RFID Application Guideline for Metal Returnable Transport Items

Part 1

(RFID: Returnable Transport Items)

1 Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees.

Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received. <u>www.iso.org/patents</u>

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

The committee responsible for this document is ISO/122, Packaging

2 Introduction

The demands for more advanced traceability and reduction of both distribution cost and logistics materials have been recently increasing in the supply chain worldwide, and the use of RFID in the supply chain is regarded as an ideal solution. In the actual logistics and material handling, a lot of materials and items are lost or missing due to a lack of efficient RTI management system and this is causing extra expenses to the companies and enterprises from additional ordering costs. To address this problem, the ISO 17364 standard for the use of RFID was developed with the aim to visualize the supply chain where RTIs can be well controlled using RFD in accordance with the international standard.

With RFID for RTI management in place, companies will be able to establish a remote batch reading system without difficulties and reduce a great amount of management cost compared with the use of conventional bar code systems. A wide range of RTIs, such as plate pallets and box pallets, should be covered by the RFID system. However, since the cost benefits may not be achieved just from the RTI asset management if the price of RTI itself is lower than the cost required for the establishment of RFID system, it is recommended to first establish an RFID system that is intended to control high-priced RTIs. An RF tag applied on a metal object may not be activated if it is a commonly available RF tag, as the tag's reading distance becomes a lot shorter attributed to its inherited characteristics against metals. Though a variety of RF tags can be used with metals, the characteristics of RF tags, such as performance and durability or requirements for installation, required to use the metal RTIs are not yet specifically defined.

This technical report specifies the requirements for the use of RFID on metal RTIs. Today, efficient

metal RTI management is in high demand especially in the automobile industry where many parts and components are exclusively designed for automotive use. They are made strong and robust to guarantee the quality of transport and so usually more expensive than ordinary RTIs. In the automotive industry, as metal RTIs are put in a consistent logistics flow running through from parts suppliers to auto manufacturers, to identify the location of RTIs within the supply chain is indispensable. The RFID technology is expected to pave the way for the creation of highly improved RTI management equipped with an enhanced ability and operability by identifying the exact location of target item via item management. As a result, significant cost reduction and resource saving are both accomplished by identifying the optimum number of RTIs just needed for the transportation.

3 Scope

This technical report is intended to denote the importance and reliability of a Returnable Transport Item (RTI) and specify its position in the supply chain (layered structure) along with its data storage structure. Applications on metal RTIs using RFID are also provided to define the characteristics of RFID that are important for a successful introduction of RFID to the supply chain.

This technical report proposes;

- types of RTIs
- types of metal RTIs
- RDID structure and control bit functionality
- required features, reliability and data structure of RFID used for metal RTIs
- metal RTI applications together with their required RFID features
- required functionality of middleware used for metal RTI applications

4 Normative References

ISO 445, Pallets for materials handling - Vocabulary

ISO/IEC 646, Information processing - ISO 7-Bit coded character set for information interchange ISO 10374, Freight containers- Automatic identification

ISO/IEC 15418, Information technology - Automatic identification and data capture techniques - GS1 Application Identifiers and ASC MH 10 Data Identifiers and maintenance

ISO/IEC 15434, Information technology - Syntax for high-capacity automatic data capture (ADC) media

ISO/IEC 15459-1, Information technology - Unique identifiers - Part 1: Unique identifiers for transport units

ISO/IEC 15459-2, Information technology - Unique identifiers – Part 2: Registration procedures

ISO/IEC 15459-3, Information technology - Unique identifiers - Part 3: Common rules for unique identifiers

ISO/IEC 15459-4, Information technology - Unique identifiers - Part 4: Unique identifiers for supply chain management

ISO/IEC 15459-5, Information technology - Unique identifiers - Part 5: Unique identifiers for returnable transport items (RTIs)

ISO/IEC 15459-6, Information technology - Unique identifiers - Part 6: Unique identifiers for product groupings

ISO/IEC 15962, Information technology - Radio frequency identification (RFID) for item management - Data protocol: data encoding rules and logical memory functions

ISO/IEC 15963, Information technology - Radio frequency identification for item management - Unique identification for RF tags

ISO 17363, Supply chain application of RFID - Freight containers

ISO 17364, Supply chain application of RFID - Returnable transport items (RTIs)

ISO 17365, Supply chain application of RFID - Transport units ISO 17366, Supply chain application of RFID - Product packaging ISO 17367, Supply chain application of RFID - Product tagging ISO/TR17370, Application Guideline on Data Carriers for Supply Chan Management

ISO/IEC 18000-3, Information technology - Radio frequency identification for item management -Part 3: Parameters for air interface communications at 13.56 MHz ISO/IEC 18000-63, Information technology -- Radio frequency identification for item management -- Part 63: Parameters for air interface communications at 860 MHz to 960 MHz Type C

ISO 18185-1 Freight containers - Electronic seals - Part 1: Communication protocol ISO 18185-2 Freight containers - Electronic seals - Part 2: Application requirements ISO 18185-3 Freight containers - Electronic seals - Part 3: Environmental characteristics ISO 18185-4 Freight containers - Electronic seals - Part 4: Data protection ISO 18185-5 Freight containers - Electronic seals - Part 5: Physical layer

ISO/IEC 19762-1, Information technology - Automatic identification and data capture (AIDC) techniques - Harmonized vocabulary - Part 1: General terms relating to AIDC ISO/IEC 19762-2, Information technology - Automatic identification and data capture (AIDC) techniques - Harmonized vocabulary - Part 2: Optically readable media ISO/IEC 19762-3, Information technology - Automatic identification and data capture (AIDC) techniques - Harmonized vocabulary - Part 3: Radio frequency identification (RFID) ISO/IEC 19762-4, Information technology - Automatic identification and data capture (AIDC) techniques - Harmonized vocabulary - Part 3: Radio frequency identification (RFID) ISO/IEC 19762-4, Information technology - Automatic identification and data capture (AIDC) techniques - Harmonized vocabulary - Part 4: General terms relating to radio communications ISO 21067 Packaging – Vocabulary

5 Terms and Definitions

For the purposes of this technical report, the terms and definitions given in ISO/IEC 19762 (all parts), ISO 445 and ISO 21067 apply.

6 Supply Chain Model

6.1 Supply chain model

The term "supply chain layers" is a multi-level concept that covers all aspects of taking a product from raw materials to a final product for shipping to a final place of sale, use, maintenance and potentially disposal and returned goods. The reverse logistics process is also included in these layers. Each of these levels covers various aspects of dealing with products and the business process as each level is both unique and overlapping with other levels.



Figure 6.1.1 Supply chain model

Figure 6.1.1 above provides a graphical representation of the supply chain. The figure is a conceptual model of supply chain relationships, not a "one-to-one" representation of physical objects. Although several layers in Figure 6.1.1 have clear physical counterparts, some common supply chain items fit into several layers, depending on their usage.

Adoption of Figure 6.1.1 for use with vehicles and automotive parts gives the following. In this Figure 6.1.1, "A" applies to the vehicles that are directly loaded on the cargo ship, "M" and "L" apply to the vehicles that are first placed in a shipping container and then loaded on a ship. With regards to engines, "B2" and "B1" apply to the engines that are first placed in a wooden frame or case and then loaded on a ship, and "N2", "N1" and "L" apply to those that are put in a wooden frame within a container and then loaded on a ship. Automotive parts carried from one manufacturing facility to another facility are represented by "G" or "F". Most automotive parts and components released to the markets take the structure "H2", "H1" or "F", where individual automotive parts are separately put in a returnable box, a few dozens of which are then put together to constitute one transport unit. The transport unit loaded on a container takes a form "T2", "R" or "L".

6.2 Supply chain model layers

The six-layered supply chain model in Figure 6.1.1 can be represented in another from as illustrated in Figure 6.2.1. In this case, the returnable transport item (RTI) represents a pallet or returnable box, see also Annex A for other types.



Figure 6.2.1 Supply chain layers

Table 6.2.1 describes each of the layers in Figure 6.2.1. With reference to the RFID supply chain standards ISO 17363 to ISO 17367.

Layer	Description	RFID standard
5	Transport means	_
4	Marin container	ISO17363
3	RTI	ISO17364
2	Transport unit	ISO17365
1	Package	ISO17366
0	Item (product)	ISO17367

Table 6.2.1 Supply chain layers

In Figure 6.2.1, Layer 5 at the top of this layered structure indicates a transport means such as a ship and air cargo and Layer 4 is a large-sized transport device, and the other layers at the lower levels are categorized into RTIs (pallets, etc.), transport units, packages and products. This structure needs a comprehensive and well-organized symbol identification system, as a variety of items with different forms and shapes are constantly dealt with within the supply flow where each item has its own management initiative. For instance, information on the layer of each item or package is important for manufacturers, while that on the layer of a transport unit and container is important for transport carriers. Layer 0 applies to the manufacturing process, Layer 1 to the packaging process, and Layer 2 and Layer 3 to the shipping or transport process.

Since the required data type and the number of characters varies depending on the process, each of the layers shall be uniquely identified. For the identification of layers, each layer shall be given its own data identifier so that it is explicitly distinguished from other layers. If the same RFID is used for all the layers, reading of only the data on Layer 3 becomes impossible as the data on Layer 2 will also be read in this case. This will adversely affect the data processing by making the process more difficult and compromising its speed.

In the supply chain model, Layer 3 is allocated to RTIs with RPIs being placed between the layers. Although RTIs cannot be distinctively distinguished from RPIs, reusable containers like pallets and returnable boxes exclusively used for the transportation work should be categorized as RTIs. Described in Annex A are the examples of transport units used in Layer 3. In many cases, a returnable packaging item (RPI) represents a reusable container, such as a plastic container or a metallic barrel, for carrying liquid or powder.

Annex B shows the examples of metal RTIs. The metal RTIs are mainly employed in the

production sites where transport units are used to carry automotive parts and components including engines and exhaust devices and they are normally placed in a container in their assembled forms. Once the engines or exhaust devices placed in metal RTIs are assembled onto a vehicle, each of these RTIs is emptied and then folded down into a smaller form for storage. Usually, they are piled up one after another to save space. Since the metal RTIs are created to be precisely fit to the target part/component, they come into a wide variety of types and shapes with different structures. This may largely affect the RFID's ability and performance depending on the shape of the object and the installation method.

6.3 Types of data carriers used in supply chain

The data carriers, such as linear symbols, two-dimensional symbols and RFID, used for supply chain management shall be selected according to their respective characteristics. Since most readers released to the market are equipped with an ability to automatically distinguish and read different types of linear and two-dimensional symbols, these symbologies can be implemented without restriction.

