INTERNATIONAL STANDARD

ISO 17367

First edition
2009-11-15

Supply chain applications of RFID — Product tagging

Applications de chaîne d'approvisionnements de RFID — Étiquetage de produit

Reference number
ISO 17367:2009(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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.

ISO 17367 was prepared by Technical Committee ISO/TC 122, *Packaging*, in collaboration with Technical Committee ISO/TC 104, *Freight containers.*

Introduction

The *supply chain* is a multi-level concept that covers all aspects of taking a product from raw materials to a final product including shipping to a final place of sale, use and maintenance and potentially disposal. Each of these levels covers many aspects of dealing with products and the business process for each level is both unique and overlapping with other levels.

This International Standard has been created in order to ensure compatibility at the physical, command and data levels with the four other International Standards under the general title: S*upply chain applications of RFID*. Where possible, this compatibility takes the form of interchangeability. Where interchangeability is not feasible, the International Standards within this suite are interoperable and non-interfering. The International Standards within the complete series of *Supply chain applications of RFID* include

— ISO 17363, *Supply chain applications of RFID — Freight containers*,

— ISO 17364, *Supply chain applications of RFID — Returnable transport items (RTIs)*,

— ISO 17365, *Supply chain applications of RFID — Transport units*,

— ISO 17366, *Supply chain applications of RFID — Product packaging*, and

— ISO 17367, *Supply chain applications of RFID — Product tagging*.

These International Standards define the technical aspects and data hierarchy of information required in each layer of the supply chain. The air-interface and communications protocol standards supported within the *Supply chain applications of RFID* International Standards are ISO/IEC 18000; commands and messages are specified by ISO/IEC 15961 and ISO/IEC 15962; semantics are defined in ISO/IEC 15418; syntax is defined in ISO/IEC 15434.

Although not pertinent to this International Standard, the work of

— ISO/IEC JTC 1, *Information technology,* SC 31, *Automatic identification and data capture techniques*, in the areas of air interface, data semantic and syntax construction and conformance standards, and

— ISO/TC 104, *Freight containers*, in the area of freight container security, including electronic seals (e-seals) (i.e. ISO 18185) and container identification

is considered valuable.

Supply chain applications of RFID — Product tagging

1 Scope

This International Standard defines the basic features of RFID for the use in the supply chain when applied to product tagging. In particular it

- provides specific recommendations about the encoded identification of the product,
- makes recommendations about additional information about the product on the RF tag,
- makes recommendations about the semantics and data syntax to be used,
- makes recommendations about the data protocol to be used to interface with business applications and the RFID system, and
- makes recommendations about the air interface standards between the RF interrogator and RF tag.

This International Standard only addresses *product tagging* and does not address *product packaging*.

2 Conformance and performance specifications

All of the devices and equipment that claim conformance with this International Standard shall also conform to the appropriate sections and parameters specified in ISO/IEC TR 18046 for performance and ISO/IEC TR 18047-6 (for ISO/IEC 18000-6, Type C) and ISO/IEC TR 18047-3 (for the ASK interface of ISO/IEC 18000-3, Mode 3) for conformance.

NOTE Annex A gives an illustrative example of an industry-specific conformance/quality document.

3 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 445, *Pallets for materials handling — Vocabulary*

ISO 830, *Freight containers — Vocabulary*

ISO/IEC 15418, *Information technology — Automatic identification and data capture techniques — GS1 Application Identifiers and ASC MH10 Data Identifiers and maintenance*

ISO/IEC 15434, *Information technology — Automatic identification and data capture techniques — Syntax for high-capacity ADC media*

ISO/IEC 15459-4, *Information technology — Unique identifiers — Part 4: Individual items*

ISO/IEC 15961, *Information technology — Radio frequency identification (RFID) for item management — Data protocol: application interface*

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/IEC 16022, *Information technology — Automatic identification and data capture techniques — Data Matrix bar code symbology specification*

ISO 17364, *Supply chain applications of RFID — Returnable transport items (RTIs)*

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 18000-6, *Information technology — Radio frequency identification for item management — Part 6: Parameters for air interface communications at 860 MHz to 960 MHz*

ISO/IEC 18004, *Information technology — Automatic identification and data capture techniques — QR Code 2005 bar code symbology specification*

ISO/IEC TR 18046, *Information technology — Automatic identification and data capture techniques — Radio frequency identification device performance test methods*

ISO/IEC TR 18047-3, *Information technology — Radio frequency identification device conformance test methods — Part 3: Test methods for air interface communications at 13,56 MHz*

ISO/IEC TR 18047-6, *Information technology — Radio frequency identification device conformance test methods — Part 6: Test methods for air interface communications at 860 MHz to 960 MHz*

ISO/IEC 19762-1, *Information technology — Automatic identification and data capture (AIDC) techniques — Harmonized vocabulary — Part 1: General terms relating to AIDC*

ISO/IEC 19762-3, *Information technology — Automatic identification and data capture (AIDC) techniques — Harmonized vocabulary — Part 3: Radio frequency identification (RFID)*

ISO 21067, *Packaging — Vocabulary*

ISO/IEC TR 24729-1, *Information technology — Radio frequency identification for item management — Implementation guidelines — Part 1: RFID-enabled labels and packaging supporting ISO/IEC 18000-6C*

ANS MH10.8.2, *Data Identifiers and Application Identifiers*

EPCglobal, *Tag Data Standards,* Version 1.3

GS1 *General Specifications*

ICNIRP Guidelines, *Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)*

IEEE 1451.7, *Smart Transducer Interface for Sensors and Actuators — Transducers to Radio Frequency Identification (RFID) Systems Communication Protocols and Transducer Electronic Data Sheet Formats*

IEEE C95-1, *IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz*

4 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 445, ISO 830, ISO 17364, ISO/IEC 19762-1, ISO/IEC 19762-3 and ISO 21067 apply.

5 Concepts

5.1 Differentiation between this layer and the preceding layers

Figure 1 gives a graphical representation of the supply chain. It shows a conceptual model of possible supply chain relationships, not a one-for-one representation of physical things. Although several layers in Figure 1 have clear physical counterparts, some common supply chain physical items fit in several layers depending on the use case. For example, a repetitively used pallet under constant ownership would be covered by ISO 17364 as an RTI; a pallet that is part of a consolidated unit load would be covered by ISO 17365 as a transport unit; and a pallet that is integral to a single item would be covered by ISO 17366 as product packaging.

Layers 0 to 4 are addressed within the series of International Standards *Supply chain applications of RFID* (see Introduction). Layer 5 is addressed by the work of ISO/TC 204/WG 7.

Layer 0 in Figure 1 and the definition of a product in ISO 17364:2009, 4.8 are the subject of this International Standard.

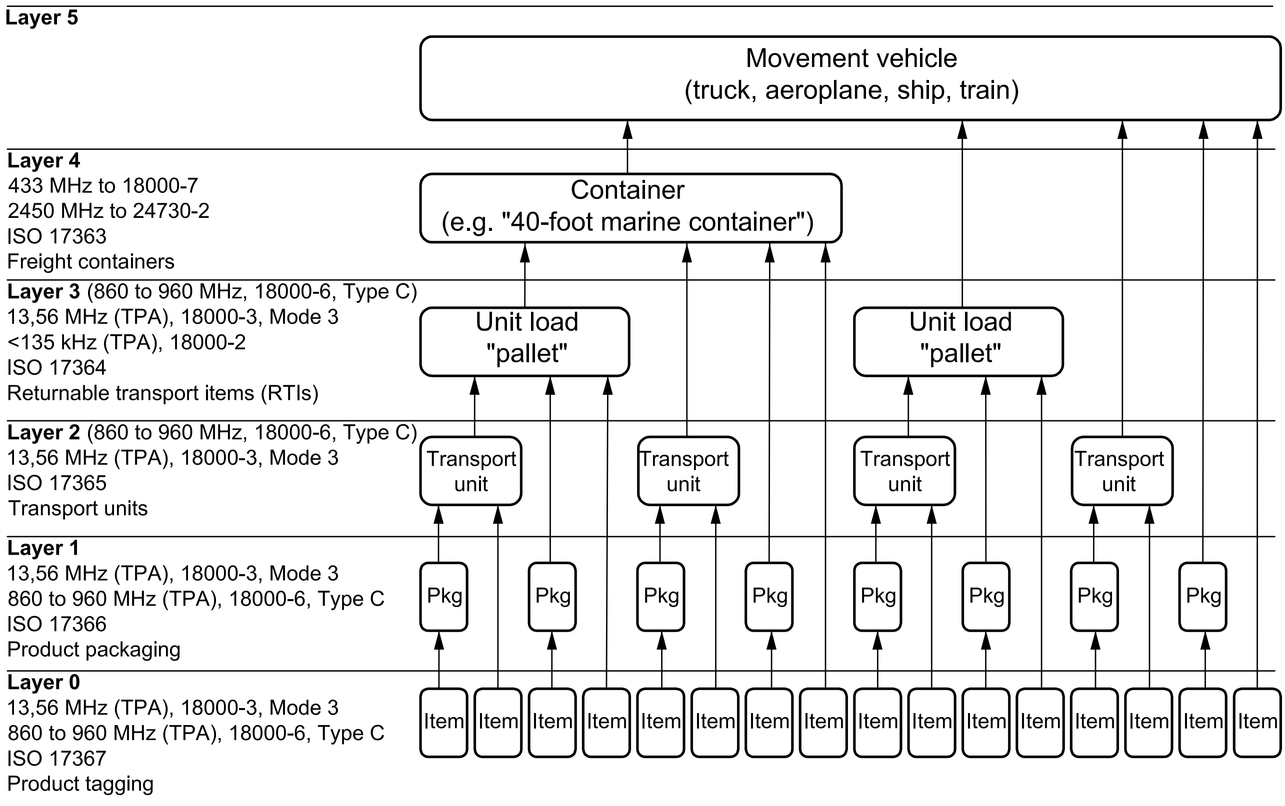


Figure 1 — Supply chain layers

Once tagged, product layer tags can be distinguished from following or preceding layer tags by use of a *group select* methodology contained in the RFID interrogator/reader. This group select function allows the interrogator and supporting automated information systems (AIS) to quickly identify product layer tags. As indicated in 5.2.2, the group select methodology is further elaborated in ISO/IEC 15961.

