Telcordia

Radio Frequency Identification (RFID) in the Telecommunications Industry

White Paper

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Abstract

Radio Frequency Identification (RFID) is the automatic identification and data collection (AIDC) technology of the 21st Century. RFID is an automated technology used to gather information about a product, place, person or transaction, quickly and easily, eliminating human error. It provides a link to data without the need to make contact with the item, without line of sight or in harsh or dirty environments that may limit other AIDC technologies such as bar codes and 2D symbols. This white paper provides a technology overview, summary of international standards and their status, potential applications and benefits, a view of "labeling" products, packages and shipments, technical issues associated with implementing RFID, opportunities for the telecommunications industry, potential risks and elements for successful implementation.

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Introduction

Radio Frequency Identification (RFID) has received much press lately as the new rising automatic identification and data collection (AIDC) technology of the 21st Century. Much discussion about the technology has occurred due to the initiatives of Wal-Mart and the United States Department of Defense (DoD) promoting and beginning to enforce mandates and usage in their supply chains. The telecommunications industry is not affected by the Wal-Mart mandate but manufacturers and suppliers are affected by the DoD mandate. Both these mandates and the news that has surrounded them have given the industry a “heads up” to make sure telecommunications does not miss out on the benefits that should be realized from implementing this long-standing but developing technology.

RFID is an automated technology used to gather information about a product, place, person or transaction, quickly and easily, eliminating human error. In general, it provides a link to data without the need to make contact with the item, without line of sight or in harsh or dirty environments that may limit other AIDC technologies (e.g., bar codes and 2D symbols). It is a proven technology, in use for over 10 years in a cross section of applications, such as road telematics (toll paying systems, e.g., E-Z Pass, SunPass, etc.), animal identification, access control, retail product theft management, (Electronic Article Surveillance (EAS), shop floor manufacturing, etc. RFID enables the automation of key business processes by removing human intervention, allowing the direct processing of information. This is a key advantage over business processes linked by bar code and 2D symbols.

RFID, as an enabling technology, can provide great benefit in many applications. However, it is not as simple to implement as bar code and 2D labeling and requires that the potential users perform detailed analyses, comparing the proper and efficient use of all the available technologies to solve the business problem.

This paper will provide an RFID technology overview, outline opportunities for the telecommunications industry, the potential risks and elements for successful implementation and discuss;

the international standards and their status,

potential applications and benefits of usage,

a view of “labeling” products, packages and shipments,

technical issues associated with implementing RFID,.

Technology Overview – RFID Basics

Radio **F**requency **ID**entification uses an integrated circuit (micro-chip) and antenna embedded in a tag or label to transmit or reflect stored data when the tag or label is exposed to radio waves of the correct frequency and modulation.

Tag Types

RFID tags can be classified by whether they are active or passive and can also be classified as read-only or read-write. Users must also decide whether to invest in read-write tags or read-only tags.

The table below shows the different tag types, how they work and the pros and cons of each.

Type	**Price Range**	**How They Work**	**Pros**	**Cons**
Active Tags	High	Battery-run tags that constantly emit radio Frequency signals; some types are battery-	Good for tracking large objects – read range is 100+ feet; not as impacted by metals/liquids .Today,	Significantly more expensive than passive tags; require maintenance Although the active tag itself

Type	Price Range	How They Work	Pros	Cons
		assisted which are only turned on when they need to transmit or receive data.	active tags transmit at a "blink rate". This rate may vary but is usually seconds to hours apart allowing for greater battery life; Have an on-board power source; Require less power from reader Finite Life	may have greater range it may be more costly. However, the infrastructure cost may be lower than for a passive tag system
Passive Tags	Low	Activated by electromagnetic waves of RFID reader. These waves turn the tag on so it can reflect the information stored in the tag (see Figures 1 and 2) Powered by energy from reader (no internal battery)	Cost-effective for implementation today; require no maintenance Smaller, lighter, less expensive Almost unlimited life	Read range is currently 10-25 feet from the reader; difficulty working through metal/liquid Requires higher power from reader
Read-Only Tags (Write Once/Read Many [WORM])	Low	Information written on the tag during manufacturing is permanent – also can be field programmable;	Good for one time recording of information only and tracking by that information in the tag (usually a serial number which allows unique access to a database of information about the item). The tag is similar to the 2D label except that the advantage of the read-only RFID tag is that line of sight is not required. Cost-effective	Information written onto the tag can never be changed
Read-Write Tags	High	Users can add new or write over existing information when tag is near a reader	Gives users the flexibility to add information at any time. Provides many more opportunities to reduce operator involvement and gain more from the RFID investment.	Were costly but now the difference in cost between read-only and read/write tags is minimal and will become effectively zero. The usage for Read-Only Tags are very small. Volumes for Read-Write Tags will allow the manufacturing costs to drop dramatically.

The variety of tag options require companies to examine their specific business needs before making a selection. For example, if a company needs to more closely monitor its receiving yard, attaching an active tag to a trailer or container of product would allow for instant location in a large area. However, if a company just needs to automate its picking processes within a distribution center, it may be more beneficial to choose to invest in passive technology.

How RFID Works

The operation of RFID transmission remains basically the same regardless of which type of tags are chosen. Once in the area of transmitted signals from the antennae of the reader/writer, both passive and active RFID tags can transmit hundreds of radio frequency signals every second. An application ("RFID appliance") serves as a liaison between the reader and the host system, discerning duplicate information and passing along only the useful information to the host system. For example, if a reader receives 50,000 tag transmissions, but only 200 of the tags are unique, this application can send the correct information to the host system. The host then knows that 200 cases, pallets or items, depending on the level of tagging, are received into inventory. As these items pass through other areas of the warehouse where readers are strategically placed, this information is continuously captured, allowing for a variety of applications. The interrogator can also write information to read/write (RW) or Write Once Read Many (WORM) tags.