RFID can operate at five types of frequencies of 135 KHz or lower, 13.56 MHz, 433 MHz, 860 to 960 MHz and 2.45 GHz. As each of these frequencies may have its own memory structure and communication protocol, it is very difficult for the existing interrogators to automatically recognize and read various types of RFID data carriers. Although an RFID with a different type of air interface can be selected for each of the supply chain layers (see Figure 6.1.1), other types of interrogators will be additionally required to read all the RFID data and this may increase the operating cost. For this reason, the types of RFID should be limited to the least possible number in the supply chain management.

6.4 Types of RFIDs used in supply chain

Table 6.4.1 describes the supported RFIDs for each of the supply chain layers defined in the RFID supply chain standards ISO 17363 to ISO 17367.

Layer	Description	Supported RFID types	
5	Transport means	—	
4	Marin container	ISO/IEC 18000-7	
3	RTI	ISO/IEC 18000-2 Type A, ISO/IEC 18000-3M3,	
5	κπ.	ISO/IEC 18000-63, ISO/IEC 18000-7	
2	Transport unit	ISO/IEC 18000-2 Type A, ISO/IEC 18000-3M3,	
2	Transport unit	ISO/IEC 18000-63, ISO/IEC 18000-7	
1	Package	ISO/IEC 18000-3M3, ISO/IEC 18000-63	
0	Item (product)	ISO/IEC 18000-3M3, ISO/IEC 18000-63	

 Table 6.4.1 Supply chain layers and RFID types

Table 6.4.2 shows the relationship between the RFID air interface and the frequency

Table 6.4.2 Air interfaces and frequencies

Air interfaces	Frequencies
ISO/IEC 18000-2 Type A	Below 135 KHz
ISO/IEC 18000-3M3	13.56 MHz
ISO/IEC 18000-63	860 to 960MHz
ISO/IEC 18000-7	433 MHz

The interfaces in ISO/IEC 18000-3M3 and ISO/IEC 18000-63 are recommended for Layer 0 to Layer 3, but ISO/IEC 18000-63 should be most applicable considering the tag's readable distance. This technical report focuses on ISO/IEC 18000-63 specifying the 860 MHz to 960 MHz UHF band.

6.5 Nation approved UHF bands

ISO/IEC 18000-63 is the air interface standard that specifies a UHF band in the range of 860 MHz to 960 MHz frequencies. Considering that the UHF band is now broadly introduced to mobile phones, development of the international standard that can be universally shared is a very difficult challenge. Looking at the global situation from a historical perspective, the widest frequency band, which is adopted in both North and South America, has long been used as a basic operating band and achieved a satisfactory result in the U.S. Refer to Annex C for which frequency is currently allocated by individual nations conforming to their respective radio regulations.

When implementing RFID to the supply chain management, the use of a band with a wider frequency range is recommended anticipating that multiple number of RFID interrogators are expected in many applications. Nations where a wider frequency is assigned include North America, South America and South Africa, each using the 26 MHz (902 to 928 MHz) frequency range, and Australia using the 6 MHz range. In contrast, operating frequency is limited to 2 MHz in most European countries. In the global supply chain, ideal characteristics of RF tags can be obtained from the frequencies of 865 MHz and 920 MHz at both ends of the specified frequency range.

6.6 Layer identification of supply chain

The identifiers for the identification of supply chain layers conform to ISO 17364 to ISO 17367 in Table 6.6.1. These identifiers can be applied not only to RFID but also to other data carriers such as liner symbols and two-dimensional symbols. The basic identification methods on Layers 0 to Layers 3 are defined in ISO/IEC 15459-1, ISO/IEC 15459-4 and ISO/IEC 15459-5.

Layer	Description	ISO standard	DI	AI
5	Transport means	—	—	—
4	Marin container	ISO 10374	—	—
3	RTI	ISO/IEC 15459-5	25B、55B	8003 (GRAI)
2	Transport unit	ISO/IEC 15459-1	J, 1J to 6J	00 (SSCC)
1	Package	ISO/IEC 15459-4	25S	SGTIN-96
0	Item (product)	ISO/IEC 15459-4	25S	SGTIN-96

 Table 6.6.1 Supply chain layers and identifiers

DI: Data Identifier, AI: Application Identifier

The data identifiers stored in the data carrier are so developed that they can be used even for different EDIs. The structure of these identifiers and data shall be globally unique, or "one and only in the world", and this uniqueness has to be guaranteed. The data identifier (DI) is mainly used in the manufacturing industry, while the application identifier (AI) is generally seen in the distribution industry. Since all data in AIs is composed only of numeric characters in accordance with GS1 that defines AIs, some alphabetical characters shall be always included in DIs to distinguish the DIs from AIs.

6.7 Applicable data types in data carriers for supply chain

The types of data that can be stored in the data carriers for supply chain management are set forth in ISO/IEC 15418. Most of the data characters used for EDI messages and their applicable identifiers conform to the ISO/IEC 15418 standard. The definitions of the data characters and their identifiers selected from ISO/IEC 15418 are found in ISO/IEC 15459-1. In today's business transactions, EDI (Electric Data Interchange) is regarded as the foundation in making a deal and trade. In customs clearance involved in the global supply chain, most procedures are electrically handled based on the UN/EDIFACT syntax rule and there may be a case when the same EDI data is directly used without any change or modification. In that event, the EDI data shall be stored complying with the rules specified in ISO/IEC 15434.

In the ISO/IEC 15418, ISO/IEC 15434 and ISO/IEC 15459 standards, all types of data carriers

including RFID are supported so that a wide range of different data carriers can be used in a combined manner.

7 Identification of RTI

7.1 Basic data structure

The definitions of identification codes for a transport package (transport unit) is provided in ISO/IEC 15459-1, that for items and item packages is in ISO/IEC 15459-4 and that for transport packages as a single unit is in ISO/IEC 15459-5. The registration method for the assignment of a company number to uniquely identify individual identification codes is given in ISO/IEC 15459-2. In ISO/IEC 15459-2, the qualification required for the Issuing Agency (association that is given the authority to issue a company number) is stipulated alongside the registration method. In the U.S., AIM acts as the Registration Authority (RA) that controls the registrations.

To get its own company number, each company should apply for a number with the appropriate Registration Authority. The basic concept of ISO/IEC15459 series standards that stipulate the code system is based on three key elements of "business interface", "internationality" and "availability of existing symbologies". Of these, the availability of existing symbologies, in other words, the possibility to use the existing code systems without any changes or modifications is of particular importance. Changing the number will not be so difficult if not many items or products are involved. However, it is almost impossible for the company to thoroughly review or change its numbering system if a huge number of items, for example, as many as 10 million items are to be covered. Described in Table 7.7.1 is the basic structure that can make each one of the item identification codes unique and distinctive without overlapping with others. To put it simply, adding an Issuing Agency Code and a Company Code assigned by the Issuing Agency to the company's existing number system should be a solution.

Table 7.1.1 Basic structure to make identification code unique

Basic structure
"Issuing Agency Code (IAC)" + "Company Identification Number (CIN)
assigned by AIC" + "Item Number by Company" + "Serial Number by Company"
Note: A plus sign "+" is not included in the symbology.

7.2 RTI data structure

Table 7.2.1 describes the data structure of RTI identifier 25B. This structure defined by ISO/IEC 15459-5 is appended with "25B" at the beginning of the basic structure (see Table 7.7.1). In this data structure, the segment "Item Number by Company + Serial Number by Company" is jointly represented by "SN". It should be noted that the number of digits may vary depending on the type of data carriers.

Table 7.2.1	Idetification	RTI data	structure
-------------	---------------	-----------------	-----------

Item code			
25S	IAC	CIN	SN
3 digits	3 digits max.	12 digits max.	50 -18= 32 digits min.

7.3 Issuing Agency Code (IAC)

The Issuing Agency Code (IAC), which consists of from one (1) character to a maximum of three (3) characters, is a code used to identify the entity, organization or company authorized by the appropriate registration authority as an Issuing Agency in accordance with ISO/IEC 15459-2. This

includes, for example, UN (Dun & Bradstreet) and OD (Odette Europe).

7.4 Company Identification Number (CIN)

The Company Identification Number (CIN) is a unique code that is assigned by the Issuing Agency to each individual company. Each Issuing Agency has its own format for the CIN. The CIN code may be partly determined by the company.

7.5 Serial Number (SN)

If the Serial Number (SN) is constructed in combination with IAC and CIN, it shall constitute a globally unique identifier for the RTI. Once created and attached to an RTI, the combination of CIN and SN is intended to be fixed and unchangeable for that specific RTI throughout its lifetime.

The Serial Number (SN) may be composed only of numeric or alphabet characters, or their combination. Significant data that has a meaning of the item can be part of the SN as is indicated in Table 7.5.1. The significant data is called an Object Data (OD) component and all the other remaining components is called an Object Serial Number (OSN). The OD itself may be composed of several attributes.

Table 7.5.1 Str	uctured S	Serial N	umber
-----------------	-----------	----------	-------

Serial Number (SN)				
Object Data (OD) Object Serial Number (OSN)				

The Object Data normally represents the RTI's Item Number and the Object Serial Number represents the Serial Number. The Object Serial Data does not have to be a sequencial number and can be structured as shown in Table 7.5.2. Remaind that a sequential number with a simple structure will have the smallest number of digits if the storage capacity of data carrier is not large enough.

Table 7.5.2 Structured Object Serial Number

	Object Seri	ial Number (OSN)	
Factory identification code (3 digits)	Year/month/day of manufacture (8 digits)	Time of manufature (4 digits)	Simple serial number (5 digits)

7.6 Maximum number of digits

The number of digits recommended by the ISO/IEC15459 series standards is 20 and the maximum number of digits is 50. For liner symbols, up to 20 digits are supported. The character sets defined in the ISO/IEC 15459 standards are upper case alphabet characters and numeric numbers from the ISO/IES 646 7-bit ASCII character sets. Types of character sets that can be used for computer systems extend to a wide range, including, for example, 16-bit code conforming to ISO/IEC 10646 and 8-bit codes conforming to ISO/IEC 8859. In the case of a data carrier, 7-bit ASCII codes defined in ISO/IES 646 are normally used by padding zeros to the most significant bit to make the carrier an 8-bit code.

How to store data depends on a liner symbol, two-dimensional symbol and RFID, but the same storage method should be used for the data exchange among the printer, the reader or interrogator and the host computer to achieve an easy-to-design system structure for the reduction of cost.

8 RF Tag Data Structure

8.1 RF tag data structure

The structure of RF tag shall be as specified in ISO/IEC 18000-63 Type C. Refer to Annex for more information on the structure of RF tag memory. Basically, the RF tag memory consists of four different banks of RESERVED (MB00₂), UII (MB01₂), TID (MB10₂) and USER (MB11₂).

