GO-TO GUIDE

The Growing Importance of Adopting Global RFID Encoding Standards

Before talking about RFID encoding standards, let's first introduce RFID. RFID is an acronym for **R**adio-**F**requency **ID**entification. It is a technology where data is encoded in smart labels or tags and the data is then captured by a reader via radio waves. Generally, RFID systems can be broken down into three frequency bands: low-frequency (LF), high-frequency (HF), and ultra-high frequency (UHF). The last, UHF, is commonly known as RAIN RFID in the 860-960 MHz band.

Radio waves in these different bands have different behavioral patterns, and each has advantages and disadvantages. RAIN RFID (UHF) is the fastest-growing segment of the RFID market. It supports relatively long read ranges, while other frequencies have much shorter ones. RAIN also supports "one-to-many" reading between readers and tags (meaning one reader can read many tags simultaneously), whereas LF and HF are generally "one-to-one" technologies (meaning a reader can only read a single tag at a time).

RFID Systems	LF	HF	UHF	
Band	120 ~ 150 kHz	13.56 MHz	433 MHz	865 ~ 868 MHz (EU) 902 ~ 928 MHz (US)
Read Range	10 cm	10 cm ~ 1 m	1 ~ 100 m	1 ~ 12 m
Data Speed	Low	Low to moderate	Moderate	Moderate to high
ISO/IEC 18000	Part 2	Part 3	Part 7	Part 6
Applications	Animal identification, factory data collection	Ticketing, ID badge, anti-theft system, payments	Defense applications with active tags	Retail items, logistics, supply chain management, vehicle identification, airline baggage, etc.

Table 1: Three Types of RFID Systems

In addition, RFID systems can be classified as passive or active.

Passive RFID: Passive RFID tags have no internal power source. The RFID tag receives a radio signal from the reader, which it then uses to turn on and reflect energy back to the reader. Passive RFID systems can use the LF, HF, or UHF radio bands to communicate.

Active RFID: Each active tag has a transmitter and associated power supply, which is typically a battery. To transmit the information stored on the microchips, active tags broadcast their own signal. They typically operate in the UHF band and offer a range of up to 100 meters, and are often used on large, high-value objects, such as rail cars.

WHAT ARE RFID STANDARDS?

The International Standards Organization (ISO) and GS1 are two organizations that work together to approve and implement standards and protocols for RFID universal specifications.

Comprehending RFID standards can help you choose the best solution for your company. It also provides insight into how the industry is governed. These standards also present guidelines for designing complementary products, and understanding how RFID systems function, what frequencies they use, how data is transmitted, and how the reader and tag communicate.

The acronym RAIN stands for **RA**dio Frequency **I**dentificatio**N**. RAIN RFID is a wireless technology that connects billions of objects to the internet, allowing businesses and customers to identify, locate, authenticate, and interact with each item.

The RAIN RFID Alliance promotes the universal adoption of standards-based, passive UHF RFID technology. A RAIN RFID solution usually comprises tags, readers, and software. It uses a reader to read and write a tagged item, manage the data, and transmit it to a server, either locally or in the cloud.

The technology follows the GS1 EPC UHF Gen2 air interface protocol which is based on the ISO/IEC 18000-63 standard. It is used in a wide variety of applications, ranging from retail inventory management to pharmaceutical anti-counterfeiting to asset management, and more.

Moreover, RAIN is based on passive RFID and is commonly deployed to track goods in the supply chain and inventory products in the retail industry. Overall, RFID standards help ensure that products are interoperable, regardless of the vendor or user. Standards provide guidelines about how RFID systems work, what frequencies they operate at, how data is transferred, and how communication works between the reader and the tag.

WHY ARE RFID ENCODING STANDARDS IMPORTANT?

Standards-based numbering systems (what a user encodes to their tags) offered by the RAIN Alliance, GS1, and the ISO ensure unique and proper RAIN RFID encodings. RAIN RFID solutions interpret the number encoded on the tag to identify the item. The success of RAIN implementations depends on the use of unique and properly encoded identifying numbers.