Figure 1 – How RFID tags work

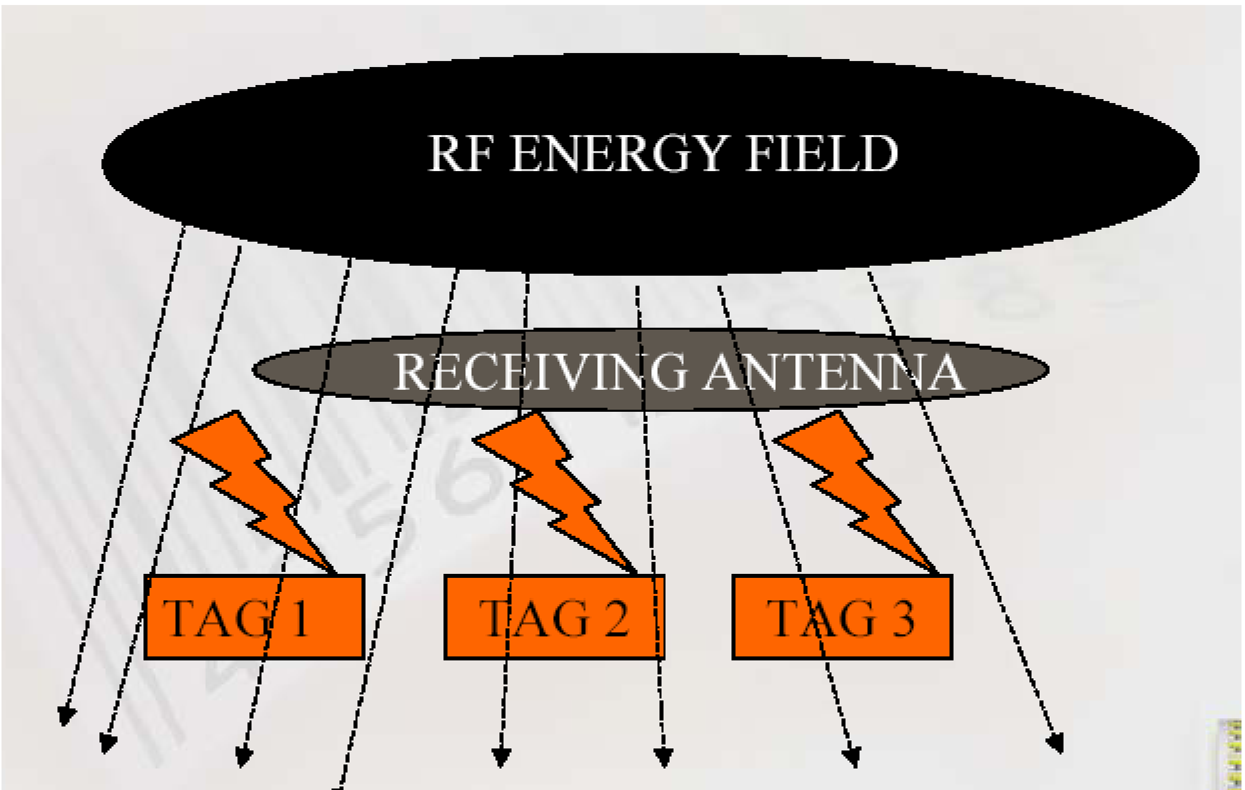
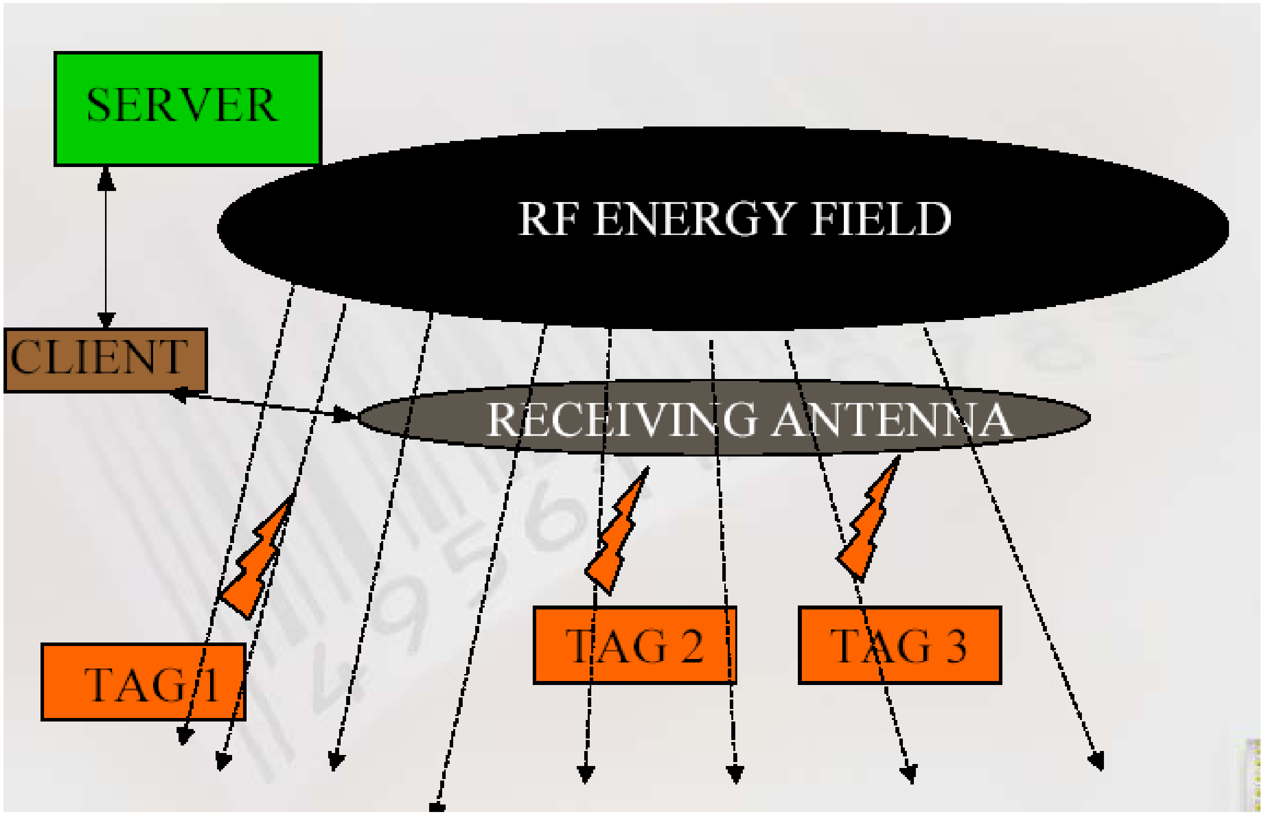