8.2 RESERVED (MB00₂)

MB00₂ is a reserved memory bank that controls a password like a kill password or access password. The kill password is set to erase the data and the access password to give the right to access the memory information. The kill password shall be stored at memory addresses 0x00 to 0x1F and the access password at memory addresses 0x20 to 0x3F. If the kill or access password is not implemented in the RF tag, the value of the password becomes "0" and therefore RESERVED (MB00₂) does not need to exist.

8.3 UII (MB01₂)

MB01₂ consists of a checksum CRC-16 used for data verification, Protocol Control (PC) bits of the data to be stored and the Unique Item Identifier (UII) of the item to be stored. Information on the item is stored in the UII memory according to ISO 17364 to ISO 17367. The size of UII memory in MB01₂ shall not be less than 240 bits for applications except for EPC (GS1). A CRC-16 is stored at memory addresses 0x00 to 0x0F, Protocol Control (PC) bits at memory addresses 0x10 to 0x1F and the UII at memory addresses after 0x20.

The Protocol Control (PC) bits are divided into the unique ID memory length indicator in memory locations 0x10 to 0x14, the USER (MB11₂) indicator in memory location 0x15, the PC extension indicator bits in memory location 0x16, the ISO/EPC identification bits in memory locations 0x17 and the AFI/EPC attribute bits defined by ISO in memory locations 0x18 to 0x1F. In the CRC-16, PC and UII memories, data is stored with the most significant bit (MSB) first. The MSB for CRC-16 is located at memory address 0x00, MSB for PC at memory address 0x10, and MSB for UII at memory address 0x20.

8.4 TID (MB10₂)

A globally unique identification number of the tag ID (TID) assigned to the chip or inlay manufacturer of each specific RF tag is written and locked in MB10₂ almost semi-permanently to prevent it from being overwritten or erased. When some privacy issues related to RF tags were brought up for discussion in the past, a new air interface ISO/IEC 18000-63 Type C that does not use a TID was developed at the initiative of GS1. To avoid such unwanted privacy issues, it is strongly recommended for a system designer to establish a system structure that does not use a TID.

8.5 USER (MB11₂)

The MB11₂ data memory area is made open and accessible to every user. The contents of data may be decided upon with the mutual agreement of the trading partners. The memory structure is defined in the storage format defined in ISO/IEC 15961 and ISO/IEC 15962. If some data is present in MB11₂, the Protocol Control (PC) bit 0x15 of MB01₂ shall be set to "1₂". If the PC bit

0x15 is set to "02", this indicates that MB112 does not exist or no data is left in MB112.

The data structure of MB11₂ shall conform to the ISO/IEC 15434 data format 06 (data having an ASC MH10 data identifier). The same storage method used for two-dimensional symbols is also adopted to MB11₂, where the first eight-bit segment of MB11₂ is called DSFID (Data Storage Format Identifier) and the subsequent eight-bit segment is called Precursor, and the total of these 16 bits constitute the structure that defines the access method, in other words, how to encode data into the tag. These 16 bits are also used in determining the data format. The memory addresses from 0x10 to 0x17 indicate the number of data bytes stored in MB11₂ by the data byte number indicator.

RFID Application Guideline for Metal Returnable Transport Items

Part 2

(RFID: Returnable Transport Items)

9 Characteristics of Metal-Applicable RFID

9.1 Introduction

Although the ISO 1736X series international standards have been established for the use of supply chain RFID, practical applications based on these standards are still very few. Meanwhile, in the manufacturing industries like automotive world, there is a need for metal RTIs (Returnable Transport Items) and actual management systems using RFID are already introduced in some manufacturing fields to meet that need. However, satisfactory results have not yet been achieved due to a lack of experience and knowledge about the RFID's ability and performance and the effects of metal. In addition to that, a number of tests and examinations should be executed for the implementation of RFID. Annex E proposes the basic functions essential to facility the introduction of RFID exclusively with respect to RFID for metal RTIs. The concept and data described are also applicable to other objects and materials.

The RFID placed on a metal RTI is basically characterized by a change in the performance according to the types of "metals" and "durability tests" and this characteristic feature is specifically observed in the following four verification tests:

- Communication distance: Measurement on the RF tag's communication performance
- Communication time: Measurement on the time required to write data into RF tag
- Durability test: Verification on the durability of RF tag
- · Filed-application test: Indication of the RFID implementation test points

9.2 Communication distance

In the above-mentioned tests, a change in the performance of RF tag was examined by measuring the tag's reading and writing distances to see how the tag changes its performance according to the material or shape of the metal on which the tag is attached and the operating environments. Refer to Annex E and Annex F for the results of these tests. Although ISO 1736x series standards specifies that the ISO/IEC 18000-63 Type C tags shall have the UII memory of more than 210 bits and the USER memory of more than 400 bits, the tags whose UII is more than 128 bits and USER is more than 300 bits are used in these tests.

Figure E.1 and Figure E.2 in Annex E respectively shows the reading distances and writing distances of several types of tags (tag A to tag E) attached on a stainless (SUS) plate with a double-faced adhesive flat tape. Figure E.3 and Figure E.4 are the reading distances of the same tags not attached on a stainless plate. All the tags used in these tests are ordinal tags available on the market. In these Figures, the horizontal axis denotes a frequency (MHz) and the vertical axis denotes a communication distance (m). The RF tag placed on a stainless plate as shown in Figure E.5 is taken as a standard. Shown in Figure E.6 is the measurement condition of the anechoic chamber used to obtain the test data in Figure E.1 and Figure E.2.

Unlike the global supply chain that uses the ISO 1736x series standards, this standard recommends the use of RF tags defined in ISO/IEC 18000-63 Type C for UHF band. A wide range of frequencies from 860 MHz to 960 MHz are covered for ISO/IEC 18000-63 Type C tags and each nation or region has its own frequency (see Annex C). For example, while frequencies around 865 MHz are designated in Europe and its related countries, those around 900 MHz to 920 MHz are generally allocated in North America and Asia. As for Japan where a 950 MHz frequency range was once designated as a national frequency, 960 MHz is taken as the highest frequency supported by ISO/IEC 18000-63 Type C. Nonetheless, the national frequency is now changed to 920 MHz and therefore 930 MHz should be regarded as the upper limit frequency for ISO/IEC

18000-63 Type C RF tags.

In figures in Annex E, the frequencies around 865 MHz shown in gray indicate the frequencies allocated in Europe and those in the range from 900 MHz to 920 MHz also in gray indicate the frequencies allocated in North America and Asia. As the global supply chain now expands across a number of counties and regions, the characteristics observed in the frequencies near 865 MHz and 900 to 920 MHz become the key point. For instance, the tags such as shown in Figure E.1 can be applied in North America and Asia, but it may be difficult to use them in Europe. In the case of tag A, the tag achieves a maximum reading distance of 14 meters near the 865 MHz frequency, but the tag's reading distance is reduced to 9 meters at a maximum, or approximately 30% down in terms of the performance, in the range from 900 to 920 MHz. This suggests that the most appropriate RF tag shall be selected according to the frequency level assigned by the country or the region.

In general, the use of RF tags developed for distribution purposes is limited solely to the reading operation. In contrast, in the manufacturing industries such as the automotive industry, RF tags are usually used for writing additional data to achieve a traceability in the applications that do not use a real-time networking architecture (stand-alone). In this case, the distance of both reading and writing becomes important. This is because, in the normal tag data writing procedure, the interrogator reads RF tag's UII first then writes data to the tag, meaning that the interrogator shall read the tag data even in its writing process. It should be noted that a reading distance of conventional RF tags largely differ from its writing distance. In Annex E, the tag's communication performance in Figure E.2 is degraded by approximately half that in Figure E.1. This means that more RF tag power is consumed on writing than reading.

Figure E.3 and Figure E.4 depict the data on the tags originally developed for applications where the tags are adhered or bolted on a metal plate, but in these tests they were measured without using a metal. As a significant change is normally anticipated in both of the reading and writing, the tag shall be so arranged that they come close contact with a metal plate to the possible extent. Check the contact distance between the tag and the metal when using a metal-applicable RF tag.

Figure F.1 in Annex F shows how the data on the communication distance changes by the types of metals, surface treatments and the shapes. All the data is measured on the tag A with respect to its reading distance and writing distance, both observed at 965 MHz and 920 MHz. Here, the RF tags placed on a stainless (SUS) plate are taken as a standard. Impact of metal materials, such as ion finished with alkaline blackening Fe_3O_4 or aluminum, is scarcely observed in these tests. As for the RF tag attached on an aluminum square pipe, the reading ability is deteriorated at 965 MHz. There is hardly a change in reading the RF tag placed on an aluminum plate (500 mm and 1000 mm).

In the test using the double-faced adhesive tape 2, the reading distance becomes shorter at a frequency of 865 MHz. There is not much difference in the thickness of the double-faced adhesive tape 1 (0.65 mm thick) and the tape 2 (0.62 mm thick), but they are made of different materials and so their respective frequency characteristics shall be checked when attaching RF tags with these double-faced adhesive tapes. The tape 1 is a foamed polymer base material with acrylic-type adhesive and the tape 2 is a polyethylene foam base material with acrylic-type adhesive.

Figure F.2 shows the data of the tag placed on other than a metal plate and the data on the tag placed on a SUS plate shielded at its midpoint. Similar to the case with a non-metal material, almost the same data with the free air is obtained, indicating that the effect of metal is diminished when a shielding placed between the antenna and the tag is a loose wire mesh panel. Figure 3 is the data on the tag operating in varying ambient conditions. Here, effects caused by the changes in the tag's temperature, humidity and environments are very scarce.

Changes in the data on the tag operating in varying installation environments are shown in Figure F.4. It is reaffirmed that the tag is largely affected by the ambient metal objects, but the effects of non-metal wall and floor is comparatively low. Figure F.5 indicates how to measure the impact caused by a direct contact with metal (see Figure F.4). In this measurement, the RF tag is attached on the base aluminum plate of 500 x 500 x 10 mm, to which a 200 x 200 x 4 mm size aluminum plate is applied on each of its sides (left, right, top and bottom).

From the above results, the communication distance can be summarized as follows:

Elements that largely change communication distance

- (a) Writing distance in comparison to a reading distance
- (b) Difference in the operating frequency range
- (c) Effects by the ambient metal objects
- (d) Adhered reflection tape
- (e) Application other than metal objects (resin, wood, cardboard, etc., including free air)
- (f) Shielding with a metal plate or fine wire mesh panel

Elements that scarcely affect communication distance

- (a) Metal type (ion, aluminium, stainless)
- (b) Metal shape (large/medium/small size plate, square pipe)
- (c) Installation method (double-faced adhesive tape, bolt, banding band)
- (d) Changes in the temperature and humidity
- (e) Extraneous matters (water drops, glass, packing tape)
- (f) Shielding with a loose wire mesh panel

9.3 Communication time

The time required for obtaining the UII and the USER data and for data rewriting was measured regarding the communication between the RF tag and the interrogator. Changes in the communication time as a result of the fluctuation in the data volume were also examined for a single FR tag and multiple RF tags. Three different types of ISO/IEC 18000-63 Type C RF tags (inlays) were tested. Refer to Table 9.3.1 for the details on these RF tags.

