BALLUFF

# CHOOSING RFID FOR INDUSTRIAL APPLICATIONS

## White Paper

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Choosing the proper Radio Frequency Identification system for use in industrial applications like machine tool, palletized assembly, or production tracking can be a confusing task these days. With all the information floating around about HF (High Frequency), UHF (Ultra High Frequency), microwave and GPS based systems, and whether to use active or passive based tags, it may seem like these systems can be used almost anywhere. However, failures because of a wrong or unreliable system can be very costly – many times in hundreds of thousands of dollars or more. Today, RFID is designed for many environments besides industrial, which can make it confusing as to what systems work the best.

Most RFID systems utilize the same basic hardware. This consists primarily of a read/write head (also known as an interrogator), coupled with a tag (also known as a data carrier) that is used to remotely carry data of some type. There is usually a processor used to convert the data from the tag to a common interface or bus in order to control processes and/or move data to or from databases. Depending on the system design, the processor may be remote from the head, allowing greater flexibility and smaller size, or it may be combined with the read/write head.

This paper explores what the best possible options are based on standard products available today, and how they are applied to get reliable data for the highest chance of success the first time. It also explains the basic principles of operation and how they will influence the performance of each type of system. The three most widely available RFID systems will be discussed:

| Definition | Frequency | Characteristics |
|---|---|---|
| LF - Low Frequency | 70 - 500 kHz | Short to medium read ranges, slowest read/write speeds, inexpensive, limited memory capacity, metal alloy resilient |
| HF – High Frequency | 13.56 MHz | Short to medium read/write ranges, fast read/write speeds, inexpensive to expensive, mid to high memory capacities |
| UHF – Ultra High Frequency | 865 – 960 MHz | Long read/write ranges, fast read/write speeds, inexpensive to expensive, limited to lower memory capacities |

Each of these frequency ranges provide advantages or disadvantages based on their characteristics, principles of operation, and application usage. The information presented in this paper should assist you in selecting the right RFID system for your application.

## Low Frequency

LF systems, as they have become known, generally operate between 70 kHz to approximately 500 kHz. These systems can vary greatly in cost depending on how proprietary they are. LF systems are typically station based. This means the tags (Figure 1) have data read and/or written to them at a specific "check" point in a process, typically by a read/write coil or "head". These systems are also commonly used as "read-only" systems for the purpose of data tracking only.


**Figure 1:Low frequency Balluff tag samples**

A read-only system typically uses a preprogrammed individual serial number normally no more than 5 bytes or 40 bits in data capacity. This data is used by a control system to track a transportation device such as a pallet. As the pallet with the tag moves from the beginning to the end of a process, the serial number is then associated with the part it carries during WIP (Work-in-Process), allowing data, generated during the process, to be collected in a central database referenced to the serial number on the tag. When the pallet is returned to the beginning of the process for a new part, the serial number is re-associated with the new part and the tracking process starts over again.

Most read/write versions of LF tags are limited to less then 200 bytes in data capacity, but allow you to write data to and from the tags when required. Many LF tags are EEPROM (Electronically Erasable Programmable Read Only Memory) and are therefore limited to around 100K write sequences, but can handle unlimited read sequences. To conserve memory, many control systems will use binary based values like pass/fail data to maximize the data capacity available on a tag. This also helps to minimize the amount of data requiring transmission, allowing for minimal dwell times at any one read/write station.

Most LF systems are based on inductively coupled technology. These systems are also known as passive and typically do not contain a power source like a battery. Instead, inductive coupling (based on Faraday's Law) powers the tag using energy generated from a coil in the read/write head to induce a voltage in the coil, thus powering it (Figure 2).