Most people are familiar with RFID in retail, which generally uses GS1 standards. To better understand the framework, there are two main categories of tag data encoding standards:

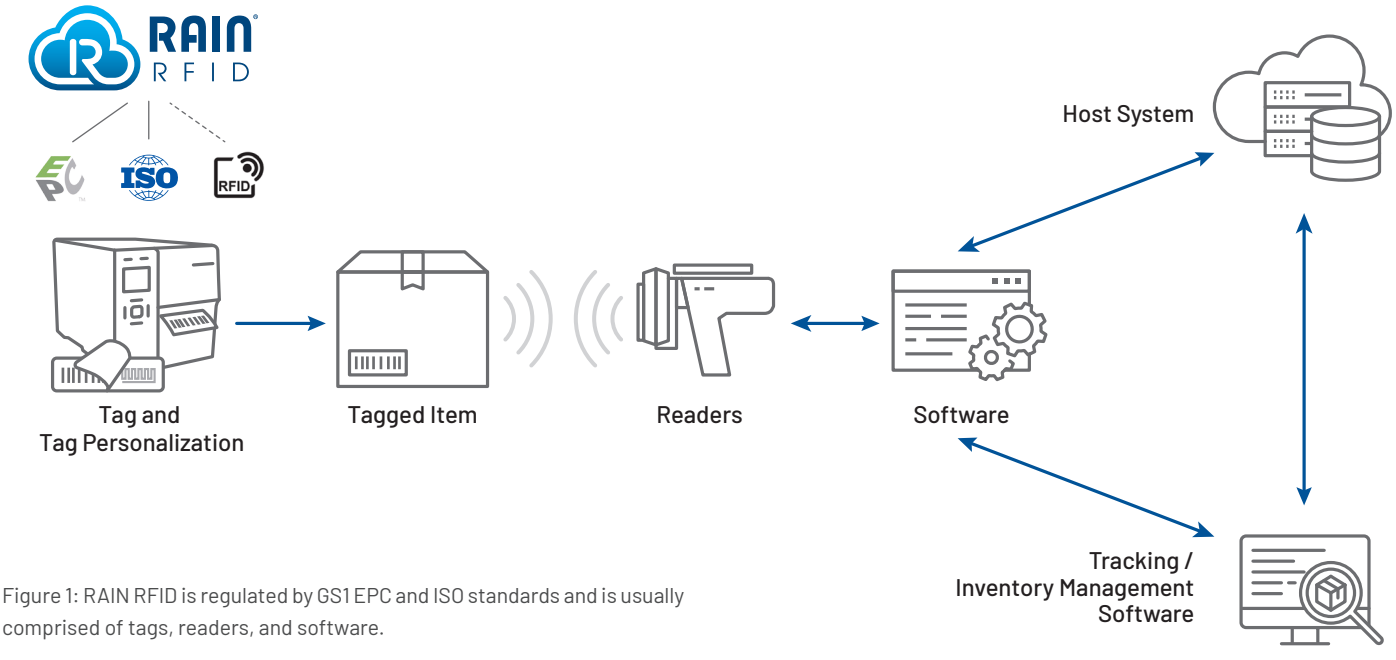

Figure 1: RAIN RFID is regulated by GS1 EPC and ISO standards and is usually comprised of tags, readers, and software.

1. GS1's EPC Tag Data Standard (TDS)

The EPC Tag Data Standard (TDS) from GS1 specifies the data format of the Electronic Product Code (EPC) and provides encodings for numbering schemes within an EPC, including the GS1 keys. TDS also defines the information transmitted by Gen 2 RFID tags. UHF (and HF) passive RFID tags are the focus of GS1 RFID standards, and they comply with the GS1 EPC UHF Gen2 air interface protocol.

2. Various ISO-Based Standards

These standards are ideal for encoding relatively complex data and "closed-loop" applications where the data is not shared across trading partners. Multiple different standards exist, which define ISO-based encodings. The best starting point to track down relevant standards is the ISO/IEC 15961-2 Data Constructs Register, which is currently maintained by the global industry alliance for automatic identification (AIDC) technologies, AIM. Based on a user's specific application, the user can identify the most correct "Application Family Identifier" (AFI) and associated ISO standards for detailed guidance on encoding.

RFID encoding standards are critical to ensure that products are interoperable across any applicable value chain. Tags might be put on returnable transport items, clothing, or parts that are shipped to customers. It would be impossible for multiple parties to read the same RFID tags if the data on the tags were not standardized. By having a regulatory authority, information standards in one location can be standardized across all locations.