Sample tag name	Tag (IC) X	Tag (IC) Y	Tag (IC) Z
UII size	96/256	256	128
USER size	512/352	512	512
Antenna size	W70/H17	W70/H14	W86/H24

Table 9.3.1 RF tags (inlays) subject to the test

The communication time was evaluated using the tags IC X, IC Y and IC Z, each having the USER memory (see Table 9.3.1). Refer to Annex G for the evaluation method and the results.

In Annex G, Figure G.1 shows the measurement conditions inside the anechoic chamber and the positional relation between the tags (ICs) placed on the formed polystyrene and the antenna, and Figure G.2 is the number of tags (ICs) and their positional arrangement. In this case, measurements were executed using one, five, fifteen and thirty tags (arranged on both sides). The positional relation between the measurement antenna and the tags are given in Figures G.3.1 and G.3.2. The antenna used is a circular polarized antenna.

Figures from G.4.1 to G4.3 describe the results of reading the three different types of tags by using four antennas. The results indicate that reading the UII is much faster than reading the USER for the ISO/IEC 18000-63 Type C tags. In reading the USER, no particular difference by the bit count is observed until up to 15 tags. The time consumed on reading remains almost the same for 32 bits and 128 bits. However, as the number of tags is incremented to 30 tags, it takes more than 1 sec. longer if the number of bits is incremented to 512 bits compared to 32 bits. More time is required for writing than reading, particularly for writing the tag Y.

Figures from G.5.1 to G5.3 describe the results of writing the three different types of tags by using four antennas. The results indicate that writing the UII is much faster than writing the USER regarding the ISO/IEC 18000-63 Type C tags. It is assumed that writing to the USER is not intended for the tag Y. For any other tags than the tag Y, a proportional relationship is observed between the number of bits to be written and the writing time. This also applies to the number of

tags to be written and the writing time.

Figures G.6.1 and G6.2 describe the time required for reading and writing a 512-bit USER memory for the tag X by using one antenna and four antennas. A proportional relationship is observed in the number of tags. As an interrogator is configured to establish communication by switching the antennas, the communication time is extended in proportion to the number of implemented tags. The number of antennas to be used should be determined according to the actual operating conditions including the direction and height of the antennas.

Based on the above results, the communication time can be summarized as follows:

Reading

- (a) UII reading is done at a much higher speed (inventory).
- (b) With an increase in the memory capacity and/or the number of tags, reading becomes longer with a larger time variation.
- (c) There was a case that reading five tags was faster than reading a single tag.

Writing

- (a) With an increase in the memory capacity and/or the number of tags, writing becomes longer.
- (b) There was a case that writing five tags was faster than writing a single tag.
- (c) Writing the tag Y was not completed under certain conditions.

9.4 Durability test

Table 9.4.1 is a list of test standards applicable to the tag A (see Section 9.2) intended for metal RTI applications. A durability test was performed in accordance with the definition of "ISO 18185-3 Freight containers-Electronic seals-Part 3: Environmental characteristics" by reference to the results of evaluation test equivalent to a 10-year outdoor durability test. An electric seal that can be used with marine containers as defined in ISO/IEC 18000-7 is selected in this test. The tag used here is an active tag that has a battery operating at 433 MHz. This kind of tag is rather similar to an electric control device and so the IEM test standard is taken as a standard.

Although the ISO/IEC 18046 series (conformance) and ISO/IEC 18047 series (performance) standards are developed for RF tags, their main objective is to define the measurement method of RFID's functional performance, not a durability test. The durability test method described in this section is stipulated based on ISO 18185-3 with referring to the ISO/IEC 18046 series and ISO/IEC 18047 series standards. The batteries for active tags defined in ISO 18185-3 shall be able to continuously operate for at least the potential longest shipping duration of three months. All the other components should have the same product life time with a marine container, or they need to realize at least a life time period of 10 years at a minimum.

Item	Standard	Test method
Low temperature	- 40 °C	IEC 60068-2-1
High temperature	+ 85 ℃	IEC 60068-2-2
Mechanical shock	30 G (11 ms)	IEC 60068-2-27
Random vibration	3G (2H, - 40 ℃ and + 85 ℃)	IEC 60068-2-53
Humidity	Up to 95%	IEC 60068-2-38
Rain/snow	1 m of salt water	IEC 60068-2-18
Salt fog	Salt fog	IEC 60068-2-11
Drop shock	3.3 m concrete	IEC 60068-2-31 and -32
Sand and dust	Sand and dust	IEC 60068-2-68

Table 9.4.1	Test standards	of container	electronic seal
-------------	-----------------------	--------------	-----------------

Two types of operating environmental tests as shown in Table 9.4.2 and Table 9.4.3 were conducted. In the basic operating environmental tests in Table 9.4.2, the electronic seal was

assessed with a high temperature high humidity storage test, a low temperature storage test, a high temperature storage test, a heat cycle test, a heat shock test and a weatherproof test. The test results indicate that, in the high temperature high humidity storage, high temperature storage and heat cycle tests, the electronic seal failed to keep above the initial 90% communication distance level for the specified test time period equivalent to 10 years.

Annex H shows the results of high temperature high humidity storage test. This Annex describes the reading ability of RF tags. Figure H.1 is the graphical representation of the tag's readability rate against its serviceable life time. In the high temperature high humidity storage test, good results are achieved in Figure H.2, while tag's performance is degraded in Figure H.3. It is assumed that the tag's reading distance becomes shorter as the contact resistance between the semiconductor and the antenna increases over time. As is seen from Figure H.1, the test samples keeping more than 90% of their initial functional ability end at 0% after having been through a test period equivalent to 32.5 years of time. In contrast, at a 19.5-year equivalent test time, more than 80% of the test samples keep more than 90% of their initial functional ability.

No.	Test item	Test conditions	Result
01	High temperature high humidity storage	+ 85 ℃ and 85% for 1000 hours	Passable
02	Low temperature storage	- 80 °C for 60 days	ОК
03	High temperature storage	100°C for 3500 hours	Passable
04	Heat cycle	- 40 °C to 100 °C, retained for 20 min. at each temperature for 630 cycles (1 °C approx. 2 hours)	Passable
05	Heat shock	- 40 °C to 125 °C, retained for 20 min. at each temperature for 730 cycles	OK
06	Weatherproof	120 min., optical irradiation (incl. 18 min. shower) cycle for 3000 hours	Unknown

OK: No problem

Passable: Unable to keep 90% of the initial communication distance at a 10-year equivalent test time (communication enabled)

The test items for the operating environmental tests include a block shock test, vibration test, shock test, salt spray test, immunity test and chemical-resistance test (see Table 9.4.3). Good results were achieved in most of these tests, except the block shock test in which the resin housing was broken and the chemical-resistance test in which the inside of RF tag's resin case was eroded by liquid.

No.	Test item	Test conditions	Result
07	Block shock test	Applies ISO 8611-1:2011 block shock test to the tags	NG
08	Vibration test	3 G, single-axis rebound random vibration for 3 hours	OK
09	Shock test	100 G, sine half-wave for 6 ms Sample attached on a pallet was dropped	ОК
10	Salt spray test	35℃ for 96 hours	OK
11	Immunity test	50 V/m (electromagnetic field), 25 kV (static electricity)	OK
12	Chemical-resistance test	Sample was submerged in assumed chemical for 2 hours	Passable
014 1			

Table 9.4.3 Operating environmental tests

OK: No problem

Passable: May be partly eroded by chemical

NG: Resin housing broken (communication enabled)

These test results suggest that a sufficient allowance should be included in the RF tag's service

period to cover the degrading communication distance observed in some of the tests. As the RF tags covered in this document are intended to be used with metal RTIs, the durability test was also conducted on the RF tags attached on metal objects. Note that a load stress caused by a difference in the heat expansion rate between the tag's resin housing and the metal is not applied to the RF tag in a single-unit tag test.

RFID Application Guideline for Metal Returnable Transport Items

Part 3

(RFID: Returnable Transport Items)

10 Applications to Supply Chain

10.1 General reading methods

As is known from Annex I, a gate type reader or a belt conveyer type reader may be used for reading RFID. In the gate type reading in Figure I.1, communication with the RF tag is established using a different frequency channel at each gate. For instance, a center frequency of the CH 1 can be set to 920 MHz, the CH 2 to 922 MHz and the CH 3 to 924 MHz. As the ISO/IEC 18000-63 Type C RF tags have a wide range of communication frequencies, they may also respond to the frequencies from other channels. So, the RF tag currently passing through the CH 1 may also respond to the interrogator at the CH 2 if the gates are arranged in adjacent to each other. This shall be prevented either with a shielding plate or radar absorbent material. This kind of preventive measures is also required when a hand-held type interrogator is activated in the vicinity.

Reading a multi-layered tag placed on a shipping container carrying items is difficult with the existent technology (see Figure 10.1.1). Basically, reading a tag applied inside the box is not easy due to the absorption or interference of radio waves if a dielectric substance like metal resides inside the box. It is difficult in principle to guarantee a tag's performance even if the tag was assessed as readable in the test.



Figure 10.1.1 Reading of multi-layered RF tags

Figure I.2 in Annex I shows the belt conveyer type reading system usually seen in many manufacturing facilities and distribution centers. Similar to the gate type system, a different frequency channel should be selected to the nearby antennas and interrogators operating within a reach of the frequency range. Interference of the radio wave shall be minimized to the least possible level without increasing the intensity of the nearby antennas more than necessity. Set up the most applicable environments by choosing the optimum antenna-to-antenna distance, operating frequency channels and output wave power intensity so that the interrogator is able to read the target RF tags without fail.

Though the use of RFID is expected in the supply chain management as an ideal solution for sorting the items on a fast moving conveyer belt, some of the tags may be bypassed in the reading process if the communication between the tag and the interrogator is blocked. In the LBT (Listen Before Talk) structure, the items will likely to pass through the gates while the tag is waiting for a response from the interrogator. A mirror sub-carrier method is recommended to address this situation. To fully secure the communication to the RF tag running right before the gate, establishment of a well-organized mechanism that can, in combination with a limit switch, ensure the RF tag reading is indispensable by reducing the antenna's output power to the lowest required

level to minimize the antenna-to-antenna interference.