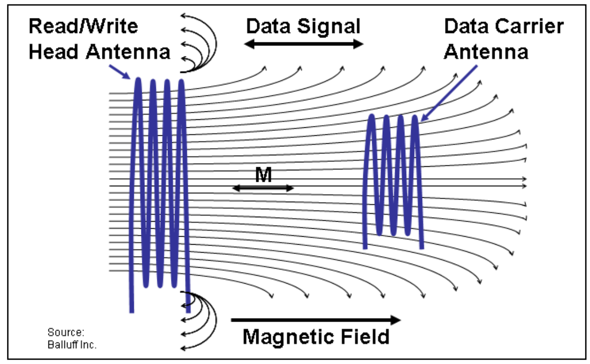


Figure 2: Inductive coupling example

Data transmission is typically done by changing one characteristic of an alternating field used to power the tag. For example, some manufacturers will use Pulse Coded Modulation to carry the data. This helps make the tags' data less susceptible to interference from other frequencies or simple magnetic forces.

LF systems can provide greater range performance, as much as 70 to 150 mm on non-alloy surfaces, and as much as 50 mm mounted on or in metal. For example, on a transportation pallet, there is less power degradation when the LF system is mounted on or flush mounted in a metal alloy. Due to the nature of a low transmission frequency, a LF system typically has the longest transmission time for a given block of data compared to HF or UHF systems. For example, to read a block of 4 bytes or 32 bits of data, a read process can take 180 milliseconds or more. To write the same 4 bytes of data can take 300 milliseconds or more. LF systems are typically not used in applications that require moving read/write or "on-the-fly" operation.

## High Frequency

HF systems typically operate at 13.56 MHz. These systems are usually based on either the ISO 14443 (also known as the Mifare standard) or the ISO 15693 standard. The benefits to these standards are that they can allow interoperability between several manufacturers of tags (Figure 3) and read/write hardware, though both standards allow the user to openly read the tags' unique serial numbers. Typically, most 14443 based tags have the user data memory password protected, ensuring that the user data can only be read by the manufacturer's hardware. Most of the time, the password is not accessible to the user.

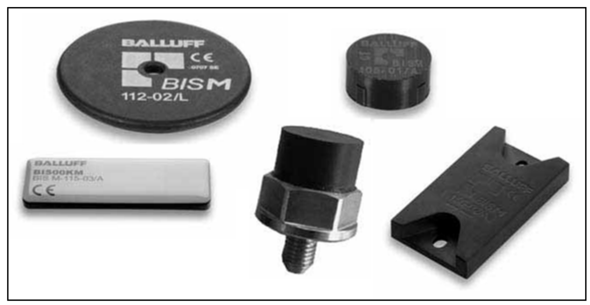


Figure 3: High frequency Balluff tag samples

Because of this standardization and commonality of hardware like tag transceivers, HF based systems also provide lower cost for the user than proprietary systems and can be comparable in cost to LF tags. HF systems are also generally station based like LF systems, where tag data is read and/or written at a specific "check" point in a process.
Unlike the LF based tags, HF tags typically see significant read/write signal degradation when mounted in a metal alloy, thus limiting range unless designed specifically for this purpose. HF read/write ranges can also be degredated by having metal in or near the field created by the head. There are exceptions where some manufacturers have created special tag and head antenna designs allowing minimal effects from metal.  These special tags and heads can use techniques like "rod" style antennas instead of coil antennas.

HF systems also have good range, as much as 150mm or more when mounted on non-metal allow surfaces. The range for HF tags mounted on or in metal is usually manufacturer specific. Because of the nature of their higher transmission speeds, HF systems can read/write tag data considerably faster then LF systems. For example, to read a block of 16 bytes or 128 bits of data, a read process can be completed in 30 milliseconds or less. To write the same 16 bytes of data can typically be completed in 60 milliseconds or less.

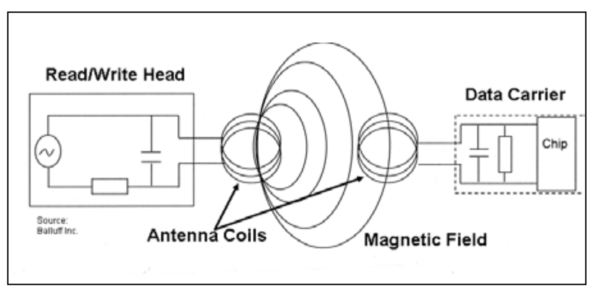


Figure 4: Near field" inductive coupling antenna example

HF tags are also available in two memory types, EEPROM with 800 bytes or less of user data memory capacity (like LF tags) or FRAM type. FRAM (Ferroelectric Random Access Memory) typically offers high memory capacity – 2K bytes or more and is not limited in write cycles making it capable of essentially unlimited read and write operations. Because of their higher read/write speeds, HF systems can be used for applications that require continuous movement at speeds of 3 meters per second or more, depending on the amount of data being transferred.