Furthermore, RFID tags that are not encoded as per standards can interfere with other applications, causing so-called "Tag Clutter." Tag Clutter is defined as two sub-problems:

1. **Acid RAIN:** This occurs when tags from another application are erroneously detected by your target application. For example, an application to detect airline luggage tags as part of a baggage handling system could be compromised if someone also has a pair of jeans with an RFID label in their suitcase. If the various tags are not encoded properly according to standards, the jeans might be detected and interpreted as a suitcase.
2. **RAIN Flooding:** This occurs when a reader cannot process all of the tags in its read zone in an allotted time. Many people believe that readers instantaneously and reliably read all tags in the read-zone. However, this is not true. Readers need time to process tags. The greater the number of tags in a read zone, the more time the readers need to process the tags. Properly encoded and formatted tag data allows readers to filter quickly and efficiently for tags of interest and ignore tags from other applications. With proper filtering, readers can process larger numbers of tags more quickly and reliably in the read zones.

BENEFITS OF RFID ENCODING STANDARDIZATION

Walmart, for example, a U.S.-based multinational retail corporation that operates a chain of hypermarkets, mandates its suppliers tag their products in many categories including apparel, sporting goods, toys, and more using GS1's Tag Data Standard, specifically the SGTIN-96 Encoding Scheme. This conformation helps Walmart manage products from various suppliers quickly and easily due to the standardized encodings.

Standards-based numbering systems offered by the RAIN Alliance, GS1, and ISO ensure unique and proper RAIN RFID encoding on a tag. The benefits of encoding standardization include:

Easy Product Track-And-Trace

Standardized RFID tags ensure the data can be captured and interpreted by all trading partners. Every checkpoint across the supply chain receives the same information. By adopting RFID, different parties can automate their operations and supply chain, reducing labor costs, human errors, and time spent identifying products. RFID enhances product visibility across the supply chain and realizes real-time product and inventory tracking which improves inventory management in the long run.

No Data Duplication or Confusion

RFID tag data is intended to be universally unique when properly formatted. In the absence of data duplication, tagged items can be correctly identified. Proper encodings based on standards ensure that there are no other tags with the same number. Duplicate data can, of course, cause conflicts in track-and-trace applications and confusion around data accuracy.

For example, if a supplier tracks product information without utilizing a single RFID standard encoding, it's possible that distinct products could be encoded with the same product identifier, resulting in confusion in backend systems when they attempt to identify products. However, with standards-based encodings and proper serial number management, this will not be a problem.

Critical to the Success of RFID Deployment Across the Supply Chain

With proper encodings, RFID reader systems can be optimized for efficiency and accuracy based on the ability to filter for tags of interest and ignore tags from other applications.

For example, if a shipper uses RFID to track cartons, luxury items within the packages may have a second RFID tag attached by the vendor. How does the RFID reader determine which data set to identify and report to the system? Or if it's required to report on all data to different systems, how will it do this? Data-standard adherence allows RFID readers to quickly filter out the tags that are relevant at the time and then communicate the correct information to the appropriate system for real-time tracking (just like barcodes). Tags not encoded according to a data standard will eventually cause problems with tags from other applications.

KEEP SECURITY IN MIND

The data on RFID chips can, however, be easily intercepted when standardized encodings are used. The data that is broadcast from a standards-based encoding can be accessible by anyone with a basic RFID scanner.

That means anyone with a scanner can walk down the street and scan people without them realizing it and collect potentially private information. Some basic security settings can be used to compensate for this vulnerability, but they are not absolute. Basic security settings can be hacked. Using tags that support encryption technology with security keys can help provide an extra level of security.

COMMIT TO A SINGLE BEST STANDARD TO MAXIMIZE RFID VALUES

Of the estimated 30 billion RAIN RFID tag chips sold in 2021, it's anticipated that only 70% adopted standards-based numbering systems[1].

RFID's value is derived from data quality. Committing to use the best standards throughout the entire supply chain is crucial. RFID use cases will collide if there isn't a unique tag-number system and a standard encoding structure to prevent confusion and conflict in track-and-trace applications. As a result, using standards-based numbering schemes is strongly advised rather than proprietary data formats, which are often used in closed systems but can cause tag clutter and related issues.

TSC Printronix Auto ID works closely with multiple standards organizations, such as GS1, ISO/IEC, AIM, and the RAIN RFID Alliance to ensure that our RFID printers correctly and adequately support the various encoding standards. These standards are evolving rapidly, so it is important to select a printer partner who is committed to supporting the current standards as they evolve.

[1] Megan Brewster, "Why Standards-Based Numbering Is Essential for RAIN RFID Encoding," April 7, 2022