Figure 2 – What happens to the data



The purpose of any RFID system is to carry data in suitable transponders ("tags") and to retrieve the data using machine-readable devices at a suitable time and place to satisfy the needs of a particular application. The data carried by the tag may provide identification for an item being manufactured (e.g., CLEI Code). The tag may include additional information which can be utilized immediately upon reading the tag without the need to access a database for this additional information. Such information as a serial number, manufacturer, and country of origin might be some of the data that a plug-in circuit card might carry in an RFID tag.

RFID tags come in all shapes, sizes and characteristics. Some of the features that are used to determine which tag best fits an application include:

Memory

- Size (16 bits - 512 kilobytes +)
- Read-Only, Read/Write or WORM (Write Once Read Many)
- Type: EEProm, Antifuse, FeRam

Arbitration (Anti-collision) - Ability to read or write one or many tags at a time

Frequency – 125KHz to 5.8 GHz

Physical Dimensions – Thumbnail to brick sizes

Price Range – $0.20 to $250.00

Bar Code Replacement or Augmentation

Although many articles have mentioned that RFID tags may replace bar code labels, most technologists understand that RFID may replace bar codes in some applications but do not expect it to completely replace the use of bar code labels. Several proposed applications require the complementary use of RFID tags and bar code (or two-dimensional) labels.

Following are some of the major advantages that RFID tags have over bar code labels:

Use non-contact, non-line of sight communications

Achieve a higher level of automation. Reading and writing to tags does not require manual intervention, i.e., the process reduces the "touch" cost.

Have environmental durability – can be used in harsh environments. In addition, depending on the tag and reader frequency specifications, they can be read through :

- Paint
- Dirt
- Grease
- Snow
- Fog
- Ice

Have multiple read capability (e.g., Items on/in shelves/frames, bags, trays, containers)

Can track people without scanning

Will operate in high speed environments (e.g., motor vehicles)

Can be read much faster than bar codes. Some tags have read frequencies of 100 times per second.

Can have maintenance-free operation

Have data encryption and authentication capability

Have the ability to add to and modify the stored data.

Frequency Ranges

Radio frequency bands are a scarce and shared resource. Regulatory authorities (e.g., Federal Communications Commission [FCC] in the United States, International Telecommunications Union [ITU] of the United Nations) regulate the frequency band allocation and resolve conflicts for the use of radio frequency devices, such as RFID readers and tags.

Table 2 shows the frequency ranges that are defined in the international standards (ISO/IEC JTC1 Subcommittee 31) for Radio Frequency Identification for Item Management and some of their characteristics. Table 3 shows other characteristics of RFID tags in these standards.

The range within which an RFID tag can be read or data written to the tag is dependent on the following:

The power of the energy field (limited by country in which the tag/reader system is used)

- From the reader
- From the tag (active)

Operating frequency

Antenna design

Whether the transponder is active or passive

The surrounding environment (e.g., radio waves, obstructions by materials which cannot be penetrated or bypassed) – more significant at higher frequencies.

Table 2 - Characteristics of RFID Tags defined in ISO/IEC 18000-n (n=Part #)

Frequency Range	**Power Source**	**Data Transfer Speed**	**Energy Absorption**	**Energy Efficiency**	**ISO/IEC 18000 Part #**
<135 KHz	Passive	Slowest - small amount of data	Lowest	Highest	2
13.56 MHz	Passive	Slow	Low	High	3
433 MHz	Active	Fast	High	Low	7
860-960 MHz	Passive	Faster	Higher	Lower	6
2.45 GHz	Passive or Active	Very Fast	Very High	Very Low	4

Table 3 – Other Characteristics of RFID Tags defined in ISO/IEC 18000-n (n=Part #)