Since an RF tags is composed of semiconductors, using a large amount of the same chips will lead to the cost reduction. If many chips and inlays are of the identical type, the price will go down, thereby promoting the further expansion of RFID technology. However, to use the same type of chips and/or air interfaces for a broad range of applications, a high-quality of selective reading mechanism is critical to recognize and choose the target application. As a result, a variety of RF tags with different objectives and layers will be coexisted in mixture in the supply chain.

As illustrated in Figure 10.1.2, it is assumed that a manufacturer will read the data on the tag A (Layer 0) or tag B (Layer 1), while a transport carrier will read the data on the tag C (Layer 2) if the same RF tag type is used for the tag A, tag B and tag C. When the tag C data is attempted to be read by the transport carrier, the data on the tag A and tag B will also return a response if no measures are taken. If the intended data is not selected until all the data on every tag has been read, much more time is consumed just on reading the data and this may deteriorate the control of conveyer line, making the interrogator unable to keep up with the speed of conveyer. An advanced selective reading mechanism to identify and choose the target RF tag is expected as a solution, but this mechanism cannot be achieved without a wide expertise and specialist knowledge of RFID technology. A middleware exclusively developed for RFID is usually in need, but such a standardized middleware is not available at the moment.



Figure 10.1.2 RF tags with layered structure

10.2 Reading Metal RTI RF tags

A typical metal RTI as shown in Annex B is normally made in a box shape and carried in a shipping container in the global supply chain flow. Many metal RTIs are usually made in the size of one-eighth or one-tenth of the container in consideration of the load efficiency of the container. Products or parts are put in the RTI at shipping (vanning) and the RTI is folded down into a smaller form to improve the load efficiency at returning (devanning). Check the following points when selecting which type of RF tag to use for metal RTIs.

- (a) Shape of metal the tag is attached to
- (b) Metal's surrounding conditions
- (c) Used frequency and output power of each home country
- (d) Need for USER
- (e) Need for writing

- (f) RF tag's orientation
- (g) Weatherproof (metal RTI product life)

When applying RF tags for metal RTIs, choose an appropriate place and method that may not largely affect the tag's communication performance or the place and method to which external impact force can be minimized to the lowest possible degree. As for the system structure, consideration should be given how to secure the time for communication (communication enabled distance and communication time), plus the maximum number of RF tags, the number of antennas and the antenna angle.

The followings are the basic requirements for the implementation of RF tags on the metal RTIs.

- (a) Metal RTI: maximum number of folded RTIs piled up one on the other (15 tiers in this example. See Figure 10.2.1)
- (b) Operating frequency: 860 to 960 MHz (920 MHz in this example)
- (c) Reading/writing: USER bank supported by ISO/IEC 18000-63 Type C tag
- (d) Radio wave output: 4 W eirp
- (e) Antenna type: linear polarized wave (oriented in RF tag's longer direction in this example), circular polarized wave
- (f) Antenna distance: antenna-to-RF tag distance (0.5 m and 1.8 m in this example)
- (g) Carrying speed: speed of moving forklift (1 to 5 km/h in this example)



RF Tag

Figure 10.2.1 Metal RTI and RF tag

Annex J shows the images of verification tests. Actual use cases for reading an RF tag are covered by many applications and so the main focus is given on the explanation of writing ability in this section. Since a writing distance of an RF tag is obviously shorter than its reading distance, the writing distance at frequencies other than 920 MHz should be calculated based on the reading-writing distance ratio at a frequency of 920 MHz In the figures in Annex J, the target is placed on the RF tags applied on the lowest tier that is likely to largely reduce its communication distance due to the effect of the floor. In most management procedures, the RTI's ID is first written in the UII memory bank and the information on the whereabouts of RTI is controlled just by reading only that ID thereafter. However, since the price of an RF tag is higher than linear and two-dimensional symbols, it is suggested for the user to write the item identification code or add the passing-by information using a writable USER bank at the gate. To do this, verification of the tag's writing ability is indispensable.

Figure 10.2.1 shows an RF tag applied on a folded metal RTI. Here, the RF tag is attached on a square-shaped pipe object. This position is disadvantageous in terms of the tag's communication distance, but potential effects from the external environments of metal RTI can be avoided. Table 10.2.1 describes the distances selected from the verified data approximate to these conditions.

Tag position	Writable distance	Comparison with base distance
Attached on a stainless plate (base)	6.247 m	100%
Attached on a square pipe 40	5.569 m	89.1%
In contact with metal at top side	3.958 m	63.4%
50 mm in parallel from a wall (to be applied at the lowest tier)	4.163 m	66.6%

A writable distance of the RF tag placed on a metal RTI at the lowest tier can be obtained with the following formula.

6.247 m (base distance) x 0.891 x 0.634 x 0.666 = 2.350 m

Considering that tag's communication range should be a circular whose diameter is equal to the communication distance, a writable distance of the tag at the antenna position (1.8 m in distance) is calculated as below from the Pythagorean Theorem:

$$\sqrt{\left(\frac{2.350}{2}\right)^2 - \left(1.8 - \frac{2.350}{2}\right)^2} \times 2 = 1.99[m]$$

Since the actually confirmed distance 1.64 m is close to the value 1.99 m calculated from a single-unit test, the result of the single-unit test is confirmed to be practical as an objective guide.

A communication time was also subject to evaluation. The time required to write 15 tiers are calculated based on the results of single-unit test in Table 10.2.2.

Item	Contents	Communication time	Remarks
RTI's ID reading	UII Read (inventory)	0.558 sec	1
USER data identification	USER 32 bits Read	0.159 sec	2
All USER data reading	USER 512 bits Read	0.196 sec	2
Data rewriting	USER 512 bits Write	3.664 sec	2
Rewrite confirmation	USER 512 bits Read	0.196 sec	2
Total	4.773 sec	3	

Table 10.2.2 Communication time for writing

Note 1: The number of antennas is adjusted to be equivalent to six antennas by increasing the test results on four antennas by half.

Note 2: In reading/writing the USER bank, communication was evaluated only on the specific antennas. The figures in this list indicate the test results for a single antenna.

Note 3: Actual communication time is "4.773 sec + upper PC processing time x 'n' times"

Measurement was done by installing the gates in a distribution warehouse as illustrated in Annex J. With the functionality of the RF tags for the test, writing was enabled if the RSSI (Received Signal Strength Indicator) value was not less than - 60 dBm, and therefore the communication distance that achieves the RSSI value of higher than - 60 dBm was measured and taken as a writable distance. Table J.3 in Annex J is a list of communication distances at the lane near the antenna. The vertical line indicates 15 RTIs. The communication distances at the lane far from the antenna are given in Table J.4.

The values calculated from a single-unit test are compared with the actual values as follows:

(a) Communication distance at the lane near (0.5 m) the antenna Single unit equivalent value 1.92 m Actual measurement value 1.80 m (90 cm × 2)

(b)	Communication distance at the I	ane far from (1.8 m) the antenna
	Single unit equivalent value	1.99 m
	Actual measurement value	1.64 m (82 cm x 2)

For the communication time, a cycle of the time required to rewrite the USER data on 15 tiers was measured using a metal RTI fixed within the range in which communication with all RF tags was enabled. The following is the result.

Single unit equivalent value	4.8 sec min.
Actual measurement value	6 to 7 sec

From the above results, it is confirmed that the value calculated from a single-unit test should be the key for establishing the gates and applications. Table 10.2.3 and Table 10.2.4 describe the respective times when the tag is passing through the gate at a speed of 5, 3 and 1 km/h. Of the time range longer than 6 seconds shown in gray, which is a cycle duration for rewriting the data on the 15 tiers, the interrogator fails in writing at a speed of 5 km/h and 3 km/h without exceptions. Even at the lane away from the antennas, the tag moving at a speed of 1 km/h has failed to achieve twice the required rewriting time and may end up unsuccessfully depending on the timing of communication cycle. With the existing RF tags, too much time is spent on rewriting RF tag data. This shall be addressed in the future. A high level of traceability that covers across the supply chain is possible at a lower cost just by writing a pass certificate in every RF tag without a need for networking in the supply chain. To make it a reality, a speed of writing shall be much faster.

Table 10.2.3 Pass-by time of communication enabled distance (lane near the antenna	Table 10.2.3 Pass-b	y time of communication	enabled distance	(lane near the antenna)
--	---------------------	-------------------------	------------------	-------------------------

No. of RTI tiers	W/ritable	Pass-by time (sec)		
(from the bottom)	distance (cm)	5 Km/h	3K m/h	1K m/h
15	142	1.02	1.70	5.11
14	172	1.24	2.06	6.19
13	142	1.02	1.70	5.11
12	142	1.02	1.70	5.11
11	192	1.38	2.30	6.91
10	172	1.24	2.06	6.19
9	181	1.30	2.17	6.52
8	181	1.30	2.17	6.52
7	217	1.56	2.60	7.81
6	217	1.56	2.60	7.81
5	244	1.76	2.93	8.78
4	204	1.47	2.45	7.34
3	234	1.68	2.81	8.42
2	180	1.30	2.16	6.48
1	180	1.30	2.16	6.48
Maximum	244	1.76	2.93	8.78
Minimum	142	1.02	1.70	5.11

No. of RTI tiers	\\/ritablo	Pass-by time (sec)		
(from the bottom)	distance (cm)	5 Km/h	3K m/h	1K m/h
15	310	2.23	3.72	11.16
14	374	2.69	4.49	13.46
13	288	2.07	3.46	10.37
12	258	1.86	3.10	9.28
11	494	3.56	5.93	17.78
10	542	3.90	6.50	19.51
9	498	3.59	5.98	17.93
8	504	3.63	6.05	18.14
7	542	3.90	6.50	19.51
6	558	4.02	6.70	20.09
5	572	4.12	6.86	20.59
4	468	3.37	5.62	16.85
3	518	3.73	6.22	18.65
2	400	2.88	4.80	14.40
1	400	2.88	4.80	14.40
Maximum	572	4.12	6.86	20.59
Minimum	258	1.86	3.10	9.29

Table 10.2.4 Pass-by time of communication enabled distance (lane far from the antenna)

10.3 Use case of metal RTI RF tags at manufacturing facility

10.3.1 Basic conditions

A trial operation was carried out with respect to a metal RTI using the system implemented at a manufacturing facility with a global supply chain structure. In this trial operation, parts and components domestically manufactured in the country were put in a metal RTI and shipped overseas. After those parts were removed, the metal RTI was folded down and returned to the original manufacturer. With this operating procedure, an advanced management mechanism for replenishment and ordering is created through the recognition of the exact inventory quantity and turnover ratio, which is closely linked to the control of metal RTIs from shipping, returning and production planning. In this management structure, an efficient system designed to automatically read and write RF tags is necessary at the time when the RTI is shipped abroad and then returned to the first place. In the logistics cycle, shipping is called as "vanning" and returning as "devanning".