5.2 Unique item identifier

5.2.1 General

Unique item identification is a process that assigns a unique data string to an individual item, or in this case to an RFID tag that is associated to the item. The unique data string is called the unique item identifier. Unique item identification of items allows data collection and management at a granular level. The benefits of granular level data are evident in such areas as maintenance, retail warranties and enabling electronic transactions of record. This granularity is possible only if each tagged item has a unique identification. Items that are not uniquely identified would not normally be tagged at the item level. Items to which unique item identifiers have been assigned are said to be serialized items. Low cost consumable items would normally be tagged at the package level or higher as a standard assortment.

Product layer tagging can uniquely identify items, thus providing differentiation between like items and between like and unlike items. Product layer tagging can also be used to identify items by differentiating unlike items but not differentiating between like items. This is used for commodity where individualization is not practical or desired.

The unique product identifier described above is a unique identifier as described in ISO/IEC 15459-4. The unique item identifier (UII) provides granular discrimination between like items that are identified with RFID tags. The unique tag ID (as defined by ISO/IEC 15963) is a mechanism to uniquely identify RFID tags and is not the unique product identifier defined in this International Standard.

The minimum data elements required for unique identification are an enterprise identifier and a serial number that is unique within that enterprise identifier. Commonly, a part or model number is also required to achieve unique identification.

This International Standard uses the following identification mechanisms for unique product identification:

— unique identifiers for supply chain items (ISO/IEC 15459-4);

— GS1 Serialized Global Trade Item Number (SGTIN).

5.2.2 International unique identification for items

The unique identifier of ISO/IEC 15459 provides identification schemes for various layers of the supply chain, from layer 0 (products) up to layer 3 (returnable transport items). The unique identification of product packages shall use ISO/IEC 15459-4. Unique identification is provided by three components:

a) issuing agency code (IAC),

b) company identification number (CIN),

c) serial number (SN),

preceded by an AFI and Data Identifier (DI). The AFI code assignments table in ISO/IEC 15961:2004, Annex B, permits identification of the supply chain layer, i.e. product = $A1_{HEX}$, transport unit = $A2_{HEX}$, returnable transport item = $A3_{HEX}$ and product package = $A5_{HEX}$.

The Data Identifier shall be “25S”. The ISO/IEC 15459 registration authority assigns the IAC. The CIN is assigned by the issuing agency. The company registered with the issuing agency assigns the serial number. The serial number shall be no longer than 20 alphanumeric characters.

Table 1 — 1736*x* AFI Assignments

AFI (HEX)	Assignment	International Standard
A1	17367_Non-EPC	ISO 17367 — *Supply chain applications of RFID — Product tagging*
A2	17365_Non-EPC	ISO 17365 — *Supply chain applications of RFID — Transport units*
A3	17364_Non-EPC	ISO 17364 — *Supply chain applications of RFID — Returnable transport items (RTIs)*
A4	17367_HazMat	ISO 17367 — *Supply chain applications of RFID — Product tagging* (HazMat)
A5	17366_Non-EPC	ISO 17366 — *Supply chain applications of RFID — Product packaging*
A6	17366_HazMat	ISO 17366 — *Supply chain applications of RFID — Product packaging* (HazMat)
A7	17365_HazMat	ISO 17365 — *Supply chain applications of RFID — Transport units* (HazMat)
A8	17364_HazMat	ISO 17364 — *Supply chain applications of RFID — Returnable transport items (RTIs)* (HazMat)
A9	17363_Non-EPC	ISO 17363 — *Supply chain applications of RFID — Freight containers*
AA	17363_HazMat	ISO 17363 — *Supply chain applications of RFID — Freight containers* (HazMat)

When stored on a tag with a technology that supports AFIs, the unique identifier shall also be associated with an AFI. EPC does not use AFIs; consequently, there are no AFIs used for products employed in retail applications using EPCglobal.

To define its class (in the ISO/IEC 15459 sense), the unique identifier shall have an associated class identifier, which is the Data Identifier “25S”. For the purposes of this International Standard, a unique identifier of products can be up to 35 alphanumeric characters in length, including the Data Identifier (an3+an..32). See Table 2.

Table 2 — UII element string

Format of the license plate	
Data Identifier	IAC, company identification number (CIN), serial number
25S	N_1 N_2 N_3 N_4 N_5 N_6 N_7 N_8 N_9 N_{10} N_{11} N_{12} N_{13} N_{14} N_{15} N_{16} N_{17} . . . N_{32}

5.2.3 Serialized global trade identification number (SGTIN)

The EPCglobal serialized global trade identification number (SGTIN) is a unique item identifier (UII) capable of providing unique item identification of product packages.

Table 3 — SGTIN element string

	Header	Filter Value	Partition	Company Prefix	Item Reference	Serial Number
Number of bits	8	3	3	20 to 40	24 to 4	38
Reference	0011 0000[a]	—[b]	—[b]	999 999 to 999 999 999 999[c]	9 999 999 to 9[c]	274 877 906 943[d]

NOTE Maximum decimal value range of Company Prefix and Item Reference fields vary according to the contents of the partition field.

a Binary value.

b Refer to EPCglobal, *Tag Data Standards*, Version 1.3 for values.

c Maximum decimal range.

d Maximum decimal value.

The SGTIN consists of the following information elements:

a) The *Header*, which is defined in EPCglobal, *Tag Data Standards,* Version 1.3. It is eight (8) bits long and for an SGTIN-96 is the value 30_{HEX}.

b) The *Filter Value*, which is defined in EPCglobal, *Tag Data Standards,* Version 1.3. It is three (3) bits long and identifies whether an EPC is for a retail trade item, a standard trade item grouping, or a single shipping/consumer trade item.

c) The *Partition*, which is defined in EPCglobal, *Tag Data Standards,* Version 1.3. It is three (3) bits long, carries one of seven (7) values, and identifies where the subsequent *Company Prefix* and *Item Reference* numbers are divided.

d) The *Company Prefix*, assigned by GS1 to an organization. The Company Prefix is the same as the Company Prefix digits within a GS1 GTIN decimal code. The combined Company Prefix and Item Reference are 44 bits long (13 decimal digits).

e) The *Item Reference*, assigned by the “Company” entity to a particular product package. The combined Company Prefix and Item Reference are 44 bits long (13 decimal digits).

f) The *Serial Number* assigned by the managing entity to an individual object. The EPC representation is only capable of representing a subset of serial numbers allowed in the GS1 *General Specifications*. Specifically, only those Serial Numbers consisting of one or more digits, with no leading zeros, are permitted. The length of the Serial Number is 38 bits.

5.3 Other identification requirements

This International Standard does not supersede or replace any applicable safety or regulatory marking or labelling requirements.

This International Standard is meant to satisfy the minimum product identification requirements of numerous applications and industry groups. As such, its applicability is to a wide range of industries, each of which may have specific implementation guidelines for this International Standard. This International Standard is to be applied in addition to any other mandated labelling requirements.

6 Differentiation within the layer

6.1 Business processes

Business processes such as those described below are illustrative of the applications envisioned by this International Standard.

— Acquisition: ordering, including the identification of relevant specifications and requirements, can be facilitated by referencing the item's original acquisition data using the RFID tag's unique ID as a database key.

— Shipping: where items can have different configurations or capabilities, such as with computer software loads that differentiate items with otherwise identical form, fit and function, such items can be issued and shipped with the tag read providing assurance that the correct item was shipped. This level of non-intrusive tracking and tracing can serve as a front end to higher level in-transit visibility RFID applications detailed in the other standards of this series.

— Receiving: non-intrusive collection of receipt data can shorten data collection times, in support of automated inventory management systems and provide an electronic *transaction of record* much earlier in the process. Earlier knowledge of on-hand inventory can reduce stock outs and the need for expedited premium transportation.