Frequency Range	**Material Penetration**	**Tag Construction**	**Antenna**	**Range**	**Other comments**	**ISO/IEC 18000 Part #**
<135 KHz	High - water, tissue, wood aluminum; Will not penetrate or travel around metals (i.e., iron, steel)	Thick; more expensive; complex (requires more turns of induction coil)	Large	Low – >1 meter		2
13.56 MHz	High - water, tissue; Will not penetrate or travel around metals (i.e., iron, steel)	Thin – requires more than one surface to complete a circuit	Large	Low - 0.7 meter	Useable in hospitals for wrist bands.	3
433 MHz	Travels around metals.	Thin, small	Small	> 1.0 meter		7
860-960 MHz	Effective around metals; does not penetrate "lossy" (highly conductive) materials - also does not penetrate water, tissue	Thin/Small	Small	Most effective >1 meter; Licensed 20m-30m, unlicensed 3m-5m	Multiple tags in a field; high data rate - large amounts of data; controlled read zone through antenna directionality;	6
2.45 GHz	Effective around metals with tuning/design adaptations; Does not penetrate "lossy" (highly conductive) materials - also does not penetrate water, tissue	Smaller tag size - 1" x 0.25"	Small		EAS - Electronic Article Surveillance[1]; high data rate - large amounts of data; controlled read zone through antenna directionality; shared frequency band with other devices- microwave ovens, portable phones, TV devices, RLANS; more susceptible to electronic noise than other bands	4

[1] Popular EAS systems operate at 8.2 MHz, 58kHz, 70 Hz to 7.5 kHz

Note that lower frequency systems will experience less absorption of the signals by moisture and better omni-directional reading but slower reading speeds. At higher frequencies, more tags can be read in the field simultaneously.

The Electronic Product Code (EPC) and EPCglobal Inc™

Note: The information in this section is based on information provided on the EPCglobal Inc™ Web site - http://www.epcglobalinc.org and from a meeting that ANSI MH10 Subcommittee 8 held with representatives from EPCglobal – U.S. on November 12, 2003.

EPCglobal is a group of companies that are developing industry-driven standards for the Electronic Product Code™ (EPC) to support the use of Radio Frequency Identification (RFID) in trading networks. They are a member-driven organization comprised of companies and industries focused on creating global standards for the EPCglobal Network™. Their goal is increased visibility and efficiency throughout the supply chain and supporting the creation of higher quality information flow between companies and their key trading partners.

The EPCglobal Network plan is to enable immediate, automatic identification and sharing of information on items in the supply chain. In this way, the EPCglobal Network plans to make organizations more effective by enabling true visibility of information about items in the supply chain. In a similar manner the CLEI Code and Catalog provides visibility today.

The Electronic Product Code (EPC) is a unique number that identifies a specific item in the supply chain. The EPC is stored on a radio frequency identification (RFID) tag, which combines a silicon chip and an antenna. Once the EPC is retrieved from the tag, it can be associated with dynamic data such as where an item originated from or the date of its production. Much like a Global Trade Item Number (GTIN). Vehicle Identification Number (VIN) or COMMON LANGUAGE® Equipment Code (CLEI™ Code), the EPC is the key that unlocks the power of the information systems that are part of the EPCglobal Network.

The EPC – as originally defined – is a numbering scheme that uniquely identifies all objects, accommodates current and future numbering methods and connects physical objects to computer networks. The EPC consists of:

- Header – identifies the length, type, structure, version, and generation of the EPC
- EPC Manager Number – entity responsible for maintaining the subsequent partitions
- Object Class – identifies a class of objects
- Serial Number – identifies the instance

The number is encoded in bits (0's and 1's) on the RFID tag. The EPC provides multiple formats for:

- Various bit length tags (initially 64 and 96; Future 256 and higher)
- Migration from existing identifiers
- EPCs independent of existing identifiers

All formats support unique EPCs. Eight (8) formats were defined in the Version 1.0 definition which included 64-bit and 96-bit formats for:

- Universal
- GTIN – Global Trade Item Number
- SSCC – Serialized Shipping Container Code
- GLN – Global Location Number
- GRAI – Global Returnable Asset Identifier

Table 4 - The 96 bit GTIN format

	Header	Filter Value	Partition	EPC Manager Number	Class	Serial
96-bit GTIN	8 bits	3 bits	3 bits	20-37 bits	7-24 bits	38 bits
	00XX XXXX	8 (decimal capacity)	8 (decimal capacity)	137,438, 953,471 (decimal capacity)	16,777, 215 (decimal capacity)	374,877,906,943 (decimal capacity)

Table 5 - For the Partition

Partition Value	Company Prefix		Item Reference and Indicator Digit	
	Bits	Digits	Bits	digits
1	37	11	7	2
2	34	10	10	3
3	30	9	14	4
4	27	8	17	5
5	24	7	20	6
6	20	6	24	7

Mapping GTIN into 96 bit EPC:

1. Header
2. Filter Value – Value from Filter Value Table
3. Partition – Value from Partition Table. Base this on the length of the company prefix.
4. EPC Manager Number – The company prefix, as if in a GTIN.
5. Object Class – The item reference, as if in a GTIN. Check digit is dropped.
6. Serial Number – as if using Application Identifier 21 (Serial Number).

- All values are right justified, zero filled.
- Indicator digit requires an additional step
- Guidelines are needed to show step-by-step.

The Filter Value is:

- Not part of the EPC identifier
- Used during RF reads to select or mask out types of EPC
  - items
  - cases
  - pallets
- Different for GTIN, SSCC, GLN formats
- Not tested

Table 6 - GTIN Format Filter Values

Type	Value
Other	0 (000)
Item	1 (001)
Inner Pack	2 (010)
Case	3 (011)
Load/Pallet	4 (100)

Similar mapping is proposed for SSCC and GLN.