(a) Vanning process

Metal RTIs filled with the contents are loaded into a shipping container in the vanning process. Metal RTIs that are piled up from two to three tiers are loaded and moved to in front of the container by a forklift for the purpose of temporary placement. At this time, the forklift operator gives instructions on the loading and conduct a visual inspection. Several antennas are installed at both sides of the area where the metal RTIs are temporarily placed and the RF tags on the metal RTIs are automatically read and written. As the width of a single metal RTI is almost half that of the container, the area the metal RTIs are temporality placed is divided in two, one at the right side of the container and the other at the left side of the container. This means that there are four different patterns in the distance relationship between the antennas and the RF tags.

(b) Devanning process

Emptied metal RTIs returned from the shipped-to destination are taken out from the shipping container in the devanning process. The metal RTIs stacked on one to three tiers are removed at a time if they are in the assembled form, or up to 15 tiers if they are in the folded form. The removed metal RTIs are temporarily placed between the antennas installed at both sides in front of the container. These metal RTIs are temporarily placed at the center between these antennas for

approximately five seconds.

Figure 10.3.1 shows the state of a metal RTI. An RF tag is attached with a double-faced adhesive tape on the metal RTI at 32 cm from its edge.



Figure 10.3.1 Positions of metal RTI and RF tag

Figure 10.3.2 shows the vanning process and the devanning process. In the actual applications, a total of six antennas, each consisting of two sets of antennas (three antennas counted as one set), are installed at either side of the area. The open side of the container is facing the other side of the shutter. In this figure, the metal RTIs are piled up into 15 tiers. Refer to Annex K for the overall system structure of vanning and devanning processes. In the vanning process with two gates, the RF tags were read using six linear polarized antennas installed at the right and left sides. In the devanning process with five gates, RF tags were read using six antennas at the right and left sides, but two of the linear polarized antennas at either one side were replaced with circular polarized antennas this time.



Figure 10.3.2 Vanning process of metal RTI

Figure 10.3.3 illustrates a various forms of loaded RTIs in the vanning and devanning processes. In this figure, No. 1 to No. 4 indicate the forms of loaded RTIs used for the vanning and No. 5 and No. 6 indicate those for the devanning process. No. 1 is placed at the left lane while No. 2 is at the right lane. No. 3 and No. 4 respectively show combinations with different types of metal RTIs other than those covered in this technical report. The RF tags are expected to be used with all types of metal RTIs in the future. There are two metal RTIs in No. 3 and one RTI in No. 4. When returned, the RTIs are directly piled up as shown in No. 5 or they are folded down and then piled up in No. 6. The number of RTIs are limited to three if they are not folded down.



Figure 10.3.3 Forms of RTIs loaded by a forklift

In the vanning process employed in Japan, the interrogator collectively read a number of RF tags currently passing in front of the antennas in a batch and accumulate the data. At this time, information on the vanning time (time stamp) is written in the RF tags. Similarly, in the devanning process, all the data on multiple RF tags passing in front of the antennas is collectively acquired in a batch reading and accumulated. Here again, information on the devanning time (time stamp) is also written in the RF tags.

The DI (Data Identifier) that begins with 25B as defined in ISO 17364 is stored in the UII storage data. The USER memory bank stores information on the time stamp, rotation number, destination and shipping order for the purpose of metal RTI management. Up to 210 bits of data can be stored in the UII and up to 380 bits in the USER.

The above-mentioned six antennas, three at the right side and three at the left side, are arranged according to the size of the vanning and devanning areas. Figure 10.3.4 is a layout of the antennas in the vanning process and Figure 10.3.5 is that in the devanning process. Radio wave power at 30 dBm is used for both the vanning process and the devanning process. A significant difference is observed in these two processes, as the size "J" is enlarged in the devanning where the metal RTIs are piled up into a 15-tier construction form.



Figure 10.3.4 Antenna arrangement in the banning process



Figure 10.3.5 Antenna arrangement in the devanning process

Table 10.3.1 describes the procedure for writing data into an RF tag. In the table below, Inventory only should be activated when reading is limited solely to the data written in the RF tag's UII.

Procedure	Description
Inventory	The RF tags near the antennas are recognized.
Read 1 (TID reading)	Information on the chip manufacturer is acquired
	assuming that various types of RF tags will be in use.
Read 2 (length reading)	From 16 to 24 bits of information on the USER is
	acquired. Bit information (length) stored in the USER
	is also acquired.
Read 3 (USER reading)	All USER data is read based on the length.
Write (USER writing)	Information such as a time stamp is written.
Read 4 (verification)	Written information is checked.

There are at least three steps to follow when writing data into the USER memory. The inventory is done in the first step, the USER data is read in the second step, and new data is written in the third step based on the USER data that was read in the second step. In this trial, the type of RF tag is identified in Read 1 (see Table 10.3.1) even if it is an ISO/IEC 18000-63 Type C tag, on the assumption that the chip or inlay embedded in the tag may be a product of different manufacturer. In fact, the owner of metal RTIs can be a manufacturer or parts maker and so the RF tag may not be of the same type. Even if the selected RF tag is classified as ISO/IEC 18000-63 Type C, its memory size and processing procedure may differ if the tag's type or manufacturer is not the same. Read 1 can be omitted when using the identical RF tags.

A measurement time for each procedure is given in Table 10.3.2 and its rate in percentage in

Figure 10.3.6. Although Inventory is not measured this time, it is known that the inventory is completed much faster than others (see Annex G). The key point in this measurement is that 1.159 sec. is spent on Read 1 and so whether or not a TID reading is required needs to be checked. The figures in Table 10.3.2 are the average values of 1,799 attempts in the Trial 2 vanning process that succeeded in the first attempt without a retry. Since an ordinary interrogator is configured to execute Read 1 and Read 2 within the same sequence, the processing can be completed in a short amount of time.

Procedure	Time (sec)	Rate (%)
Inventory	—	—
Read 1 (TID reading)	1.159	29.2
Read 2 (length reading)	0.107	2.8
Read 3 (USER reading)	1.008	26.0
Write (USER writing)	0.995	25.6
Read 4 (verification)	0.612	15.8
Total	3.882	

 Table 10.3.2 Communication procedure and communication time



Figure 10.3.6 Communication time rate

Figure 10.3.7 is a flow chart of the reading/writing software. This is merely a pattern diagram and a maximum of three metal RTIs can be accepted in the vanning process and a maximum of 15 metal RTIs in the devanning process. Data is read and written in the following procedure.

- (a) Read begins with the RF tag (UII) acquired in Inventory.
- (b) Write begins with the RF tag (UII) that was correctly acquired by USER by the Read command
- (c) The process is repeated until the result of Write is successfully completed.



Figure 10.3.7 Software flow chart

10.3.2 Trial 1

To obtain the conditions in Section 10.3.1, trials were carried out. Table 10.3.3 is the results of the trials on writing data into RF tags. Writing was successfully completed in every trial.

	No. of	Vanı	ning (3 tiers)		Devanning (15 tiers)			
Distance	times	Inventory	USER	USER	Inventory	USER	USER	
	umes	Inventory	reading	writing	inventory	reading	writing	
	1	3	3	3	15	15	15	
	2	3	3	3	15	15	15	
Close	3	3	3	3	15	15	15	
	4	3	3	3	15	15	15	
	5	3	3	3	15	15	15	
	1	3	3	3	15	15	15	
Far	2	3	3	3	15	15	15	
	3	3 3		3	15	15	15	
	4	3	3	3	15	15	15	
	5	3	3	3	15	15	15	

 Table 10.3.3 Results of trials in writing data into tags

Note: Each numerical value indicates the number of successes.

Given in Table 10.3.4 is the results of writing when the RF tag attached on a metal RTI being carried by a forklift is passing through the gates without stopping in front of the antennas. A speed of the moving forklift was switched in three levels of 1 km/h, 3 km/h and 5 km/h, with 5 km/h at a maximum that is the highest velocity normally permitted inside a warehouse. In the vanning process where metal RTIs were piled up into three tiers, writing was enabled in every trial at a speed of 1 km/h and 3 km/h if the tag is positioned near the antenna. For the devanning process using 15-tiered metal RTIs, Inventory only was permitted at all speeds. This means that, in the actual applications, the tag's requirements shall be identified to achieve a 100% successful writing. An RF tag may be hardly read or written if it comes to stop outside the communication range due to the electrical interference.

	Speed	No. of		Vanning		D	evanning	
Distance	Speeu km/b	timos	Inventory	USER	USER	Inventory	USER	USER
	KIII/II	umes	inventory	reading	writing	Inventory	reading	writing
		1	3	3	3	15	15	14
		2	3	3	3	15	14	10
	1	3	3	3	3	15	15	13
		4	3	3	3	15	15	10
		5	3	3	3	15	15	12
		1	3	3	3	15	12	4
		2	3	3	3	15	13	6
Close	3	3	3	3	3	15	15	6
		4	3	3	3	15	12	4
		5	3	3	3	15	14	3
		1	3	3	1	15	9	0
		2	3	3	2	15	13	0
	5	3	3	3	1	15	7	0
		4	3	3	2	15	11	0
		5	3	3	2	15	6	0
		1	3	3	3	15	15	15
		2	3	3	3	15	15	11
	1	3	3	3	3	15	15	15
		4	3	3	3	15	14	14
		5	3	3	3	15	15	14
		1	3	3	3	15	14	10
		2	3	3	3	15	15	7
Far	3	3	3	3	3	15	15	10
		4	3	3	3	15	14	10
		5	3	3	3	15	14	10
		1	3	3	3	15	14	7
		2	3	3	3	15	13	5
	5	3	3	3	3	15	13	6
		4	3	3	3	15	14	4
		5	3	3	3	15	15	5

Table 10.3.4 Results of trials in writing data into moving tags

10.3.3 Trial 2

In Trial 2, RF tag reading and writing were verified in the actual operating environments.

1. Vanning process

- Trial time period: Oct. 2015 to Nov. 2015
- No. of target tags: 1,327 tags
- Success rate of UII reading: 100% (1,327 tags out of 1,327 tags)
- Success rate of USER reading: 99.8% (1,324 tags out of 1,327 tags)
- Success rate of USER writing: 99.4% (1,319 tags out of 1,327 tags)

In the USER reading, three attempts were ended in failure due to the positional relationship between the RF tag and the antennas and the reading was suspended until it was tried again. However, a 100% successful reading was accomplished by changing the retry logic thereafter. Five attempts were ended in failure in the USER writing. As the ability of reading is different from that of writing in terms of the distance, a writing may become impossible even if a reading is enabled. In this test, writing was set to be repeated if the interrogator failed in writing but the number of retires was limited to 100 at a maximum. Of these retries, the interrogator stopped writing in excess of this 100-time limit in five attempts. This may be because the tag was happened to be in the write-disabled area (null point) caused by the interference from reflected waves. This shall be resolved by increasing the writing speed to a level similar to that of reading, or taking some effective measures against a null point in the operation.

