White paper

UHF vs. HF RFID: New Insight on the Old Debate

Intermec

It's time to bring new facts to the old debate as to whether high frequency (13.56 MHz) or ultra-high frequency (UHF, which includes EPC Gen 2) RFID technology is best for meeting business needs. The technologies have changed, therefore so too should the debate. Specifically, three long-held assumptions about the technologies need to be reexamined:

- UHF is unusable around liquid and metal
- Short-range reading requires 13.56 MHz
- 13.56 MHz is best for item-level tagging

The capabilities of each technology have changed, therefore so should biases held about them. For example, 13.56 MHz technology has historically been advocated for use around liquid and metal, but today UHF is commonly used in these environments, and UHF tags have been developed to take advantage of metal to improve RF performance. Meanwhile, HF is being promoted for some uses in the supply chain, which is the traditional territory for UHF.

In truth, there is no "best" RFID technology, just as there is no single bar code symbology that is best for all uses. Certain RFID frequencies and products are best suited to specific usage environments. Processes can be developed to accommodate different technologies, but fitting the process to the technology is usually a poor approach. When users understand how RFID will perform in specific environments and how it can improve their own processes, there is usually very little debate as to which frequency should be used.

This white paper will bring clarity to frequency considerations by:
- Providing a brief overview of UHF and HF technologies;
- Highlighting new developments and capabilities;
- Presenting examples that illustrate why some long-held beliefs and biases are no longer valid, and;
- Explaining why process considerations are key to selecting the right frequency and getting the most value from an RFID system.

Technology Overview

UHF and HF are general technology categories and there are many separate protocols within each. HF is more homogenized, at 13.56 MHz, although there are multiple international and industry standards for 13.56 MHz RFID. UHF RFID has been commercialized between 858 and 960 MHz. It too is supported by multiple standards, including EPCglobal Gen 2.

Tags and readers exchange data by forming a wireless connection. The connection can be made through either the electromagnetic (EMF) or RF field, which are both present at all frequencies. The fields have different ranges and interference resistance. High frequency RFID technology communicates via the electromagnetic field. Most UHF systems communicate by radio waves that provide longer range. Electromagnetic UHF technology is available, and is referred to as "near field" UHF, which also references its shorter range in comparison to UHF that uses radio wave propagation. Unless otherwise noted, when this white paper references UHF technology (including all references to Gen 2), it refers to commonly used, RF propagation technology.

The range any RFID tag can attain is primarily dependent on its wavelength, and therefore its frequency, because each radio frequency has specific wavelength characteristics. Antenna size and power output are other leading variables that impact RFID range.

Frequency aside, the primary difference between HF and UHF RFID technologies is their read/write range. Because HF and UHF technologies operate at vastly different frequencies, there is a big difference in the range they provide. Maximum range for 13.56 MHz technology is approximately 3 feet, and maximum range for UHF technology is approximately 30 feet (10 meters) . Spec sheets may claim better performance, but these figures are widely accepted as an accurate and useful reference. Figure 1 provides a quick reference to HF and UHF technologies and how they are commonly used.

	High Frequency (HF) RFID	Ultrahigh Frequency (UHF) RFID
Frequency	13.56 MHz	858 – 930 MHz
Key Standards	ISO 15693; ISO 14443; ISO 18000-3	EPCglobal Gen 2; ISO 18000-6 A, B, C; ISO 17363-67
Minimum Range	Near contact	About 1 inch
Maximum Range	1 meter (3 feet)	10 meters (30 feet)
Typical Uses	Electronic ticketing and fare collection; contactless payment; access control; commercial laundry and garment tracking; sample tracking.	Compliance tagging and other case and pallet ID; returnable container tracking, work-in-process tracking; asset management; baggage tagging; WiFi-based RTLS.

Figure 1: HF and UHF RFID Technologies at a Glance

13.56 MHz

High frequency 13.56 MHz technology is mature and was one of the first forms of RFID to be successfully commercialized especially for access control and contactless payment applications. Tags and readers in 13.56 MHz systems communicate by coupling in the electromagnetic field. The frequency, and electromagnetic communication, provides excellent resistance to common sources of interference found in commercial and industrial environments. The well-known drawback of 13.56 MHz technology is its limited range, which tops out at about 1 meter. Reading speed for 13.56 MHz tags is also relatively slow compared to UHF technology.

There are several widely used protocols and standards for 13.56 MHz technology. The best-known standard is ISO 15693, which is often used as the basis for presenting 13.56 MHz technology characteristics and making comparisons to UHF technology (which itself is most commonly represented by the EPCglobal Gen 2 protocol). ISO 15963 was developed as a standard for contactless cards. There are many interoperable ISO 15693 tag and reader products, which are also used for other applications, including commercial laundry tracking, library book management, file tracking and sample identification.