- Cross docking: in addition to recording inbound receipts and outbound shipments, tagged items can be sorted. Many items will have exterior marking (tagging) that are used in lieu of reading the product tag.
- Work in process: used to track individual components and the final assembly (bill of material) and to monitor any item through a fabrication or manufacturing process.
- Maintenance: related to work in progress and differentiated in that it covers functions prior to and subsequent to the actual work. This includes fault analysis, identification, preparation of packing and packaging.
- Inventory control: item level serialization yields a granularity of visibility that supports the management of individual items. This allows data collection, tracking and tracing of individual items and selection at point of issue.
- Disposal: identification of items that have recycling or other disposal requirements.
- Picking and put-away: selection of items from a package or transport unit prior to placement into shelf stock in a warehouse situation or other storage situation where a specific asset is desired or knowledge of the specific item selected is required for issue.
- Pick and place: selection of items from shelf stock in a warehouse situation or other storage situation where a specific asset is desired or knowledge of the specific item selected is required incident to the placement of the item into or onto another asset incident to a manufacturing or assembly process.
- Sortation: process that places individual items into groups based upon some selection criteria, often performed at speed.
- Identification: process that is an inherent part of each of the functions set out above. It allows the positive differentiation of an item consistent with the business process in use. Identification can be at the discrete item level for serialized products or by commodity for non-serialized products. Identification is often the underlying base process that enables the other uses of the tag.
- Network topology: can be used to identify discrete nodes or locations on a network.
- Configuration management: discrete identification of the individual component items that comprise a higher assembly. This component data can be tiered to cover each of the multiple levels of configuration (e.g. the circuit board inside the radio installed in the communications suite of an aircraft).

The multitude of different business processes circumscribed by the supply chain will employ distinctly different groupings of functions and processes outlined above. The reading, writing or erasing of data to/from a tag is intended to effect identification and data capture about the product and the process involved and shall be integrated into business processes as required by the business process owner.

6.2 Lot/batch vs. serial number vs. product identification only

Just as different business processes have varying data requirements, different items will have varying identification requirements. Use of structured or intelligent serialization schemes include additional data such as part number or lot number in the serialization scheme and should be avoided whenever possible. This means ideally that the serialization is unique within the enterprise.

The lowest level of identification would be product ID only. Lot and batch type items shall be marked with the product ID of the item and the lot or batch of that item that this particular item belongs to. Serialized items shall be marked with a unique serial number in conformance with the appropriate part of ISO/IEC 15459, which details the differing methods of serialization that provide unique identification.

The need to identify an item at each level is not absolute. Many items are manufactured, sold, and used at the commodity level. Examples are sand, coal and bulk liquids. These items may be marked at the lot level or simply as a generic commodity.

Medicines are typical of the type of item that is manufactured and managed at the lot level but sold and used at the item level. Thus a particular dosage of medicine will require unique identification of that dose and the ability to reference that back to the original manufacturing lot. Looking up associated information on the information system may accomplish this reference.

6.3 Consumer products vs. industrial/government

Personal privacy considerations present a unique set of considerations for consumer products as opposed to products that remain exclusively in the industrial/government sectors. Consumer privacy regulations shall be considered in the design and operation of every consumer level product scenario. Encryption and data security are addressed in Clause 8.

7 Data Content

7.1 Introduction

Subclauses 7.2 to 7.7 describe the data content of RFID tags for the product layer. They identify, amongst others,

— the data elements that shall or may be present on the tag,

— the way in which the data elements are identified (semantics),

— the representation of data elements in tag memory, and

— the placement of data elements in the memory of the tag.

7.2 System data elements

7.2.1 Unique product identification

The first data element on a compliant tag shall be the unique identification described in ISO/IEC 15459-4. The length and nature of this unique identification is defined in this data element. For an ISO/IEC 18000-6, Type C and ISO/IEC 18000-3, Mode 3 compliant tag, the “unique identification” data element is segregated from any additional (user data) by the memory architecture. The unique identification data element shall be stored in UII memory (Bank 01), with any additional data being stored in user memory (Bank 11). For the purposes of this International Standard, a unique identifier of product packages can be up to 35 alphanumeric characters in length, including the Data Identifier (an3+an..32).

7.2.2 Data semantics

Tags that only encode the unique product identity should conform to ISO/IEC 15961. Tags containing complex data structures or larger data sets shall include semantics that conform to ISO/IEC 15418, ISO/IEC 15962, and ISO/IEC 15961.

7.2.3 Data syntax

Tags that encode identity only are considered to have no syntax. Tags containing complex data structures or larger data sets shall conform to ISO/IEC 15434 and should also conform to ISO/IEC 15962.

7.3 Tag structure

7.3.1 Tag header

Tag headers should contain either an ISO/IEC defined AFI or an EPCglobal defined NSI. The ISO/IEC 15961 AFI for product packages, i.e. $A5_{HEX}$, in bits 18_{HEX} to $1F_{HEX}$ as described in Tables 1 and 4. Support for ISO standards (including AFIs) is indicated when bit 17_{HEX} is set to “1”. Alternatively, such headers may contain an EPC header as described in EPCglobal, *Tag Data Standard*, Version 1.3. Support for EPCglobal coding is indicated when bit 17_{HEX} is set to “0”.

NOTE A 96-bit SGTIN is represented by EPC header 30_{HEX}.

7.3.2 Tag memory

Figure 2 provides a graphical representation of tag memory.

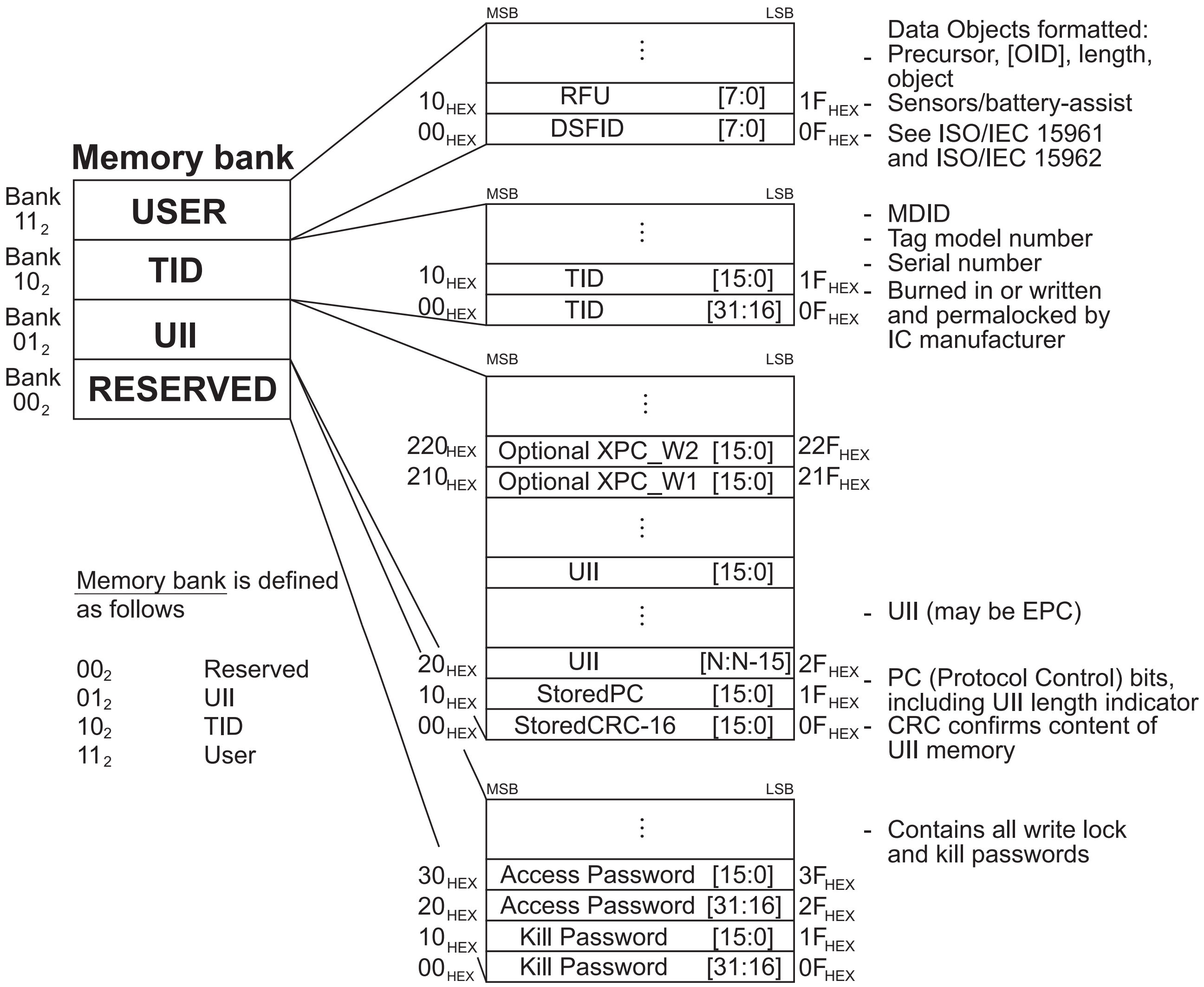


Figure 2 — Segmented memory map

7.3.3 Tag memory banks

Tag memory shall be logically separated into four distinct banks, each of which may comprise one or more memory words. A logical memory map is given in Figure 2. The memory banks are as follows.

a) Reserved memory: shall contain the kill and access passwords. The kill password shall be stored at memory addresses 00_{HEX} to $1F_{HEX}$; the access password shall be stored at memory addresses 20_{HEX} to $3F_{HEX}$. If a tag does not implement the kill and/or access password(s), the tag shall act as though it had zero-valued password(s) that are permanently read/write locked and the corresponding memory locations in reserved memory need not exist.

b) UII memory: shall contain a CRC-16 at memory addresses 00_{HEX} to $0F_{HEX}$, Protocol Control (PC) bits at memory addresses 10_{HEX} to $1F_{HEX}$ and a code, i.e. a UII, that identifies the object to which the tag is or will be attached beginning at address 20_{HEX}. The PC is subdivided into a UII length field in memory locations 10_{HEX} to 14_{HEX}, an indication of user memory bit in memory location 15_{HEX}, a PC extension indicator bit in memory location 16_{HEX}, an ISO/EPC bit in memory location 17_{HEX} and a numbering system identifier (NSI) in memory locations 18_{HEX} to $1F_{HEX}$. The CRC-16, PC and UII shall be stored MSB first (the UII's MSB is stored in location 20_{HEX}).

c) TID memory: shall contain an 8-bit ISO/IEC 15963 allocation class identifier at memory locations 00_{HEX} to 07_{HEX}. TID memory shall contain sufficient identifying information above 07_{HEX} for an interrogator to uniquely identify the custom commands and/or optional features that a tag supports.