- 2. Devanning process
 - Trial time period: Nov. 2015 to Jan. 2016
 - No. of target tags: 1,253 tags
 - Success rate of UII reading: 100% (1,253 tags out of 1,253 tags)
 - Success rate of USER reading: 99.7% (1,249 tags out of 1,253 tags)
 - Success rate of USER writing: 99.4% (1,210 tags out of 1,253 tags)

In the above four USER reading attempts that ended in failure, the number of retries exceeded its upper limit. It is assumed that the tag was positioned at a null point like the case of vanning.

In the USER writing, 43 attempts were ended in failure. In Trial 2, a special mechanism to repeat retries up to the specified upper limit (100 times) was applied to both the reading and writing but communication with the RF tag was disconnected before that limit was reached in many cases. This may be attributed to the communication procedure and also to a temporal change in the radio wave environments between the antennas and RF tag, in other words, the radio wave environment was changed due to the moving RF tag while the data was still being read or written. The interrogator is not allowed to write the USER data unless it has succeeded in reading both the UII data and the USER data (see Table 10.3.2), but it is likely that the interrogator failed in writing because of a poor radio field intensity at the USER data writing, or else no RF tag was found within the communication range. It was confirmed from the previous evaluation that a success rate of USER writing is higher if the RSSI (Received Signal Strength Indicator) value is not lower than - 60. However, it is acknowledged in the actual applications that there will be a case in which the interrogator fails in writing the USER data even if the RSSI value is higher than - 60. Based on these factors, the cause of failure in the USER writing cannot be known just from the RSSI value.



radio field intensity((RSSI): dBm

Figure 10.3.8 Software flow chart

In the devanning process, since metal RTIs are piled up in several packing forms from one to three tiers and 15 tiers, the results of reading and writing vary depending on the packing forms. For the RTIs piled up in three tiers or less, writing was enabled for all RF tags except the one attached on the 2nd tier at the right side. See Table 10.3.5.

Тад	position	No. of attempts	UII r	eading	USEF	R reading	USEI	R writing
	3rd tier	23	23	100.0%	23	100.0%	23	100.0%
Left	2nd tier	67	67	100.0%	67	100.0%	67	100.0%
	1st tier	87	87	100.0%	87	100.0%	87	100.0%
Right	3rd tier	24	24	100.0%	24	100.0%	24	100.0%
	2nd tier	70	70	100.0%	70	100.0%	69	98.6%
	1st tier	114	114	100.0%	114	100.0%	114	100.0%
-	Total	385	385	100.0%	385	100.0%	384	99.7%

Table 10.3.5 Reading and writing of 3-tier metal RTIs

In reading the 15-tier metal RTIs, the USER data was successfully read by 100% except the 15th tier at the left side. In contrast, a 100% success rate was not accomplished at the 15th, 13th and 8th tiers in the right side. In USER writing, good results were not achieved at the 15th to 7th tiers and at the 4th to 1st tiers at both of the sides. These results indicate that the accuracy of reading and writing can be increased through the improvement in the radio wave environments at the upper and lower parts of the antennas, for example, by adding more antennas. See Table 10.3.6 and Table 10.3.7.

Тад	Tag position No. of attempts Ull read		eading	USER reading		USER writing		
	15th tier	25	25	100.0%	24	96.0%	21	84.0%
	14th tier	26	26	100.0%	26	100.0%	23	88.5%
	13th tier	28	28	100.0%	28	100.0%	27	96.4%
	12th tier	36	36	100.0%	36	100.0%	35	97.2%
	11th tier	29	29	100.0%	29	100.0%	28	96.6%
Left	10th tier	18	18	100.0%	18	100.0%	17	94.4%
	9th tier	25	25	100.0%	25	100.0%	23	92.0%
	8th tier	27	27	100.0%	27	100.0%	26	96.3%
	7th tier	25	25	100.0%	25	100.0%	23	92.0%
	6th tier	21	21	100.0%	21	100.0%	21	100.0%
	5th tier	26	26	100.0%	26	100.0%	26	100.0%
	4th tier	30	30	100.0%	30	100.0%	30	100.0%
	3rd tier	30	30	100.0%	30	100.0%	30	100.0%
	2nd tier	25	25	100.0%	25	100.0%	25	100.0%
	1st tier	23	23	100.0%	23	100.0%	22	95.7%

 Table 10.3.6 Reading and writing of 15-tier metal RTIs (left side)

Tag position		No. of attempts	Ull reading		USER reading		USER writing	
	15th tier	35	35	100.0%	34	97.1%	32	91.4%
	14th tier	34	34	100.0%	34	100.0%	29	85.3%
	13th tier	31	31	100.0%	30	96.8%	26	83.9%
	12th tier	23	23	100.0%	23	100.0%	21	91.3%
	11th tier	28	28	100.0%	28	100.0%	25	89.3%
	10th tier	38	38	100.0%	38	100.0%	37	97.4%
	9th tier	32	32	100.0%	32	100.0%	31	96.9%
Right	8th tier	31	31	100.0%	30	96.8%	29	93.5%
	7th tier	31	31	100.0%	31	100.0%	31	100.0%
	6th tier	36	36	100.0%	36	100.0%	36	100.0%
	5th tier	30	30	100.0%	30	100.0%	30	100.0%
	4th tier	29	29	100.0%	29	100.0%	28	96.6%
	3rd tier	31	31	100.0%	31	100.0%	31	100.0%
	2nd tier	33	33	100.0%	33	100.0%	33	100.0%
	1st tier	32	32	100.0%	32	100.0%	30	93.8%
- (left	Total & right)	868	868	100.0%	864	99.5%	826	95.2%

Table 10.3.7 Reading and writing of 15-tier metal RTIs (right side)

In Trial 2, reading and writing of USER data was conducted for the use of USER. Not only a reading of the UII memory bank by a normal inventory command but also a reading and writing of individual information stored in the USER memory bank was examined to determine its function accuracy. The operations accomplished a 100% success when RF tags were read and written one by one with a fixed antenna. In the applications for reading and writing several RF tags using fixed-type antennas, the RF device alone cannot guarantee 100% accuracy without a help of supplementary measures for the system, due to the inconsistencies in the installation environments, positional differences in the operation and disparities in the communication characteristics of individual RF tags.

A 99.4% accuracy was realized in writing data into the tag on the 3-tiered metal RTIs. For operations that ended in failure, it was reaffirmed that a new recovery mechanism is required to find and recover the fault. In writing to the 15-tiered metal RTIs, a 96.6% accuracy was achieved. Considering that a 100% accuracy was accomplished for the 3-tiered and 15-tiered metal RTIs in the UII memory reading, a mechanism using a UII reading should be implemented depending on the application.

If the mechanism for reading the UII data only is all that needed, unread data can be easily recovered just by keying that data by referring to the textual information pre-printed on the surface of the RF tag if the interrogator has failed in reading, and this may be a reason why no other system than a key entry operation has been seriously considered until now. On the other hand, as is seen in Trial 2, information on the USER memory bank that is overwritten at every process cannot be visualized just by pre-printing it on the tag and thus the establishment of a high quality recovery system is critical. The RF tags that ended in failure can be found on the scene if they are read or written individually one by one. However, when reading and writing multiple tags simultaneously at a time, a special technology or procedure capable of identifying which RF tag has marked NG is shall be provided.

11 Middleware

11.1 Demand for middleware

Generally, RFID is introduced as an additional system to the operating environments where linear and/or two-dimensional symbols are already in use. Although there is no need to change the programs on the application side on most occasions, a compatibility in the specifications with linear and/or two-dimensional symbols may be required for the implementation of RFID. This section describes the key points that should be taken into account when establishing a compatibility. Many of these key points are related to the features of RF tag's middleware defined in ISO/IEC 15961 series using the ANS.1 syntax rule are not common and have very heavy specification, all the points described here do not need to be satisfied. There is not such an interrogator or a middleware that meets all these requirements in the world.

11.2 Re-reading prevention

Since a reader used for linear and two-dimensional symbols is configured to read and capture data once in several msec. to several tens of msec., approximately ten data sets can be collected if it took 100 msec. for the label (or the object) to pass through the reader's field of view. Of these data sets, if the label having the same data is found, that label is determined as an identical label and it is transmitted to the host computer only once. If a linear or two-dimensional symbol is lost or the existence of another linear or two-dimensional symbol that has different data is detected within the field of view, the preceding symbol data is cancelled.

Once the symbol data is cancelled, that data is transmitted to the host computer even if it is read again next time. This functional characteristic employed in linear and two-dimensional symbol readers may be a legacy of the linear symbol that has long been used from the early days when the computer's processing power was obviously far less than it is today. This mechanism is very useful in reducing the load applied on the computer, but the development of an RFID interrogator equipped with this re-reading preventive measures has not been realized until now. This mechanism can be achieved with a middleware, but development of the middleware is a tough challenge for application engineers unless they are well-versed in the RFID technology. This is the work that should be done by the engineers of interrogators. The middleware should be made in such way that it can be shared by all interrogators regardless of their manufacturers and model types.

11.3 Data concatenation

Data concatenation is not required if the RF tag has enough memory capacity, but MB01₂ (UII bank) and MB11₂ shall be concatenated to make a single data field if not much memory is left in the tag's memory. In this case, the two respective data fields in MB01₂ and MB11₂ are concatenated and then transmitted to the host computer as a single data segment.