Because both LF and HF systems operate on the principle of inductive coupling (Figure 4), they operate in what's known as "near field". This means that these systems are less susceptible to interference from other adjacent systems and minimal distances are required between read/write heads compared to other RFID system types.

## Ultra High Frequency

UHF systems typically operate between 865 MHz and 960 MHz. Unlike LF or HF based systems, UHF systems are based on an operating principal known as “Backscatter Coupling” (Figure 5), where the reader uses a dipole antenna that transmits electromagnetic waves, creating mostly magnetic power, which is modulated and reflected from the dipole antenna of the tag (or sometimes also referred to as a transponder).

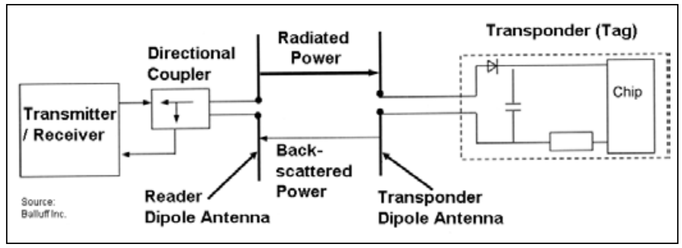


Figure 5: Back scatter dipole antenna example

This electromagnetic wave propagation is used for data transmission (Figure 6) and powering the tags, thus making them “passive”. Unlike inductive based systems, where the propagation waves transect (Example seen in Figure 6, wave patterns E & H), the signal can create a “dead zone” where a tag may not be powered or detected. Most UHF systems today are based on “Gen 2” (second generation) hardware and the tags will comply with the EPC (Electronic Product Code) data and memory standards. Gen 2 provides multiple frequency capability from a system based on what part of the world the system is located, making these systems very flexible in complying with international radio spectrum frequency usage restrictions. The EPC standard allows the data written to the tag to be referred to a common database to describe the product the data represents, similar to its UPC (Universal Product Code) barcode based counterpart.

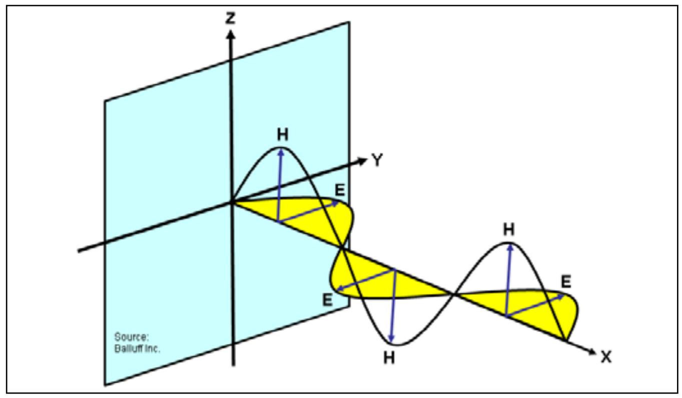


Figure 6: Electromagnetic wave propogation example

Some of the advantages of UHF over its LF or HF counterparts are that it can be used for much longer read/write distances, as far as 4 to 5 meters reliably, sometimes farther depending on antenna and tag designs. Because of the nature of the propagating wave transmission method, UHF can also be reflected off conductive or partially conductive surfaces like metal, water, concrete, etc. This reflection property can be helpful by causing the waves to be redirected around objects allowing greater flexibility, for example when locating and reading tags while mobile from a fork lift (Figure 7). But this can also be a disadvantage when trying to isolate a specific tag when a large quantity of tags are present in the field. The system will detect all of the tags in its field and can make isolating a specific tag difficult. It can also lead to reading the wrong tag because of reflected waves from another location. Newer “near field” forms of UHF are entering the market that may help resolve this condition.