   For EPC tags whose ISO/IEC 15963 allocation class identifier is 11100010_2, this identifying information shall comprise a 12-bit tag mask-designer identifier at memory locations 08_{HEX} to 13_{HEX} and a 12-bit tag model number at memory locations 14_{HEX} to $1F_{HEX}$.

   For ISO/IEC 15459-4 tags operating conformant to ISO/IEC 18000-6, Type C and whose ISO/IEC 15963 allocation class identifier is 11100000_2 ($E0_{HEX}$), this identifying information shall comprise a 12-bit tag mask-designer identifier at memory locations 08_{HEX} to 13_{HEX} and a 12-bit tag model number at memory locations 14_{HEX} to $1F_{HEX}$.

   For ISO/IEC 15459-4 tags operating conformant to ISO/IEC 18000-3, Mode 3, and whose ISO/IEC 15963 allocation class identifier is 11100000_2 ($E0_{HEX}$), this identifying information shall comprise a 12-bit tag mask-designer identifier at memory locations 08_{HEX} to 13_{HEX} and a 12-bit tag model number at memory locations 14_{HEX} to $1F_{HEX}$.

   Tags may contain tag- and vendor-specific data (for example, a tag serial number) in TID memory above $1F_{HEX}$.

d) User memory: allows user-specific data storage. The StorageFormat ID described in ISO/IEC 15961 and ISO/IEC 15962 defines the memory organization. The presence of data in user memory in MB11 shall be indicated by the presence of a 1 in the 15_{HEX} PC bit. A zero in the 15_{HEX} PC bit shall indicate that there is no user memory at MB11 or that there is no data in MB11.

7.4 Protocol Control (PC) bits

The PC bits contain physical-layer information that a tag backscatters with its UII during an inventory operation. There are 16 PC bits, stored in UII memory at addresses 10_{HEX} to $1F_{HEX}$, with bit values defined as follows.

— Bits 10_{HEX} to 14_{HEX}: The length of the (PC + UII) that a tag backscatters, in words:

  — 00000_2: one word (addresses 10_{HEX} to $1F_{HEX}$ in UII memory).

  — 00001_2: two words (addresses 10_{HEX} to $2F_{HEX}$ in UII memory).

  — 00010_2: three words (addresses 10_{HEX} to $3F_{HEX}$ in UII memory).

  — ...11111_2: 32 words (addresses 10_{HEX} to $20F_{HEX}$ in UII memory).

— Bit 15_{HEX}: User Memory; shall be set to "0" for tags without data in user memory (MB "11") or tags without User Memory and shall be set to "1" for tags with data in user memory.

— Bit 16_{HEX}: Shall be set to "0" if there are no extended PC (XPC) bits or the XPC bits have a zero value and shall be set to "1" if the PC bits are extended by an additional 16 bits.

NOTE 1 If a tag implements XPC bits then PC bit 16_{HEX} will be the logical OR of the XPC bits contents. The tag computes this logical OR, and maps the result into PC bit 16_{HEX}, at power up. Readers can select on this bit, and tags will backscatter it.

NOTE 2 The XPC will be logically located at word 32 of UII memory. If a reader wants to select on the XPC bits, then it issues a Select command targeting this memory location.

— Bit 17_{HEX}: Shall be set to "0" if encoding an EPC and shall be set to "1" if encoding an ISO/IEC 15961 AFI in bits 18_{HEX} to $1F_{HEX}$.

— Bits 18_{HEX} to $1F_{HEX}$: A numbering system identifier (NSI) whose default value is 00000000_2 and which may include an AFI as defined in ISO/IEC 15961 (when encoding the tag pursuant to ISO standards). The MSB of the NSI is stored in memory location 18_{HEX}.

The default (unprogrammed) PC value shall be 0000_{HEX}.

Table 4 summarizes the content.

Table 4 — Segmented memory: memory bank "01"

Protocol Control bits run from 10_{HEX} to $1F_{HEX}$															
					0/1	0/1	0/1								
10	11	12	13	14	15	16	17	18	19	1A	1B	1C	1D	1E	1F
Length indicator					User memory	XPC bit	EPC/ISO	Application family identifier (AFI)/ Numbering system identifier (NSI)							Haz Mat

7.5 Data elements

7.5.1 Unique product identifier

The UII – Product package shall be present on all conformant product package tags. For non-retail tags, the unique product package identifier shall conform to ISO/IEC 15459-4 and shall be used as described in 5.2.2. For retail tags, the unique product package identifier shall conform to EPCglobal, *Tag Data Standards*, Version 1.3 for the SGTIN-96 and shall be used as described in 5.2.3.

7.5.2 Hazardous goods

RFID tags for product packaging that is classified as hazardous for storage, transportation or use shall contain a bit reference indicating that the item is hazardous. In addition, the tag, regulations and statutes may require a more detailed categorization of the hazard. The setting of this bit ("1") directs the material handler to the included material safety data sheet. This additional categorization shall not be mandatory unless it provides an approved replacement for hazard data otherwise required by the requiring authority.

The specific hazardous goods code shall include the appropriate Data Identifier and qualifier and shall be reflected in the user data memory. The presence of hazardous material for EPC products is indicated by bit "1F" of memory bank MB01 as defined in ISO/IEC 18000-6, Type C and ISO/IEC 18000-3, Mode 3. The presence of hazardous material for ISO transport units is indicated by the AFI "A8" in bits "18" to "1F" of memory bank MB01 as defined in ISO/IEC 18000-6, Type C and ISO/IEC 18000-3, Mode 3.

This International Standard does not supersede or replace any applicable safety or regulatory marking or labelling requirements. This International Standard is meant to satisfy the minimum product identification requirements of numerous applications and industry groups. As such, its applicability is to a wide range of industries, each of which may have specific implementation guidelines for this International Standard. This International Standard is to be applied in addition to any other mandated labelling requirements.

7.5.3 Optional data

Dependent upon the tag type and capacity, optional data may be written to tags as required. Agreement between trading partners is not required. Optional data may be encrypted or otherwise secured at the discretion of the tag writer. Note that encrypted or secured data may not be readable by subsequent applications or users. Unless written in a read-only format or locked, optional data may be removed or changed by subsequent applications. Optional data shall be contained in ISO/IEC 15434 syntax and ISO/IEC 15418 semantics using ISO/IEC 15962.

7.6 Traceability

Unique identification enables traceability. Traceability can relate to specific items yielding the ability to differentiate between like items and traceability can also relate to groups of like items differentiating them from unlike items.

Serialization schemes shall comply with ISO/IEC 15459-4.

Traceability of commodity items may be achieved by concatenating data elements representing the manufacturer, the part/model number and the lot or batch number assigned by the manufacturer.

7.7 Unique item serialization

Unique item identification can be assured by concatenating three elements of data: the issuing agency code (IAC), an enterprise identifier (relating to the IAC), and a unique serialization as described in ISO/IEC 15459-3.

Product package-RFID tag data formats shall make a clear distinction in the leading eight bits of the tag between unique product package identification and its contents, in addition to a ninth bit (at seventeenth HEX position) indicating ISO (AFI) or EPCglobal.

8 Data security

8.1 Confidentiality

Tag users desiring to have their tags read only by authorized users shall have the ability to secure/protect data written to a tag. The tag shall be capable of having secured/protected data written to it and read from it without interference from the tag design or structure. Use of this feature shall be at the discretion of the user. The type of security/protection to be utilized shall be commensurate with the degree of risk and vulnerability associated with the tag data, and shall be agreed upon between the enterprise writing to the tag and any/all authorized readers/users of the data.

8.2 Data integrity

Tags shall have the ability to prevent the alteration or erasure of data commonly known as *locking* data. This shall be at the discretion of the user. Tag manufacturers shall have the option of locking a portion of the tag data for identification and storage of data related to the manufacturer and not the user. A CRC-16 is required to enhance the integrity of the data. The location of the CRC-16 shall be as per the memory map in Figure 2.

8.3 Interrogator authentication

A tag's data storage schemas for user memory and future data transfer protocols should provide for the user-enabled option to require authentication of the interrogator's authorization prior to reading the tag data. Reading of the tag ID alone shall not require authentication.