ISO 14443 is another leading 13.56 MHz standard. It was created for contactless fare collection and other electronic payment transactions, and is widely used in public transportation systems. The ISO 18000 series of standards for item management includes a 13.56 MHz standard, known as ISO 18000-3. This standard was developed before the ISO 18000-6 UHF series, which includes EPCglobal Gen 2 (which is equivalent to ISO 18000-6 Part C).

Because 13.56 MHz was one of the first RFID technologies to be standardized and gain wide vendor support, it was tried for numerous applications. Some companies that could see the benefits of contactless identification and high-speed reading tried using 13.56 MHz for distribution and other supply chain applications. However, the range limitations of 13.56 MHz technology didn’t support efficient case and pallet handling operations, a shortcoming that helped lead to the development of EPCglobal Gen 2 and other UHF supply chain standards. These early experiences also stunted RFID development and adoption. The shortcomings specific to 13.56 MHz technology for identifying goods in distribution and supply chain operations led some to conclude that RFID in general was an unreliable or ineffective technology. This misperception has lingered, despite being disproved by numerous successful UHF applications.

UHF

Most UHF RFID systems operate in the 858-930 MHz frequency band and communicate by RF propagation, with maximum read distances between 20 and 30 feet. Less well-known and commercialized are near field UHF systems that communicate in the electromagnetic field and are optimized for short-range reading. There are numerous UHF standards, most notably Gen 2, which may well be the most widely supported RFID standard.

UHF is the dominant technology for supply chain applications such as case and pallet tracking and returnable container identification, and is also widely used for industrial automation, work-in-process tracking, asset management, inventory monitoring, forklift monitoring, personal ID, vehicle access control, document security and other applications.

In early deployments, the UHF systems were susceptible to interference and performance degradation when used around liquid and metal. However, the technology has improved and been adapted to mitigate or eliminate this interference. For example, some UHF tags have been designed specifically for use in close proximity to metal and to take advantage of metal’s conductive properties to enhance RF performance. Advances in antenna design, reader tuning and best practices are also overcoming traditional limitations.

New Thinking Needed

Technology maturation is one reason the traditional positions of the HF vs. UHF debate are no longer valid. According to conventional thinking, UHF was the best technology for longer-range applications, and HF was best for short range, item-level identification or for use around liquid or metal. This thinking tends to oversimplify the considerations for choosing the most appropriate business processes and technology, and may cause potential users to unnecessarily limit the technology options they consider for their applications.

Rethinking Range

For example, range requirements do not have to dictate whether UHF or HF technology is used. UHF systems don’t need to be of the near field variety to work at close range. The same tags that can be read from 30 feet away can also be read from an inch. UHF systems can be optimized for various processes and read distances through the placement and configuration of readers. UHF is the technology of choice for many work-in-process tracking, case and pallet identification, check in/check out, inventory monitoring and security applications because it can provide the range and coverage users need, but there are no physics or technological reasons it can’t be used for short-range applications.

When longer read range is required 13.56 MHz technology is not an option, because it simply cannot match the range of UHF technologies. Therefore, it is important to consider future needs and potential expansion of RFID uses when planning systems. For example, if RFID tagging will initially be involved a low volume of items that are processed with handheld readers, 13.56 MHz technology would perform just fine. However if the application could expand to unattended, higher-speed processing, such as reading items moving on a conveyor belt, longer-range technology would be advantageous. Regardless of which frequency is chosen, organizations should strive to select a single frequency to avoid having to double-tag items (with HF and UHF tags) to support different processes and applications.

Items of Contention

Historically, 13.56 MHz technology has been more widely used for item-level tagging, but recent history suggests performance and preferences may be tipping toward UHF. Consider the following:

- Pan-European retailer METRO Group uses Gen 2 UHF tags on individual garment hangars in a high-speed system that sorts 8,000 items per hour at a distribution center.
- Leading U.K. retailer Marks & Spencer reported its UHF-based item-level tagging program has surpassed 35 million products.
- Boeing announced it will apply permanent UHF tags to between 1,700 and 2,000 parts on each of its state-of-the-art "Dreamliner" 787 aircraft.
- Cardinal Health, one of the largest worldwide pharmaceutical distributors, announced it will apply item-level UHF tags to pharmaceutical products to satisfy e-pedigree requirements.
- Blue C Sushi, a Seattle kaiten sushi restaurant that serves customers with plates that pass tables on a conveyor belt, uses UHF RFID to track individual plates with read ranges of less than 1 foot.
- UHF is also gaining support for identification documents and cards, which have traditionally been dominated by 13.56 MHz technology. The U.S. State Department selected Gen 2 as the standard for its passport card program. UHF was already used in the NEXUS program to identify and streamline exit/entry for frequent U.S. border crossers.