Figure 7: Ultra high frequency Balluff tag sample

Read and write speeds with UHF can vary greatly and many vendors claim reads of 20 to 1000 per second can be achieved. But be careful as these claims can be misleading. There are many factors that can significantly reduce the reliability of such claims. A “read rate” is typically defined as the ratio of the number of times a tag is read per number of seconds reads were performed. Many times the only way to determine a reliable read rate is to perform a site survey and actually test the system’s performance with the environmental factors that can affect read rate performance.

Most UHF tags are divided into to memory spaces. There is typically an EPC space only, but some have a user memory area. Many lower cost tags are limited to 96 bits or bytes of data for the EPC data with no user data memory. There are tags becoming available now with user memory, but are generally limited to less than their LF or HF counterparts.

| | Machine Tool | Assembly Conveyors | Mold and Die Management | Logistics and Storage/ Retrieval | Asset Management | Access Control | Automatic Guided Vehicles | Anti-counterfeiting |
|---|---|---|---|---|---|---|---|---|
| Low Frequency | ✓ Best suited | ✓ Application dependent | ✓ Best suited | | ✓ Best suited | ✓ Best suited | ✓ Application dependent | |
| High Frequency | ✓ Application dependent | ✓ Best suited | ✓ Application dependent | ✓ Application dependent | | | ✓ Best suited | ✓ Best suited |
| Ultra-High Frequency | | | | ✓ Best suited | ✓ Application dependent | | | ✓ Application dependent |

Source: Balluff Inc. ✓ (green) = Best suited ✓ (yellow) = Application dependent No check means not recommended

Chart 1: Application reference chart

## RFID Tag Application Guide

It can be confusing what tag to use in a given application. Most RFID manufacturers, especially those that support multiple RFID frequencies, will provide recommendations for where to use each tag type. (See chart 1)

## Criteria For Choosing An RFID System

Choosing an RFID system can seem daunting. With each passing year, more options become available. The three options presented in this paper are the most commonly available today. Due to the nature of the infrastructure required to implement even a small RFID installation, choosing the wrong technology will have expensive and unreliable data collection consequences.

When selecting the correct technology, several factors should be considered. Each of the factors discussed in this paper should be weighed based on the relevance to your installation. The best recommendation is to not by looking at cost alone. After all, the most important part of an RFID system is its ability to move and store data reliably. Without reliable data, everything else is inconsequential.
The following is a list of recommended factors to think about before even considering a vendor. If these factors are difficult to determine, it is always recommended to seek out an integrator/advisor with RFID experience to help guide you through the factors involved.

## RFID project considerations:

- Functionality
    - Read-only or Read/Write
- Data tracking or tracking and traceability
    - Mounting Surface Compatibility
- Metal, plastic, etc. and product contents – liquids or solids
    - Data Capacity
- Few or many characters (typically in bytes)
    - Survivability
- Temperature, environment (indoor, outdoor), vibration, shock
    - Bus Communication
- Ethernet, field buses, serial, etc, - networking connectivity
    - Support Software Requirements
- Middleware, database, PLC or controller software, security, etc.

## Form Factor

- Tag Mountability
  - Dimensions, mounting holes,
- Read/Write Head Mountability
  - Dimensions, mounting holes, connectivity

## System Costs

- Tag Costs
  - Throw away vs. re-usable – total number of tags
- Read/Write (Interrogator) Hardware
  - Read/write head and processor costs, mounting hardware
- Software Infrastructure
  - Server needs, control programming (PLC, Controllers, etc…), ERP – database support, etc…
- Engineering/Design
  - Site surveys (internal, external services)
- Maintenance Service
  - Tag replacement, software updates, modifications (long term)

In the world of RFID today, no one system type fits every application. Some systems will excel at performance in one area, but suffer in another area. It's critical to learn and understand all of the demands you want to place on your installation. Be sure to work with each group affected by the performance of the RFID installation, from the maintenance person to the IT group. Once you understand what they need and based on your criteria for performance, you should be well armed to begin to determine which system is going to best solve the requirements of your application and set the stage for your success.

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