11.4 Filtering

Filtering 1

Selective reading is enabled by using the first one to three characters at the beginning of the UII memory bank in MB01₂ (bit hex 20 and above) (J, 1J to 6J, 25P, 25S, 15K, 25K)

The first 24 bits if 1 character is represented by 8 bits The first 21 bits if 1 character is represented by 7 bits

The first 18 bits if 1 character is represented by 6 bits

Filtering 2

Selective reading is enabled by using the bit 17 (bit 17 = 1 by ISO) of the PC bit in MB01₂ and the first one to three characters at the beginning of the UII memory bank (bit hex 20 and above) (J, 1J to 6J, 25P, 25S, 15K, 25K)

The first 24 bits if 1 character is represented by 8 bits

The first 21 bits if 1 character is represented by 7 bits The first 18 bits if 1 character is represented by 6 bits

• Filtering 3

More than one type of selective reading is enabled by using the first one to three characters at the beginning of the UII memory bank in MB01₂ (bit hex 20 and above) (1J and 2J, 25S and 25B, 15K and 25K)

The first 24 bits if 1 character is represented by 8 bits The first 21 bits if 1 character is represented by 7 bits The first 18 bits if 1 character is represented by 6 bits

• Filtering 4

More than one type of selective reading is enabled by using the bit 17 (bit 17 = 1 by ISO) of the PC bit in MB01₂ and the first one to three characters at the beginning of the UII memory bank (bit hex 20 and above) (1J and 2J, 25S and 25B, 15K and 25K)

The first 24 bits if 1 character is represented by 8 bits

The first 21 bits if 1 character is represented by 7 bits The first 18 bits if 1 character is represented by 6 bits

11.5 Data compaction

Eight-bit data (one character) transmitted to the middleware from the application (host computer) is converted into either binary, 6-bit or 7-bit data by the middleware in accordance with the type of compaction for the precursor. The data is then transmitted to the interrogator and written in the RF tag after that. In this case, a 6-bit compaction method represents the character set defined in the ISO 17364 to ISO 17367 standards.

11.6 Processing flow of interrogator

It is assumed that most engineers who write application programs scarcely have knowledge of the RFID technology and do not know how and which interrogator commands to use in combination, and so a practical program flowchart with applicable examples will be necessary. Though there is actually a concern that potential problems arising from the program flowchart proposed by an interrogator or middleware maker may lead to a claim, the development of easy-to-write programs is mandatory for the progress and diversification of RFID systems. It is strongly suggested that commonly available instruction manuals should be prepared by the interrogator makers well-acquainted with the characteristic features of RF tags.

RFID Application Guideline for Metal Returnable Transport Items

Annexes

Part 1

(RFID: Returnable Transport Items)

Annex A

Examples of Returnable Transport Items (RTIs) and Returnable Packaging Items (RPIs)

A reusable RTI (Returnable Transport Item) or RPI (Returnable Packaging Item) is usually used in each of the layers in the supply chain (SC) layers. This Annex provides the practical examples of RTIs or RPIs used in the supply chain layers.

A.1 Containers used in Layer 4

Shown in Figure A.1 are the freight containers used in Layer 4 of the SC model. In Layer 4, freight containers including air cargo, marine container and railway container are used to carry substances associated with manufacturing such as liquids, oil and powders.



Figure A.1 Containers

A.2 RTIs (pallets) used in Layer 3

Figure A.2 and Figure A.3 show the examples of RTIs used in Layer 3 of the SC model.



Figure A.2 Plate pallet



Figure A.3 Roll box pallet

A.3 RTIs (e.g., returnable boxes) used in Layer 3

Figure A.4 and Figure A.5 show the examples of RTIs used in Layer 3 of the SC model.



Figure A.4 Large-sized returnable boxes



Figure A.5 Medium-sized returnable boxes

A.4 RTIs or RPIs (e.g., liquid containers like metallic drums) used in Layer 2 or Layer 3

Figure A.6 shows the examples of liquid containers such as metallic drums. These containers are used as RTIs or RPIs depending on the application.



Figure A.6 Metal RTI or RPI

A.5 RPIs used in Layer 0 or Layer 1

Most containers in Layer 1 are designed to carry liquid or powder substances and are normally made of paper, plastic, glass or metal. Particularly, metallic cases for transporting milk or soft drinks, glass bottles for wine or beer and plastic cases for baby powder or powder soap are classified in this category. Some of these cases or bottles are actually reused and recycled, mainly in the consumer market. There are also containers that are repeatedly used for carrying substances necessary for products, for example, electrical parts/assemblies, lubricants, oil coolant or washer liquid.



Figure A.7 RPIs

Annex B

Examples of Metal RTIs for Supply Chain

The metal RTIs intended for supply chain management are typically used for the distribution of parts and components mainly associated with vehicle production. Given in this Annex B are some of the applications of such metal RTIs.

B.1 Metal RTIs carrying items



Figure B.1 Metal RTIs carrying automotive parts



Figure B.2 Metal RTIs carrying automotive parts (small items)



Figure B.3 Example of metal RTIs carrying items



Figure B.4 Example of metal RTIs carrying items

B.2 Emptied metal RTIs (unfolded)



Figure B.5 Example of emptied metal RTIs

B.3 Emptied metal RTIs (folded, controlled)



Figure B.6 Storage of emptied metal RTIs under control (controlled)



Figure B.7 Storage of emptied metal RTIs (controlled)

B.4 Emptied metal RTIs (folded, uncontrolled)



Figure B.8 Storage of emptied metal RTIs (uncontrolled)

Annex C

Radio Law of Each Country

Figure C.1 shows the approved frequencies and output powers by each country based on the national radio laws with respect to the UHF RFID. In the global supply chain, the operating frequency band (860 MHz to 960 MHz) conforming to ISO/IEC 18000-63 Type C specified as a UHF standard shall be taken as the criterion for the evaluation of performance, as every nation in the world constitutes a part of the worldwide supply chain network.



Figure C.1 Radio law of each country

Annex D

RFID Memory Structure

Figure D.1 provides a graphical representation of the memory structure of an ISO/IEC 18000-63 Type C RF tag. The memory of RF tag defined in ISO/IEC 18000-63 Type C is logically separated into four distinct banks consisting of RESERVED, UII, TID ad USER. The memory organization of each bank shall conform to Stored PC (UII), Data Storage Format ID (DSFID) and Precursor (USER).



Figure D.1 ISO/IEC 18000-63 Type C tag memory structure

RFID Application Guideline for Metal Returnable Transport Items

Annexes

Part 2

(RFID: Returnable Transport Items)

Annex E

Communication Distance of RF Tags for Metal RTI

The important characteristics that shall be considered when selecting an appropriate RF tag should be the tag's communication distance and communication range. At present, various kinds of RF tags (A to E) that can be used on metal objects are released to the market from several business entities. The following figures in this Annex illustrate the typical characteristics of these tags.

E.1 RF tags applied on SUS (stainless) plate: Read



Figure E.1 Tags applied on SUS plate: Reading

E.2 RF tags applied on SUS (stainless) plate: Write





Figure E.2 Tags applied on SUS plate: Writing







E.4 Free air: Write

E.3 Free air: Read





Figure E.5 RF tag applied on SUS (basic)



Figure E.6 RF tag under measurement: Free air

Annex F

Communication Distance of RF Tags for Metal RTI

This Annex gives the communication distances of the ISO/IEC 18000-63 Type C RF tag measured for different kinds of metal substances. The communication distances of the same RF tag attached on substances other than metal are also provided. The data shown here is measured using the tag A.



Figure F.1 Tag's communication distances applied on different metals



Figure F.2 Tag's communication distances applied on other than metal



Figure F.3 Tag's communication distances in different ambient environments



Figure F.4 Tag's communication distances in different installation environments



Figure F.5 State of tag on the square pipe in Figure 1



Lower Aluminum Plate 200 × 200 × 4mm

Figure F.6 State of tag in contact with the upper and lower metal plates in Figure 4

Annex G

Communication Time of RF Tags for Metal RTI

Considering that an RF tag for metal RTIs is generally configured to read and write a maximum of 15 metal plates, the communication time shall be taken into account to keep up with a speed of moving forklift.

G.1 Measurement outline



Foamed Styrol Table Radar Absorbent Material

Figure G.1 Measurement outline

G.2 Layout of RF tags (inlays) to be measured

Number of RF Tag							
1 piece	15 pieces	30 pieces					
center	Center (1x5)	3x5	3x5x2(Reverse side)				





G.3 Positional relation between antenna and RF tags to be measured





Figure G.3.2 Positions of antennas and RF tags to be measured (4 antennas)

G.4 Measurement results: Read







Figure G.4.2 Measurement results: IC-Y reading



Figure G.4.3 Measurement results: IC-Z reading

G.5 Measurement results: Write







Figure G.5.2 Measurement results: IC-Y writing



Figure G.5.2 Measurement results: IC-Z writing

G.6 Measurement results: Write



Figure G.6.1 Measurement results: IC-X reading



Figure G.6.2 Measurement results: IC-X writing

Annex H

Environmental Requirements of RF Tags for Metal RTI

RF tags developed for metal RTIs shall achieve a higher reliability than electric seals used on containers (refer to ISO 18185-3) because metal RTIs are usually put in a container at transportation. Figures from H.1 to H.3 are the results of high temperature and high humidity storage tests obtained from the accelerating test 01.



Figure H.1 Results of high temperature high humidity storage test in accelerating test 01



Figure H.2 Results of high temperature high humidity storage test in accelerating test 01: Distance-frequency characteristics at good reading



Figure H.3 Results of high temperature high humidity storage test in accelerating test 01: Distance-frequency characteristics degraded over time at poor reading

RFID Application Guideline for Metal Returnable Transport Items

Annexes

Part 3

(RFID: Returnable Transport Items)

Annex I

General RF Tag Reading

Two types of reading forms, i.e., a gate type and a belt conveyer type, are available for RF tag reading.

I.1 Gate type reading

The gate type reading is used at a load receiving point in the distribution center. Usually, a multiple number of gates are installed in distribution centers. In this gate type reading, interference between the interrogators operating at adjacent gates may cause a difficulty.



Figure I.1 Gate type RF tag reading

I.2 Belt conveyer type reading

The belt type reading is normally employed for sorting tasks in the distribution center. As is the case with the gate type reading, interference between the adjacent interrogators will also be a problem due to the complicated structure of the lanes.



Figure I.2 Belt conveyer type RF tag reading

Annex J

RF Tag Reading Using Metal RTIs

With products and/or parts loaded, up to three RF tags placed on metal RTIs are supported for reading and writing. Once the products or parts carried in the metal RTIs are taken out and sent for the assembling process, the metal RTIs are emptied and piled up into 15 layers at a maximum, and after that RF tags on these RTIs are read and written altogether at a time. The speed of loading and unloading to and from a container by a forklift should be 1 km/h to 5 km/h.

J.1 Data writing method 1





J.2 Data writing method 2



Figure J.2 Data writing method 2

J.3 Communication distances in the data writing method 1





J.4 Communication distances in the data writing method 2





















Annex K

Metal RTI RF Tag Reading at Manufacturing Facility

With products and/or parts loaded, up to three RF tags placed on metal RTIs are supported for reading and writing. Once the products or parts carried in the metal RTIs are taken out and sent for the assembling process, the metal RTIs are emptied and piled up into 15 layers at a maximum, and after that RF tags on these RTIs are read and written altogether at a time. Loading and unloading to and from a container by a forklift should be temporally stopped.

K.1 Overall system



Figure K.1 Reading/writing system