Several of these organizations already had Gen 2 UHF systems in place for case- and pallet-level processing. Using UHF at the item level enables them to leverage their legacy systems without having to invest in new tags and readers to create a separate infrastructure for item-level identification processes.

Static Ideas are Outdated

The idea that HF technology is required for use around metal and liquid is also more of a perception than a reality. In supply chain applications, UHF is frequently used to successfully identify cases and entire pallets of consumer goods with high liquid or metal content.

Hong Kong International Airport provides an example. It is one of several airports around the world that is using Gen 2 RFID to identify, sort and route passenger baggage. The layout and configuration of legacy material handling systems – which contain a lot of metal – often requires readers to be mounted quite close to tagged bags moving by at high speeds.

Thailand's Suvarnabhumi Airport, the newest and largest airport in southeast Asia, uses UHF RFID tags to identify airline cargo containers as they enter and exit customs and holding areas. The containers themselves are metal and there is a lot of other metal – racks, shelves, material handling vehicles, etc. – where the RFID tags are read.

Reliable UHF performance in the presence of these materials extends to the item level – in the pharmaceutical industry, UHF tags are used to identify liquid drugs in foil packaging. Item-level UHF tags are used for packaging validation, product authentication and other applications, some of which require dozens or hundreds of items to be read simultaneously.

Another example illustrates how much technology has improved to make UHF a reliable option in industrial environments. After testing UHF and HF technologies, Boeing chose to identify flight-critical aircraft parts with UHF tags to streamline maintenance and pre-flight inspection processes. Tagged aircraft parts are often read at closes ranges where metal and other potential interference sources are present, and Boeing has used metal-mount UHF tags designed specifically to identify metal objects – a product option that was not available when many long-held opinions about UHF capabilities were formed.

These few examples illustrate how RFID technology and its applications are evolving, and why some strongly-held beliefs about its limitations are no longer true. Planning based heavily on the limitations of technology can overlook the importance of developing processes that create business value before selecting a technology. RFID technology should support the desired process, not the other way around.

Plan for Processes, Not Technology

When used as a straight replacement for bar coding, or strictly to meet compliance mandates, RFID is rarely cost effective. As referenced previously, RFID was initially considered a failure for supply chain operations because of the performance of 13.56 MHz-based applications. Companies could successfully read 13.56 MHz tags on cases or cartons, but only at ranges comparable to (and even shorter than) their legacy bar code systems. Therefore efficient new processes could not be developed.

Today many bar code processes involve bringing the bar coded object to the reader, either by conveyor, forklift or manual handling. These processes usually require some labor to handle objects (whether they be samples, WIP assemblies, totes or shipping containers) and orient the bar code for proper presentation to the reader. RFID, with its ability to read tags without a direct line of sight and to identify multiple objects simultaneously, can be used to eliminate much of the labor now required. The more coverage the RFID system provides, the less control over object location is required – and therefore the more potential to create labor-free processes . This is an important advantage RFID provides over bar code technology. For example, bar code ID often limits the performance of conveyor systems, because they often must run considerably slower than their top speeds so bar code readers can identify passing objects.

Users are at risk to be disappointed if they choose a technology without first carefully planning processes that will return business value. It is also important to consider future needs so that a single RFID infrastructure can support multiple uses. For example, if an initial RFID project for WIP tracking could be expanded in the future to track inventory and shipments, it would be wise to specify UHF technology, which can satisfy requirements for short-range reading at assembly stations and long-range storage, shipping and receiving processes.

Conclusion

There is no debate that the UHF and HF varieties of RFID are mature, standardized and widely supported, and that they provide reliable, excellent performance when used appropriately. What is debatable are the best usage scenarios for each technology. This decision doesn't need to be confusing. What's most important is to develop a solid understanding of business needs and how RFID processes can be beneficial. Create the working conditions and design the changes that are best for your business, not for a specific RFID technology. When users know what they need, there's little debate as to what technology is best suited to providing it.

Intermec, an RFID pioneer, has extensive experience in helping organizations understand their RFID needs and opportunities and in designing and implementing successful systems. Intermec Inc. (NYSE:IN) develops, manufactures and integrates technologies that identify, track and manage supply chain assets. Core technologies include RFID, mobile computing and data collection systems, bar code printers and label media. The company's products and services are used by customers in many industries worldwide to improve the productivity, quality and responsiveness of business operations. For more information about Intermec, visit www.intermec.com or call 800-347-2636. Contact Intermec Investor Relations Director Kevin McCarty at kevin.mccarty@intermec.com, 425-265-2472.

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