8.4 Non-repudiation/audit trail

Tags shall be capable of supporting non-repudiation when programmed to provide non-forgeable evidence that a specific action occurred. Nothing in this non-repudiation feature shall interfere with or degrade the performance of the tag or other tags in the field of view.

8.5 Product authentication/anti-counterfeiting

RFID devices by themselves do not prevent counterfeiting; the serialization of product and a secure chain of custody can aid in anti-counterfeiting.

9 Identification of RFID labelled material

RF tags and RF label inlays compliant with this International Standard shall include one or more of the internationally accepted RFID emblems. The accepted emblems are given in Figure 3.

NOTE 1 The above emblems only represent the 860 MHz to 960 MHz air interface for this application standard. Other air interface designations can be found in ISO/IEC 29160.

NOTE 2 These graphics can be scaled to the appropriate size and are available in either dark-on-light or light-on-dark.

Figure 3 — Examples of the RFID emblem and EPCglobal seal as described in ISO/IEC 29160

10 Backup in case of RF tag failure

10.1 Human readable interpretation (HRI)

Other than as stated in 5.3, human readable interpretation or human readable translation of unique item identifiers is not mandatory. Where used, the mandatory information (UII) contained in the binary encodations in RF tags shall be represented in their octal or hexadecimal equivalent as shown in ISO/IEC TR 24729-1. ISO standard two-dimensional symbols, for example Data Matrix ECC 200 or QR code, encoded in conformance with ISO/IEC 15418 and ISO/IEC 15434, should be considered as a primary backup to RF tags on products. An additional level of backup of human readable interpretation may be considered.

10.2 Human readable translation

Human readable translation of the data on the tag is selected data rather than complete data and may or may not contain data semantics. Human readable translation should be used when space constraints or privacy considerations do not permit the use of human readable interpretation.

HRI of either ISO UII or EPC tags shall be the upper case alphabetic and numeric representation of the encoded data as set forth in ISO/IEC TR 24729-1.

10.3 Data titles

The use of data titles shall be as specified in ANS MH10.8.2 or the GS1 *General Specifications*.

10.4 Backup

Use of human readable information is strongly encouraged for data that is critical to the item's use or sale and shall function as the first backup in the event that the RFID tag is unreadable/misleading for any reason. If optically readable media is used, trading partners shall agree upon a linear symbol such as Code 128, as described in ISO/IEC 15417, or a two-dimensional symbol such as Data Matrix, as described in ISO/IEC 16022 or QR Code, as described in ISO/IEC 18004.

11 Tag operation

11.1 Data protocol

The data protocol for this International Standard shall support the requirements of ISO/IEC 15961 and the semantics of ISO/IEC 15418 and ISO/IEC 15962 and the syntax of the ISO/IEC 15434.

11.2 Minimum performance requirements (range and rate)

The performance for tags shall be measured in accordance with ISO/IEC TR 18046. Minimum performance requirements will vary for different functional applications of RFID. Table 5 shows the typical performance requirements for passive tags operating in the three normal configurations to transfer tag data of 256 bits. These specifications also relate to the writing of the tag. Greater distances can be achieved in reading from RF tags than writing to RF tags.[1)]

Table 5 — Typical passive tag performance

Parameter	860 MHz to 960 MHz ISO/IEC 18000-6, Type C	13,56 MHz ISO/IEC 18000-3, Mode 3	<135 kHz ISO/IEC 18000-2, Type A	433,92 MHz ISO/IEC 18000-7
How far? [Minimum supported read distance (in metres)]	3	0,7	0,7	30
How fast? [Minimum supported item speed when read (in kilometres per hour)]	16	16	0	16
How many? [Minimum supported effective measure of tag data transfer rate and ability to do anti-collision (in tags per second)]	200[a] or 500[b]	200	1	1

a This value corresponds to the 200 kHz bandwidth.
b This value corresponds to the 500 kHz bandwidth.

1) In case regulatory restrictions provide fewer channels than there are interrogators in the environment, this performance can only be achieved by appropriate shielding of the interrogators against other interrogators.

11.3 Environmental considerations

The operating environment will vary significantly by location. A description of various environmental factors associated with RFID can be found in ISO/IEC TR 18001. Consideration will be given to the following general parameter set, as derived from the product packaging user community.

— The product RFID tag shall function properly in the temperature range –40 °C to +70 °C and be able to endure, for a specified period of time, harsher conditions in the range –50 °C to +85 °C.

— An operating environment with relative humidity of 95 %.

— Warehouse construction, including racking.

— Transportation mode.

— Speed and direction of movement of tag relative to reader.

— Orientation of tag to reader (i.e. controlled or random).

— Read distance.

— Write distance (if applicable).

— Electromagnetic interference from motors, fluorescent lights and other spectrum users.

— Electromagnetic characteristics of the packaging and contents of the tagged item.

— Shape and size constraints on antenna, and any requirement to decouple antenna from tagged item.

— Form factor constraints in terms of size, shape, resistance to pressure, temperature, moisture, cleaning and contaminants [dust, oil (natural food, petroleum and synthetic), acids and alkalis].

— Method of attachment of form factor.

— Resistance of readers to heat, moisture, impact damage.

— Health and safety regulations.

The performance of passive RFID (range and rate) can be adversely affected by the presence of metal and/or liquids in the container, transport unit or (packaged) product. Appropriate shielding can be used to reduce interference.

If the process requires read rates in excess of 200 tags per second sequentially, parallel readings should be envisioned.

11.4 Tag orientation

It should be assumed that the handling operation is unable to predict the orientation of the individual (packed) products in higher levels of packaging and transport. This can hamper the effective use of the reading equipment on site and/or *en route*.

11.5 Packaging material

A wide range of materials (such as wood, metal, plastic, glass, paper and textile) is utilized in primary packaging and small and large transport units. Also, materials for coding and identification, as well as branding and the representation of legally required information, are used. These can interfere with the RFID equipment.

11.6 Shock loads and abrasions

Typically, the various products are subject to shock loads during the physical handling process. This can result in intentional or unintentional damage to the RFID tag. Placement and insertion of the tag should be done in such a way that damage due to shocks is minimized.

11.7 Tag lifetime

Tags attached to the product will be continuously used throughout the life of the product. Product RFID tags shall be capable of a minimum 100 000 read or read/write cycles, as appropriate, without failure.

11.8 Minimum system reliability

Systems where tags are positioned, programmed and presented to reading equipment in accordance with the provisions of 11.3 and ISO/IEC TR 18046, shall have a minimum read reliability of 99,99 %, i.e. no more than one no-read event in 10 000 readings, and a read accuracy of 99,998 %, i.e. two undetected incorrect readings in 100 000 readings.

11.9 Air interface

Product RFID tags shall operate in one of two frequency ranges and comply with the appropriate parts of ISO/IEC 18000. With agreement between trading partners, either ISO/IEC 18000-6, Type C or the ASK air interface of ISO/IEC 18000-3, Mode 3 may be used. It is recommended that tags supporting ISO/IEC 18000-6, Type C also be able to support ISO/IEC 18000-3, Mode 3.

11.10 Memory requirements for application

The memory requirements for product tagging RFID tags can be grouped into three basic categories: 96 bits, 256 bits, and greater than 256 bits. Industry surveys have yielded recommendations for RF chip manufacturers to provide for 2 kbits and 4 kbits. Memory capacities shall not alter the air interface. Use of alternate memory requirements shall not result in changes to the minimum and mandatory data elements of their format or tag data structure, as otherwise specified in this International Standard. Annex B gives a list of useful data fields for product life cycle management totalling 152 bytes (1 216 bits).

11.11 External communications

External communications (interactive as opposed to simple data transfer and read/write) shall not be required for, but may be a part of, product tagging RFID tags where the optional supporting commands meet the requirements of the optional commands in the air interface (ISO/IEC 18000). Proprietary commands should not be used.

11.12 Sensor interface, if applicable

Sensors integrated into or onto a tag and their tag operations or management shall not interfere with the operation of the tag as required by this International Standard.

Battery assisted tags shall be free from interference from the battery operation and/or battery management functions.

Sensor equipped product RFID tags shall conform to IEEE 1451.7 for the physical interface between the tag and the sensor.

11.13 Real time clock option

A real time clock shall be included with product packaging RFID tags that are sensor equipped and where the application requires a time stamp. The accuracy of the time compared to actual Coordinated Universal Time (UTC) shall be no worse than $\pm$five seconds per day.

11.14 Safety and regulatory considerations

All tags, interrogators and antennas conforming to this International Standard shall meet the safety and regulatory requirements of the country where the technology is used. The use of passive or semi-passive (battery assisted) RFID tags shall also be restricted in hazardous environments, such as near or around explosives or flammable gasses, unless these devices have been certified as safe for such use by appropriate authorities.

All tags conforming to this International Standard shall meet national safety and regulatory requirements to include power, duty cycle and electromagnetic radiation.

11.15 Non-observable data

The nature of non-observable data is such that when individual data fields within a tag are protected by an interrogator command, the command may implement whatever protection measures are chosen, provided that the protection measures do nothing to impact, interfere with or deteriorate the operation of other tags in the supply chain. Tags that are intended for use over the supply chain shall have the mandatory data elements readable.

11.16 Tag recyclability

All tags attached to the product may be used to facilitate the recycling of the product and the tag itself. In this respect, it may also be feasible to reuse the tag after reprogramming, however without compromising the supply chain data structure. The exact implementation depends on cost of the tag and environmental implications of reuse/recycling. It will not be possible to use RF tags for recycling if the tags are “killed” at point-of-sale.

