In addition, one or two persons should be designated as RFID "experts" and receive more in-depth training on RFID, such as classes offered by 3rd party companies.

The more employees are educated about RFID (and, in particular, the actual system being deployed), the more effective the system will be and a company should see fewer issues and errors.

When will I see a return on investment from my RFID system?

The amount of time between purchasing an RFID system and seeing a return on investment (ROI) will be different for each company and application. Ideally, a company will have already completed a feasibility analysis and ROI assessment before deciding to install an RFID system.

Depending on the value the system provides, a company may start seeing an ROI immediately. Full system payback depends on the cost of the system as well as the rate of return on investment; however, properly implemented RFID systems tend to fully pay back within 1 to 3 years.

Where can I learn more about RFID?

There are a few RFID books on the market that can be purchased in order to gain a better understanding of how RFID works. Additionally, there are multiple sources online dedicated to helping customers learn more about RFID:

- RFIDjournal.com - RFID Journal is a news website covering companies and applications around the world deploying RFID.
- RFIDinsider Blog - A go-to blog on all things RFID, specializing in news and knowledge for the beginner, intermediate, and advanced RFID enthusiasts.
- RFID Resources - An atlasRFIDstore webpage dedicated to eBooks, customer profiles, and videos for enhancing RFID knowledge.
- RFID Videos - atlasRFIDstore's YouTube page containing videos about how RFID works, RFID products, and tutorials.

Deploying RFID Worksheet

1. What are the two main reasons that RFID would not be suitable for an application?
   a. Application Feasibility
   b. Read Range Feasibility
   c. Integration Feasibility
   d. Cost/ROI Feasibility
   e. A & D
   f. A & B
   g. A & C

2. Which of the following is not an example of a Start-Up Cost?
   a. RFID Hardware
   b. Software
   c. RFID Tags
   d. Support Contracts

3. Which of the following is not an example of a Recurring Cost?
   a. RFID Hardware
   b. Software Licenses
   c. Support Contracts
   d. Consumable Supplies

4. True or False. RFID tags, like inlays and labels, can be pre-printed and encoded for my application.

5. True or False. RFID systems can be setup without software.

6. Where are the best places for RFID Read Zones within an application?
    a. At every entrance and exit
    b. At every point it is necessary to gather data
    c. At every 20 to 30 feet, dependent on read range
    d. It depends on the square footage of your warehouse

7. If the items you wish to tag have an element that is typically not RFID friendly, should you move on to a different technology/system?
    a. Yes, RFID will not be possible
    b. Yes, RFID will cost too much and take too much time
    c. Yes, RFID hasn't come far enough to mitigate this problem.
    d. No, RFID is evolving and metal mount tags and tags for tagging liquid-filled items are now offered - test RFID or speak to an RFID expert before moving on.

8. True or False. In general, a DIY RFID system can be fully deployed relatively quickly, only in a few weeks.

9. True or False. The more educated employees are on an RFID system, the more effective the system will be.

Answers: 1) E; 2) D; 3) A; 4) True; 5) False; 6) B; 7) D; 8) False; 9) True;

We’re atlasRFIDstore

atlasRFIDstore was founded in 2008. We started out as one person with a vision, and today our team numbers just over 35 talented individuals. We began life as part of a startup in Birmingham, Alabama’s burgeoning tech scene, and we’re proud to remain and participate in the revitalization of Downtown Birmingham.

Over a Decade in the RFID Industry

It probably comes as no surprise to you, but we’re big believers in RFID. We’ve been fortunate to ride the wave of RFID’s success and adoption across a number of industries. In that success, we see a lot of responsibility. We need to be good, honest ambassadors of RFID, which means we need to be experts in our field. Come to us with your questions, and we’ll provide you with answers.

We care about one thing: Our Partners (That’s You).

We’ve built our business around one core tenet, and that’s providing a superior customer experience. It doesn’t mean we’re perfect 100% of the time, but we’ll always take care of you. We take a lot of pride in helping both small businesses and huge, multi-national organizations alike. Our efforts go toward making sure your projects are as successful as possible.

We’re here to serve.

We try to be as accessible as possible, so you can contact us via phone, email, or chat. We’re typically in office during standard business hours (Birmingham is in the North American Central Time Zone). Even if we’re not online or in office, drop us an email, and we’ll respond within a business day.

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THE INSIDER'S GUIDE TO WORKING WITH RFID

The Insider's Guide to Working with RFID is a collection of the most popular and informative articles and guides found at RFID Insider, the widely regarded trade publication of atlasRFIDstore. These selected compositions range from RFID basics to intermediate topics and cover RFID concepts to frequently asked questions. Topics are arranged in an order that welcomes those new to RFID, but the book can be read in any particular order.

ABOUT THE AUTHOR

Suzanne Smiley is the Director of Content at atlasRFIDstore. She loves learning and writing about RFID and is a chief contributor to RFIDInsider.