Other keys will be accommodated by EPC in additional formats

- Other EAN.UCC system keys (GIAI, GRAI)
- Other industry (not EAN.UCC) keys
- The formats must always result in unique EPCs

There is significant work to be done to integrate the needs of the telecommunication industry and other industries into this EPC format.

What is the "class" of a tag?

The term "class" in the name of a protocol is a nomenclature adopted by EPCglobal to describe the functionality of an RFID tag.

Class 0 tags are minimal tags that carry an EPC number, and are intended to be read-only. Class 1 tags can have the EPC number (or some other data) written on to the tag in the field. However, once this number has been entered, the tag is generally locked and then used in read-only mode.

Class 0 and Class 1 tags are also referred to as license-plate tags.

Class 2 tags can have significant amounts of data written to them. For example, a Class 2 tag on a pallet might have not only its EPC, but also a shipment manifold. Of course, Class 2 tags have lower range and generally are more expensive.

Class 3 tags are semi-passive tags and offer greater range.

Class 4 tags are active tags and offer the greatest performance, but are also the most expensive and bulky.

Standards

The final approval process began in early 2003 for RFID International standards that will promote usage in the global supply chain.. The following standards from the ISO/IEC JTC1 Subcommittee 31 (SC31) and ISO TC104 (Freight Containers)/TC122 (Packaging) Joint Work Group (JWG) are the significant ones to watch and use, as they will be the basis for RFID applications in most industries throughout the world. Their status (indicating that the ballot on that document form - i.e., Committee Draft, Working Draft, etc. - is either expected or has closed in 2004) is indicated after the standard number as follows:

PDTR – Preliminary Draft Technical Report
DTR – Draft Technical Report
WD – Working Draft
CD – Committee Draft
DIS – Draft International Standard
FCD – Final Committee Draft (JTC1 equivalent of DIS in ISO terminology)
FDIS – Final Draft international Standard
IS – International Standard (final – available for purchase)

ISO/IEC JTC1 SC31

ISO IEC 18000-1 – *Part 1: Reference architecture and definition of parameters to be standardized* – Determines the common parameters to be defined in an item identification air interface standard, the method and means of their definition and provide a common format for their elaboration and definition.

ISO/IEC 18000-2 – *Part 2: Parameters for air interface communications below 135 kHz* – Specifies the physical layer for communications between interrogator and tag (passive) of either Type A (Full Duplex at 125 kHz) or Tape B (Half Duplex at 134,2 kHz). It specifies the protocol, the commands and the method to communicate with one tag among several tags (“anti-collision”).

ISO/IEC 18000-3 – *Part 3: Parameters for air interface communications at 13,56 MHz* –Provides physical layer, collision management system and protocol values for RFID systems for Item Identification and defines 2 MODES of operation which do not interfere with each other, except in certain specified countries or conditions (specified in Annex B).

ISO/IEC 18000-4 – *Part 4: Parameters for air interface communications at 2,45 GHz* –Defines the air interface for radio-frequency identification (RFID) devices operating in the 2.45 GHz Industrial, Scientific, and Medical (ISM) band used in item management applications. Two (2) operating modes are defined; MODE 1 - Passive Frequency Hopping Spread Spectrum (FHSS) backscatter (narrow band) and MODE 2 – Active Long Range High Data Rate.

ISO/IEC 18000-5 – *Part 5: Parameters for air interface communications at 5,8 GHz* (**WITHDRAWN -** Due to lack of interest from several countries)– Defined the air interface for radio-frequency identification (RFID) devices with 2 MODES of operation; MODE 1 was a read/write tag, MODE 2 was never defined.

ISO/IEC 18000-6 – *Part 6: Parameters for air interface communications at 860 – 960 MHz* – Describes a passive backscatter RFID system that supports identification and communication with multiple tags in the field; selection of a subgroup of tags for identification or with which to communicate; reading from and writing to or rewriting data many times to individual tags; user-controlled permanently lockable memory; data integrity protection; interrogator-to-tag communications link with error detection; tag-to-interrogator communications link with error detection; support for both passive back-scatter tags with or without batteries.

ISO/IEC 18000-7 – *Part 7: Parameters for active RFID air interface communications at 433 MHz* - Defines the air interface for radio-frequency identification (RFID) devices operating as an active RF tag in this band for item management applications.

Following are other standards that are indispensable in understanding and defining an RFID system:

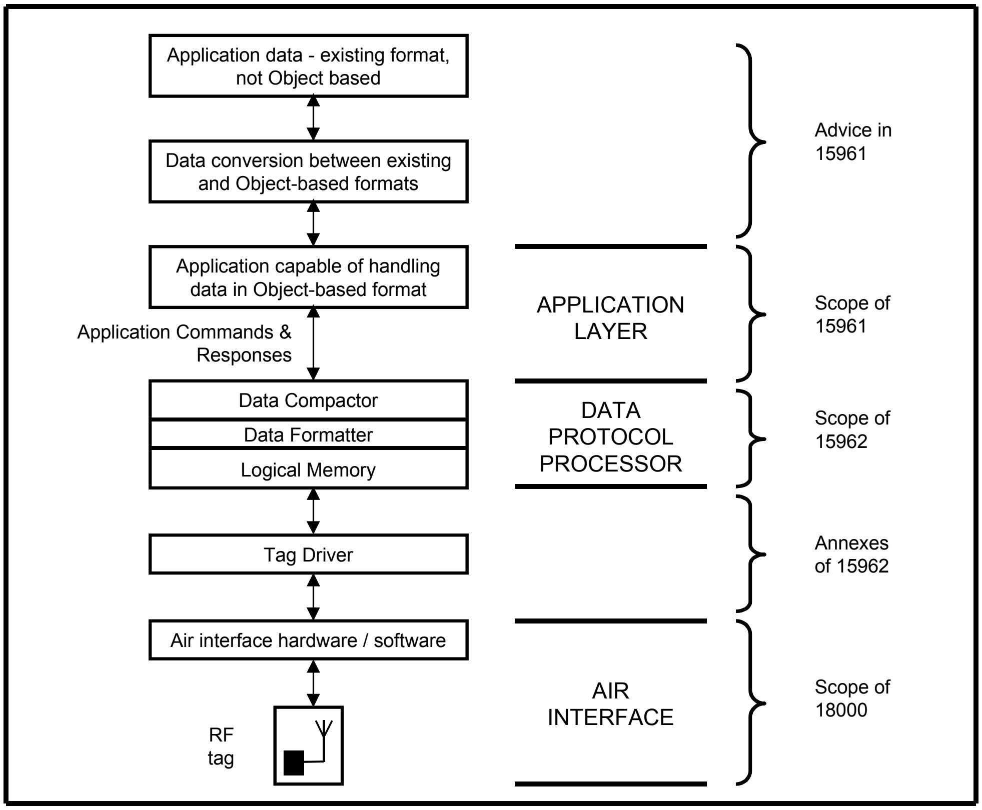
ISO/IEC 15961 - *Information Technology - Automatic identification and data capture techniques - Radio frequency identification (RFID) for item management - Data protocol: application interface* – Specifies the air interface-independent data protocol which allows data to be formatted in an RF tag to be reliably read at the point of use. Use with ISO/IEC 15962.

ISO/IEC 15962 - *Information technology -- Automatic identification and data capture techniques — Radio frequency identification (RFID) for item management — Data protocol: data encoding rules and logical memory functions* – Specifies the overall process and the methodologies developed to format the application data into a structure to store on the RF tag. This standard focuses on encoding the transfer syntax, as defined in ISO/IEC 15961 according to the application commands defined in that standard. The encodation is in a Logical Memory as a software analogue of the physical memory of the RF tag being addressed by the interrogator.

ISO/IEC 15963 - *Automatic identification – Radio Frequency Identification for item management – Unique identification for RF tags* – Describes numbering systems for the unique identification (unique ID) of RF tags which is required as part of the write operation to RFID tags. The unique ID guarantees that the information written to a tag is unambiguously written to the correct data carrier (tag). A unique ID is also required in many read situations where the contents of the tag are tied to a specific item and that item needs to be unambiguously identified.

ISO/IEC 18000 – Information technology, automatic identification and data capture techniques - Radio-frequency identification for item management. This standard was developed with 7 parts, each being voted on as a standard separately. All are published except Part 5 (5.8 GHz) which has been withdrawn. Below are the titles of each of these parts and a brief description of their purpose:

Figure 3 – Schematic of Protocol Layers for an Implementation of RFID for Item Management (per ISO/IEC 15962)



ISO/IEC 18001 - *Draft Technical Report on Application Requirements Profile of Radio Frequency Identification for Item Management*

ISO/IEC 18046 (DTR) - *RFID Tag and Interrogator Performance Test Methods*

ISO/IEC 18047 - *RFID Device Conformance Test Methods* – is a series of standards corresponding to ISO/IEC 18000-n for each frequency band. The standards describe how to test devices (readers and tags) for conformance to the corresponding ISO/IEC 18000-n standard.

ISO/IEC 18047-2 (PDTR) – *Part 2: Parameters for air interface communications below 135 kHz*

ISO/IEC 18047-3 (DTR) – *Part 3: Parameters for air interface communications at 13,56 MHz*

ISO/IEC 18047-4 (PDTR) – *Part 4: Parameters for air interface communications at 2,45 GHz*

ISO/IEC 18047-6 (PDTR) – *Part 6: Parameters for air interface communications at 860 – 930 MHz*

ISO/IEC 18047-7 (PDTR) – *Part 7: Parameters for active RFID air interface communications at 433 MHz*

ISO/IEC 24710 (PDTR) – *RFID for Item Management - ISO 18000 Air Interface Communications - Elementary Tag license plate functionality for ISO 18000 air interface definitions*

ISO TC104/TC122 JWG

ISO 17363 (CD) - *Supply chain applications of RFID - Freight Containers*

ISO 17364 (CD) – *Supply chain applications of RFID - Returnable Transport Items*

ISO 17365 (CD) – *Supply chain applications of RFID - Transport Units*

ISO 17366 (CD) – *Supply chain applications of RFID - Product Packaging*

ISO 17367 (WD) – *Supply chain applications of RFID - Product Tagging*

Potential Telecommunications RFID Applications

As part of management of telecommunication equipment throughout its life cycle, RFID may have several beneficial applications.

The Telcordia COMMON LANGUAGE Equipment Identification Standards organization is leading the RFID specification effort for the Telecommunications industry, and is actively participating in the Alliance for Telecommunications Industry Solutions (ATIS) Bar Code/Standard Coding Committee (BCSC) and the European Telecommunications Standards Institute (ETSI). ATIS/BCSC and ETSI, along with Telcordia, have discussed and identified several potential applications for using RFID technology. These can be grouped into three (3) areas of identification and tracking:

1. Product
2. Package
3. Shipment

This section describes various applications, benefits and implementation issues. However, specifics on implementing these applications should be developed by the industry.