The recyclability of product tags described in this International Standard is dependent upon the component materials used in the individual tags. The tag manufacturer shall clearly mark product tags with recycling instructions or an appropriate logo to assist in the proper disposal of the tag. Guidelines for tag recyclability can be found in ISO/IEC TR 24729-2.

11.17 Tag reusability

Technologically, all RFID tags are theoretically reusable. Because of the unique identification aspects of product tagging, the permanent nature of the physical attachment of the tag, and the low cost of the tags themselves, product level tags are generally not reusable for commercial retail items and commodity items.

High value and mission critical items may utilize higher functionality (read/write, larger memory, and possibly sensors) tags whose cost may justify their reuse. Tags intended for reuse shall clearly be marked with appropriate human readable characters or logos to enable identification, reclamation and return. Prior to reuse, reusable tags shall have their headers checked for data integrity and user memory cleared.

12 Tag location and presentation

Guidelines for tag location and presentation can be found in ISO/IEC TR 24729-1.

12.1 Material on which the tag is mounted or inserted

The potential disturbance of metals and other reflective materials as well as liquids and other absorptive materials on the product shall be considered in the design to minimize disturbance of the RF signal.

12.2 Geometry of the package/tag environment

RF tags should be affixed to the product in such a way to minimise the disturbance of the RF signal. This pertains to both the product package and the products it is containing. See ISO/IEC TR 24729-1.

13 Interrogator and reader requirements

13.1 Safety and regulatory considerations

All RFID tags and interrogators shall comply with IEEE C95-1 and ICNIRP Guidelines.

All interrogators and readers shall comply with the specific power, bandwidth and duty cycle requirements in addition to all of the local radio frequency regulations for the location in which they are used. In addition, all interrogators and readers intended for use in hazardous environments shall carry the appropriate specific information.

13.2 Data privacy

13.2.1 Aggregated data

Security of aggregated data shall be the responsibility of the collector. Data collectors and data storage operators shall comply with all personal privacy regulations and rules governing the collection, storage and dissemination of personal data. Personal data collected by or incident to the reading of an RFID tag shall be accorded the same protection and security as personal data collected by any other means.

13.2.2 Company proprietary data

Security of product packaging data collected from or incident to the reading of a product packaging RFID tag is the responsibility of the company collecting the data. Companies wishing to restrict the collection of company proprietary data from product RFID tags shall utilize appropriate forms of data security. As security/protection of tag data can be compromised, use of RFID product packaging tags to carry sensitive, classified or proprietary data should be limited.

14 Interoperability, compatibility and non-interference with other RF systems

All RFID systems including tags, interrogators and readers shall operate on a strict non-interference basis with all other RF systems operating in the same spectrum. All RFID systems including tags, interrogators and readers claiming conformance with this International Standard shall be interoperable and compatible at the specific frequency designed.

Annex A
(informative)

Proposed guidelines for the verification and qualification of design and manufacture for RFID chips and transponders for tyres

A.1 General

The objective of this annex is to provide background, reference information, and practical knowledge in the selection and verification of the design and manufacturing quality for *RFID chips and transponders for tyres*.

The performance of RFID devices, particularly those operating in the UHF band (860 MHz to 960 MHz), is strongly influenced by the construction of the RFID-enabled device (from the chip to the transponder), where it is applied to the object, and the characteristics of the underlying object. In this regard, much more care has to be taken in selection and placement of the RFID-enabled device on/or in the tyre in comparison with a conventional bar code as specified in MIL-STD-129 or ISO 15394. This in turn requires the additional knowledge and practical guidelines for RFID chip and transponder selection and verification of design and manufacturing quality that are provided here. This annex targets item level tagging where the RFID tag may be present in various formats, including a label, incorporated into a patch which then becomes permanently affixed to the inner or outer surface of a tyre, or incorporated during manufacture into the structure of the tyre as an integral part of the tyre.

This annex includes chip as well as transponder design and manufacture guidelines.

A.2 General terms and definitions for initial reference design

Subclauses A.2.1 to A.2.4 give a general description of the current design of a tag for use in tyres, broadly describing the physical design for a first generation tag for this service condition.

A.2.1 Life-of-tyre application

The category of “life-of-tyre” RFID installations, where an RFID is permanently associated with a tyre and is intended to remain functional for a substantial portion of the tyre's life. These RFID transponders can be included in the structure of a tyre as it is being built, or they can be applied as a “patch” to an interior or exterior surface of a tyre after manufacture. This International Standard addresses both types, and is orientated specifically to the case where an RFID with a dipole antenna is embedded and cured into rubber.

Temporary label RFID solutions will also be addressed only to assure that the correct degree of testing and qualification occurs.

A.2.2 Tyre size specification

Tyres come in a variety of sizes, spanning several orders of magnitude in size, weight, and load-carrying capacity. Most of the requirements that follow are common to all tyres, but every specific application shall be examined carefully to assure optimum performance.

A.2.3 “Rubber”

In this context, the term “rubber” refers to either natural or synthetic compounds commonly used in tyre construction.

A.2.4 Passive RFID

The term passive RFID transponder is used to describe the combination of an RFID integrated circuit (chip) bonded to an antenna, where the antenna is used for both two-way wireless communication and to draw power from the reader RF signal to operate the RFID chip.

A.3 Management systems

The ISO 9000 and ISO 14000 series of International Standards emphasize the importance of audits as a management tool for monitoring and verifying the effective implementation of an organization's quality and/or environmental policies. Specifically, manufacturers of RFID hardware (such as readers, interrogators, transponders, and tags), will benefit from well established and implemented ISO 9000 and ISO 14000 compliance programmes. The ISO 9000 certification process requires individual companies to undergo and pass an outside compliance audit and can include internal assessments.

ISO 9000 compliance requires use of documented repeatable processes that result in products that meet customer requirements. Fully compliant process outputs meet or exceed customer requirements by the use of process control and total quality management techniques. Use of specific techniques or procedures is not required for compliance.

ISO 9000 lays out the basic principles that underlay a quality management system. ISO 9001 details the specifics of the quality system at each of the organizational levels. ISO 19011 contains the actual audit guidelines. ISO 9004 contains guidelines on continual process improvement.

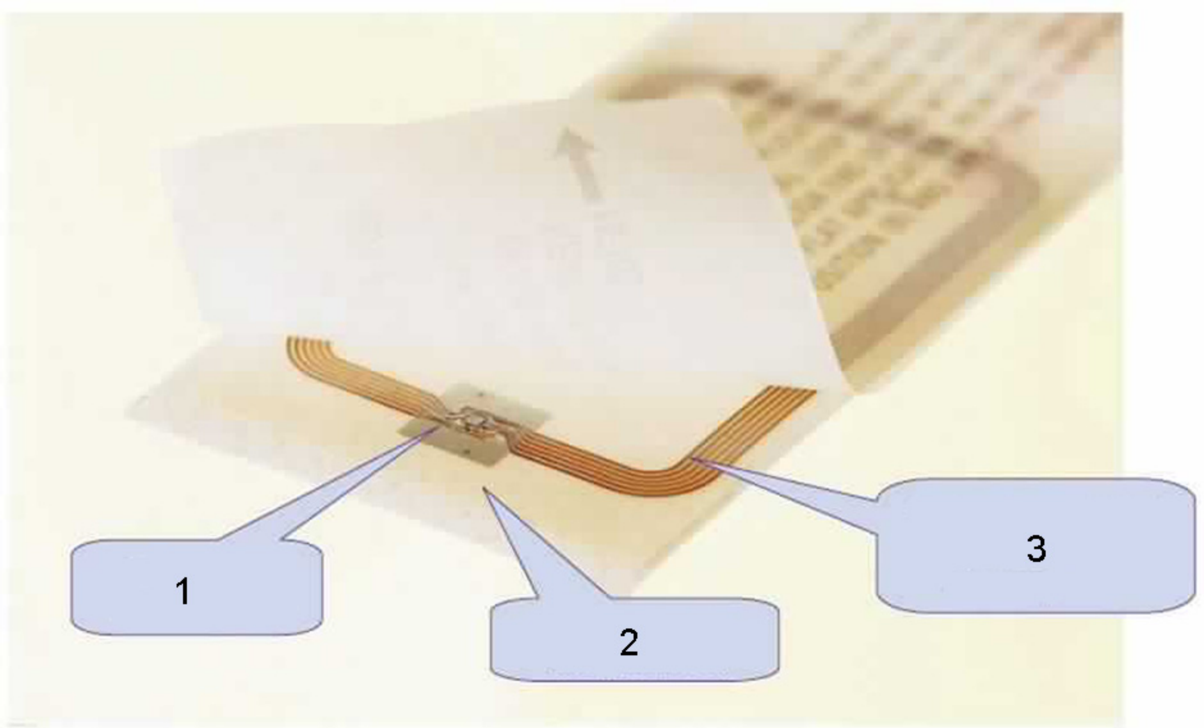
The ISO 14000 International Standards utilize the same format as the ISO 9000 series and are designed to be complementary to each other. Compliance with ISO 14001 does not mean that the production processes and policies for the company are environmentally friendly, rather that the company meets regulatory requirements and has an established policy and commitment to continuous process improvement.

Compliant hardware manufacturers shall be independently certified as ISO 9000 compliant and ISO 14000 compliant.

A.4 RFID chip technology and quality

Two approaches to placement of transponders are shown by way of examples in Figures A.1 and A.2. These examples do not indicate that an acceptable RFID transponder is in any way restricted to these concepts; rather they illustrate examples of working concepts available at the time of writing.

Figure A.1 depicts an RFID transponder in the form of an RFID Smart Label with the various components identified. This section is instructive for temporary RFID labels for tyres.



Key

1 RFID chip

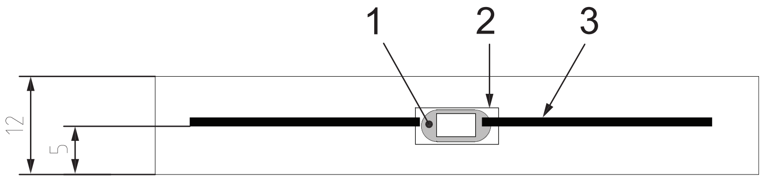
2 substrate (e.g. plastic foil)

3 antenna (printed, etched or stamped)

Figure A.1 — RFID transponder (Smart Label)

Figure A.2 is instructive for RFID transponders capable of being cured directly into or onto a tyre. The transponder consists of a UHF/SHF RFID chip packaged in a TSOP-8. The TSOP-8 is soldered to a thin FR4 circuit board, and soldered to the TSOP-8 are two helical springs forming a dipole antenna. The antenna leads have been tuned to resonate at 868 MHz and 960 MHz when cured into the tyre.

Dimensions in millimetres



Key

1 solder

2 PC board w/IC

3 helix, 12 turns/cm, 1 mr OD

NOTE 1 Overall length to be specified in purchase order.

NOTE 2 Tolerance window shown (tag is placed ± 6 mm in a straight line).

Figure A.2 — Initial reference design: RFID transponder directly cured into or onto tyre

A.4.1 RFID chip quality

The quality of any component contributes to the quality of the integrated product whether the product is a single device or a system. Practical consideration of quality results in a definition that quality of any item (or component) is represented through the characteristics that result in meeting the item's intended use (i.e. user requirements). In the case of an electronic component such as an RFID chip, the characteristics of interest are

— physical,

— electrical, and

— functional.

The physical characteristics are defined by the various mechanical qualities and interfaces involved in the manufacturing process whereby the RFID chip is attached to an antenna/substrate to produce a functioning RFID transponder. It should be noted that not all transponder assembly processes have the same requirements for the physical characteristics of RFID chips for the production of quality RFID transponders. Consideration should be given to specifying RFID performance requirements that are not peculiar (or unique) to a specific transponder manufacturing process. This is particularly important where the manufacturing process is proprietary. Applications of RFID chip and transponder technology to tyres are perhaps the most challenging with regard to mechanical endurance. In addition, for the embedded version, the transponder shall survive the moulding/curing process.

The electrical characteristics for an RFID chip are generally well defined in the product specifications of the various RFID chips. As the primary electrical interface for a passive RFID chip is through the contacts for the RFID antenna, impedance matching between the RFID chip and antenna is usually the most critical electrical interface issue. Under the rigors of the tyre applications, secondary packaging for the chip may be required. The chip may first be packaged in a standard small outline package (SOP) prior to antenna attachment. The SOP package adds the potential benefit of both mechanical and thermal isolation of the IC. This secondary packaging shall also be taken into account in the process of impedance matching of the system.

The functional characteristics of an RFID chip are completely defined by the air interface protocol to which the RFID chip is compliant. RFID conformance testing (e.g. ISO/IEC 18047) shall be used to verify the functional quality of the RFID chip. This is key to assuring design robustness, and in avoidance of an inadequate design.

Proper compliance to the physical, electrical and functional requirements allow a wide variety of passive RFID transponders to be produced from a common RFID chip. This results in increased interoperability and reduced cost. For example, a large variety of passive RFID transponders are available with a common RFID chip, but only a few designs are capable of being an integral part of a tyre.

A.4.2 Chip packaging — Physical interface

A.4.2.1 Label-based transponders

The RFID label chip is generally connected to an antenna via a direct electrical contact, though there are other concepts in development that may afford advantages for low cost assembly. A caution is that even an RFID label designed for tyres as a temporary attachment, such as for logistics, needs to have robust mechanical features (see 7.3). Most transponder assembly methods currently use a direct connection between the RFID chip and the tag antenna.

A.4.2.2 Pick and place chip

Currently, most inlet manufacturers use pick-and-place machines (robots) to pick an integrated circuit (IC) from a silicon wafer, flip it over, and carefully place it on an antenna. Two tiny metal pads on the chip have to touch the ends of the antenna to make the electrical connection (there are a variety of ways to bond the antenna to the pads). However, picking and placing chips is costly and is becoming more difficult as RFID chip sizes decrease.

A.4.2.3 Intermediate carrier

As chip size decreases, the traditional intermediate carrier process becomes more challenging, as the alignment requirement (RFID chip to antenna pad) becomes more demanding. As a result, there have been developments focused on providing a “standardized” RFID chip delivery method using an intermediate attachment mechanism. This approach calls for the semiconductor manufacture to deliver the RFID chips attached to a standardized delivery structure (carriers, tabs, interposers, etc.). The inlay manufacturer/label converter can then handle the RFID chips (subassemblies) in a standardized manner since the connection structure to which they are attached is “fixed”, independent of the chip size. Additionally, the carriers to which they attach the antenna have a physically larger structure allowing greater flexibility and reduced precision requirements.

Such delivery mechanisms provide significant benefits, including:

- simple, flexible RFID manufacturing process, independent of IC size;
- standard delivery type, i.e. 35 mm tape reel format with four units per 4,75 mm pitch allows one package format;
- robust, well-industrialized, high volume technology, with high yields and high assembly throughput of 10 000 units per hour;
- removal of the need for transponder manufacturers/label converters to connect the RFID ICs in a clean room environment;
- allowing flexibility for inlet antenna design, as connect areas on the flip chip package are larger than the bond pads of the ICs;
- allowing many different connection strategies between the IC and the inlet antenna, such as soldering, gluing, crimping;
- better protection of the IC.

Negative aspects include:

- carriers add one unit operation to assembly;
- more connections that may fail.

See also A.4.2.6.

A.4.2.4 Example of a novel manufacturing assembly technology

Alien Technology Corporation® has developed and holds exclusive patent rights to a manufacturing assembly technology called fluidic self assembly (FSA®). FSA® enables efficient placement of very large numbers of small components across a surface in a single operation. FSA® has numerous potential uses, including the high-volume manufacture of very inexpensive RFID tags. Alien Technology Corporation® looks to utilize this technology as a method for placement of RFID chips onto a delivery structure analogous to the strap mechanism currently being utilized by traditional semiconductor industry with “pick and place” technology.

The FSA® process allows Alien Technology Corporation® to package tiny integrated circuits (NanoBlock® ICs) for assembly into RFID tags at rates upwards of 2 000 000 per hour. This contrasts with the approximately 10 000 per hour possible with conventional methods that were developed to handle much larger and more costly integrated circuits. While this appears advantageous, the FSA® equipment costs are significantly higher that that of traditional “pick and place” equipment. Additionally, as this technology is proprietary, it is not generally available to the industry.

This novel assembly process places significant geometric requirements on the RFID chip. The chamfered edges of the silicon are required to match the receiving structure for proper and efficient placement. The shaped edges typically extend the region near the end where IC circuitry cannot be placed. This can reduce the effective usable area of the chip for circuit implementation.

An additional requirement the FSA® process places on the RFID chip design and manufacture is the need to maintain rotational insensitivity (about a vector normal to the plane of the silicon wafer). The process prefers the chips being placed to be “square” and have pads for contact that allow rotation of the chip relative to the receiving structure to be any of the four available quadrants. While “non-square” rectangular chip structures are possible, the assembly efficiency is reduced.

The FSA® process requires a large number of ICs in the fluid to achieve consistent placement. When a bad wafer is added to the fluid, statistically, the residence time of the corresponding bad ICs is long, or the cost to discard and refill is large.

A.4.2.5 Vibratory assembly

Another approach to addressing the need to move beyond the current “pick and place” techniques in tag assembly is vibratory assembly. Philips Semiconductors has been pursuing this approach for RFID chip placement as an alternative to traditional “pick and place”. In this approach, mechanical vibration, in conjunction with physical guidance, is used as the mechanism to place an RFID chip in the receiving structure. This approach provides a similar (though contrasting) method for chip placement to that of FSA®. It should be noted that this concept is not proprietary and is very scalable. Additionally, the issue with chip orientation is quite manageable as the process allows for a direct assessment of chip orientation. Corrective action can be taken on an individual chip basis.

While this method is novel for chip assembly, it has already been industrialized in the semiconductor industry for diode manufacture. This process is also compatible with existing flip chip bonding techniques.