ISO/IEC 18001 was developed to help specify application requirements (the Application Requirements Profile [ARP]) for RFID tags. Based on that draft, the following information should be developed for each application:

1. Application description
2. Tag information:
    - a. Memory size
        - i. Small • 128 bytes
        - ii. 128 bytes < Middle • 1 Kilobyte
        - iii. Large > 1 Kilobyte
    - b. Type – Read/Write (RW), Read Only (RO), Write Once Read Many (WORM)
    - c. Physical size
    - d. Reusable or disposable tag
3. Tag access – Read and/or write:
    - a. Single or multiple antennas
    - b. Reader/writer type –
        - i. Hand-held
        - ii. Fixed antenna(s)
    - c. Maximum read/write distance
        - i. Short Range • 0.1 meter
        - ii. 0.1 meter < Middle Range • 0.7 meter
        - iii. Long Range > 0.7 meter
    - d. Maximum speed in field of reader/writer
    - e. How much data is transferred during the read operation
    - f. How much data is transferred during the write operation (typically 60% - 75% of read range – requiring more dwell time)
    - g. Minimum separation distance between tags
    - h. Packaging or containers material (contain metallic material?)
    - i. Package contents (contain liquids or metals?)
    - j. Tag orientation
        - i. Controlled
        - ii. Not controlled
    - k. Anti-collision issues – one or many tags
    - l. Security system:
        - i. Encryption

ii. Authentication

m. Environmental requirements:

i. Radio interference from other (non-application) sources
ii. Temperature
iii. Vibration
iv. Water proofing
v. Chemicals
vi. Other

Product Identification and Tracking

RFID systems require readers/writers that activate (”wakes up”) RFID tags entering the scanning field in order for the tags to transmit their data. For inventory applications in a warehouse or distribution center, the reader/writer antennas can be placed so that their combined range covers the entire facility. For tracking items moving in and out of a facility, antennas could be placed on both sides of the entry/exit portal so that the direction of travel of the item can be determined. Note that readers are being developed which can determine direction from a single antenna using Doppler techniques.

Potential users of RFID technology have identified the applications in the following subsections for Product Identification and tracking.

Product Data and Tracking

The EPCglobal RFID System is based on the concept of a network and database in place that is accessed each time an EPC tag is read. A Warehouse Management System (WMS), Enterprise Resource Planning (ERP) system or other business system must be capable of using the information flowing over this network. With the continuing development of inexpensive and new technologies for storage, access and transmission of data, some data could easily be made accessible through other enabling technologies (e.g., WiFi, mobile communications, satellite transmission, global positioning systems [GPS] for locating items or vehicles carrying items). Requirements would need to be developed by the industry for the specification of the data elements of the highest importance in the tag and the process of reading and updating tag information.

The major advantage that the telecommunications industry has is an established database of most of the products used in telecommunications networks around the world. The COMMON LANGUAGE® Equipment Code (CLEI™ Code) is the primary key to this data. An important point to note is that this data is already centralized and distributed, so the telecommunications industry is one step ahead of EPCglobal in this regard.

There have been discussions about what to include in a telecommunications RFID tag. It should start with the content of the 2D label and potentially add other data items.

The following minimum data elements should be mandatory for any RFID application using an RFID product tag:

- CLEI™ Code
- Unique Serial Identification (USI) (see TCIF-98-005)

In addition, each tag would require a Unique Identification (UID) per ISO/IEC 15963 and a method to determine level of packaging (see ISO 17366 clause 5.1). The USI may serve this purpose. (NOTE: The UID specified in ISO/IEC 15963 is *not* the same as the UID specified by the United States Department of Defense [DoD]). These data requirements point toward usage of a read/write (RW) tag. This data element “wish” list may not be necessary or practical to include in the tag itself.

Potential Applications and Examples

Examples of potential applications include:

1. **Labor-free inventory** - Inventory all plug-in cards which are not in-service (spares) in a CO, DC or warehouse by issuing a query to RFID system to provide that information. (Note: Only a few significant applications were selected)
2. **Improved plug-in card locating** - Finds one or more specific plug-in cards (e.g., by CLEI Code, by USI or a range of USI's or multiple CLEI Codes)
3. **Automated database update without manual scanning** - The database is automatically updated when a technician removes a plug-in card from service and places it in a storage location.
4. **Tracking plug-in inventory** - When a technician removes a plug-in card from the CO, DC or warehouse, the RFID tracking system updates the inventory for that location and notes that the card was removed by a specific employee (an RFID tag identifying the employee must be used as well – if not, the system just tracks that the card left the location.
5. **Tracking defective plug-ins** - When a defective plug is removed from service, the RFID tag is updated to note that the plug is defective.
6. **Tracking service truck inventory** - Service trucks could also have RFID read/write capabilities and the truck inventory can be taken passively and transmitted (e.g., through mobile phone or satellite link) to a central data storage.
7. **Minimizing or eliminating false dispatches** - Service truck accurate inventory can lead to significant savings in false dispatches, if it can be assured that the correct plug-ins are on the truck prior to dispatch.
8. **Minimizing network outages** - Having the above capabilities and tagging in place, would allow a maintenance technician to locate a needed plug-in card in the network, find the card closest to his/her location and obtain and install the card in a timely and efficient manner, minimizing outages.
9. **Reduce warranty/repair costs** - Knowing the warranty information obtained directly from the plug-in card could help reduce repair time and costs.
10. **Tracking recurring defective plug-ins** - Having the service record, on the card, helps the service provider determine which cards are having recurring problems.
11. **Collecting life cycle information** - Compliance with mandated product recovery requirements in Europe and Japan (UED/WEEE/ROHS info) for collecting end of life information, allowing recyclers to recover internal and external design and disassembly information.

Each of the above applications must be examined to determine whether the RFID tag and associated system offers the best solution over other available technologies.

RFID Product Tagging

This section will discuss issues related to tagging, tag size and placement, frequency ranges and data content.

Tag Size and Placement

The 2D label was developed because space on most plug-ins is scarce. Since RFID tags would not require line-of-sight, there may be additional options for placement of RFID tags. The RFID chip (where the data is stored) can be quite small. Tag size and antenna geometry are critical factors. Antenna geometry is determined by several factors: frequency, read/write ranges and transponder power level. The industry manufacturers will need to examine whether imbedding a tag within the circuit card itself is feasible. There may also be products that can accept the tag on an external portion of the plug-in – such as on an ejector tab.

Frequency Ranges

Due to the wide variety of identified applications and benefits, it may be necessary to examine several of the frequency range(s) defined in ISO/IEC 18000. The 860-960 MHz band (ISO/IEC 18000-6) is normally considered for reading multiple tags in a field for the inventory application.

Testing will need to be performed to ensure the safety of equipment when RFID scanning is performed in a Central Office (CO) environment.

Package Data and Tracking

Product packages can also have RFID tags which can hold information contained in the product package label. (Figure 7.) Product packages are often reused. If printed product package labels have RFID tags embedded on them, assuring that the information on the printed product label and the embedded RFID tag matches the product that is contained in the package is uncertain.. Package tags may only need to be implemented if product tags cannot be implemented. In the early stages and trials of this emerging and changing technology, the package RFID tag may be helpful to gain early efficiencies. RFID tags can be "printed" (i.e., written to) when the package label is printed. The key information needed on a package RFID tag could include – as defined by ATIS030006 (formerly TCIF-93-002-5), section 3.2.5 for plug-in circuit packs:

Figure 7 – RFID package tags

Item Identification
CLEI Code
Unique Serial Identification
Quantity
Country of Origin
Net Weight
Condition – Defective (Repair/Scrap)/Working

Technical Issues for RFID Package Tagging

Many of the issues associated with product tagging also apply to packages. Those issues related to frequency ranges are still critical with package tagging. Tag information must include a method to determine whether the RFID tag is for a product, package or shipment. International application standards (see TC122/Joint work Group [JWG] standards specify how to encode this difference. If an EPCglobal tag is used, GTIN Format Filter Values could be used.

Shipping Data and Tracking

The "Wal-Mart Application"!!

- List info on the Shipping Label (Unit Load) tag – see associated ISO standards
- List applications
  - Shipping
  - Receiving
- Benefits

Wal-Mart currently uses this technology to track shipping containers and pallets.

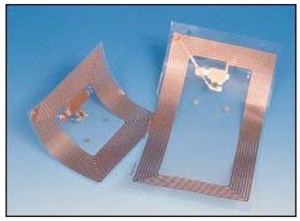
RFID Shipping Labels

As with product package labels, the combined bar code/RFID tag labels can be used. Following are a few thermal transfer printer manufacturers (this is not a complete list) who provide printers that also write to RFID tags on the back of the label:

- DataMax
- Intermec

- Printronix
- Zebra

Figure 9 - RFID tags for the back of shipping labels



Antenna design is critical. In the current Wal-Mart RFID tag reading trials, there are approximately 12 different antenna designs used. The design of the antenna depends on the product (e.g., liquid detergent can affect the reading ability of an RFID tag attached to it).

Technical Issues for RFID Tags on Shipping Labels

Most of the technical issues for shipping labels should be resolved during the early stages and trials for retailers and the DoD.

A major issue is not being able to control what is behind the label in the box. High liquid or metal content can radically change the read range. Because telecom products have metal content that may affect tag reading, this must be tested in the appropriate environment.

Some printing companies are researching ways to print the antenna from the printer (e.g., metal-based inks) to minimize label stock cost and changes in media during production. This could solve the multiple antenna design issues that Wal-Mart is encountering.

Summary

RFID is a promising technology that could provide significant benefits for the telecommunications industry. This paper has outlined RFID basics and potential applications which could provide these benefits. However, there is significant testing and analysis that is required before the industry can move ahead to implementation.

At a recent conference, Dr. John Hamilton, (Assistant Professor of Management and Management Information Systems, John Cook School of Business, St. Louis University) noted that a complete transition to RFID will take 10 and 15 years. This means companies implementing the technology will need to make important strategic decisions and not look at RFID simply as the technology that will solve supply-chain problems. "RFID implementation will take a long time, which means bar codes aren't going away. They both must co-exist in order to serve different user needs," Hamilton said.

Wal-Mart (and other retail companies) initiatives and mandates do not directly affect the telecommunications industry. However, the RFID mandates by the U.S. Department of Defense (DoD) will have an impact on manufacturers/suppliers and some service providers. Companies in the industry should begin pursuing RFID for gains in internal operating efficiency and strive to differentiate themselves from their competition by incorporating RFID as part of their product or service offerings.

The industry needs to start RFID specifications and trials with packages and shipments, as well as developing environmental testing and trials for product level tagging. While pursuing these opportunities, companies must continue to address the technical challenges of today's RFID technology, stay involved with the standards bodies helping to direct the technology, work the issues necessary to synchronize the data over the Internet and remove disconnects in collaborative processing.

Waiting for RFID to be 100% proven, understood and standardized is a losing strategy and companies need to move forward with clear business goals to improve their internal operating efficiency and competitive advantage. The Telcordia COMMON LANGUAGE® Products organization welcomes partners of the telecommunications industry to join for RFID testing and application analysis before the industry can move ahead towards full implementation.

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