A.4.2.6 SOP packaging and solder bonding — Method used in baseline tyre transponder design

Two different style RFID transponders can be used. Each type uses a Mini Small Outline Package (MSOP – Ref. JEDEC MO-187E/AA) packaged chip solder attached to antennas. An MSOP is a traditional electronic package employed to protect the chip from its environment, including the ability to cure the device into rubber. Other attachment techniques such as flip chip or direct bonding have not been proven to be sufficiently robust in the tyre application. One style of an MSOP tag may be manufactured on a flexible substrate. The other style of MSOP transponder has spring wire antenna solder bonded directly to the MSOP on miniature thin board. Compliance with environmental directives (e.g. RoHS) can require process changes due to materials' characteristics. Lead-free solder reflow will likely require higher temperatures resulting in higher peak component temperatures. Care should be taken to ensure against package damage due to higher internal pressure resulting from absorbed moisture.

A.5 Assembly — Transponder

Various assembly process approaches have been explored in search of a reliable means to attach the RFID chip to the tag antenna. The intent is to make the processes as independent as possible while minimizing assembly cost.

An example is given in Figure A.3, which shows the general process chain for RFID Smart Labels. The activity depicted in the centre of Figure A.3, the transition from the RFID chip manufacturer to the inlay manufacturer/label converter, is critical to the production of cost effective RFID transponders.

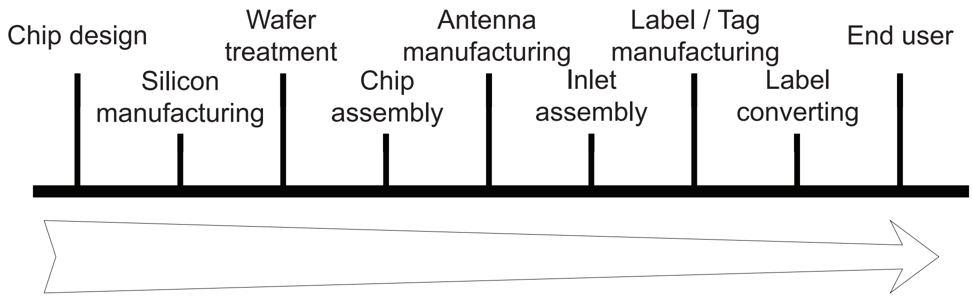


Figure A.3 — Label process chain

A.6 Chip/transponder interface

A.6.1 Physical interface

A.6.1.1 Physical interface requirements

As noted above, there are a variety of assembly methods potentially usable for establishing the mechanical interface between the RFID chip and the transponder antenna. Proper matching of chip physical characteristics to the assembly process is crucial. Requirements related to these critical physical characteristics are as follows:

— Antenna contact points shall be widely separated to minimize interaction.

— Antenna contact areas shall be maximized while maintaining physical isolation and separation.

— Flip chip assembly shall use an appropriate underfill to provide mechanical durability across specified operating environment.

— Chip design shall include a buffer region along edge boundaries.

— Chip delivery structures (straps, tabs, interposers, etc.) shall survive flexure due to thermal expansion and mechanical stress transmitted through inlay substrate.

— Bonding materials shall support compliance to RoHS and WEEE requirements/directives.

A.6.1.2 Attachment methods — Chip/antenna

Some examples of different chip/antenna attachment mechanisms include:

— Direct Connection: RFID chip is directly connected to the antenna, such as with conductive epoxy, stud bumping, wire bonding, wet conductive ink, etc.

— Capacitive Coupling: Antenna on tag substrate couples capacitively to RFID chip.

— Inductive Coupling: Integrated coil on chip is inductively coupled to external passive resonant circuit.

A.6.2 Electromagnetic interface

The electromagnetic interface of a passive RFID chip is defined primarily through the air interface definition along with the design characteristics of the product. Performance characteristics are defined for the transponder by the application requirements. These performance characteristics include:

— Range (identification, reading, and writing), i.e. distance (metres) from the reader antenna to the transponder.

— Rate (identification, reading, and writing), i.e. speed of data transaction (tags/second).

In addition to the system level performance characteristics, transponders also have directly measurable performance characteristics that are defined through the air interface specification to which they are compliant. Some critical parameters include the following.

— Delta radar cross-section (RCS): This parameter reflects the differential radio reflectivity of the tag based on the digital modulation definition (i.e. 0/1). The differential radio reflectivity is a direct and significant driver of the Signal-to-Noise-Ratio (SNR) available from the rag in the return link.

— Activation power density/field strength: This parameter defines the minimum power density/field strength required to activate a passive RFID tag. This is usually the most significant parameter in defining the maximum communication range (i.e. distance) of an RFID system.

— Modulation depth: This parameter represents the signal available from the RFID chip through load or impedance modulation and is a direct contributor to the Delta RCS parameter noted above. It is separate from the antenna characteristics (e.g. gain, polarization).

— Bandwidth: This parameter defines the signal performance of a tag across the defined operating band. As there may be significant differences in antenna characteristics as a function of frequency, this parameter is a strong indicator of range performance for tags across the defined RF band. This is of particular interest when the defined RF band is significantly broad (e.g. 860 MHz to 960 MHz).

It should be noted that many of these defined requirements imply a matching of characteristics between the RFID chip and the antenna as represented in the transponder. As such, many electromagnetic interface characteristics of the RFID chip (e.g. impedance, bandwidth) shall be matched to the antenna/inlay design and fabrication process. Thus a less sensitive, as measured by activation power density, RFID chip can be combined with a larger and more efficient antenna structure to meet the same user performance requirement (i.e. range) as a more sensitive RFID chip matched to a smaller/less efficient antenna. Both may be completely acceptable to the user from an application performance standpoint.

RFID chip electromagnetic interface compliance shall be established through appropriate conformance tests using ISO/IEC 18047. In a similar manner, electromagnetic interface compliance relating to performance shall be verified through conformance testing using ISO/IEC TR 18046.

A.6.3 Functional interface

The functional interface directs relates to the RFID chip's compliance to the air interface protocol for which it is designed to implement. Functionality is defined by the various actions the RFID chip can perform in its support of the specified air interface protocol. These functions can include

— wake-up,

— group selection,

— anti-collision,

— reading,

— writing,

— error handling, and

— locking/security.

RFID chip compliance shall be established through conformance testing using ISO/IEC 18047 for the appropriate air interface supported.

A.7 Transponder

A.7.1 General

The current AIAG B-11 Tyre and Wheel Standard for passive RFID transponder chips for tyre transponders meets ISO/IEC 18000-6, Type C. Additional transponder types may be utilized in the future, once defined. The nominal memory size is 1 024 bits, with the size of the EPC and user memory banks defined in the AIAG B-11 specification.

A.7.2 Passive UHF transponder frequency considerations

RFID readers are subject to local regulations regarding frequency and allowed reader power. For example, in North America, the nominal operating frequencies are 902 MHz to 928 MHz, conforming to FCC Part 15.247. In Europe, the nominal operating frequencies are 865 MHz to 868 MHz, conforming to EN 302-208-1 (this is a recommendation where only national countries have national regulations guided by pan-European recommendations). In Japan, the pending nominal frequencies are in the range of 950 MHz to 956 MHz, conforming to the Radio Law of Japan. Local regulations should be consulted before purchasing and deploying UHF RFID readers.

The transponder, when embedded within or applied to the inside wall of the tyre, shall be functional over the full range of UHF RFID frequencies that are approved for use in most countries, i.e. 860 MHz to 960 MHz. It is acknowledged that transponder-reading performance may differ in different regulatory environments. The mandatory minimum read range is 0,6 m for passenger tyres in a factory environment.

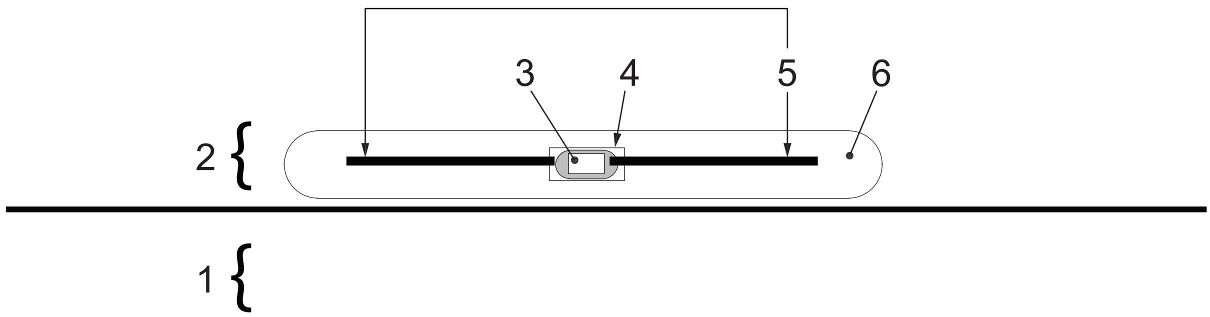
A.7.3 Transponder antenna design considerations for initial reference design

The method of transponder construction affects its technical performance, operating life, and environmental compatibility, as well as its cost. Certain special considerations apply for use in tyres.

UHF transponder antennas may be fabricated in a number of ways. Antennas produced by each process have different electrical and mechanical properties.

The antenna shall be a dipole configuration with the two radiating elements made from a spring steel coil or similar material which shall not deteriorate in conductivity or fracture over the expected tyre life and the full range environmental conditions. Antenna tuning may be optimized for the primary region of tyre sale or intended usage, but in any case the transponder shall be functional with reduced read range over 860 MHz to 960 MHz.

Figure A.4 gives the basic conceptual arrangement of parts.



Key

1 another layer of tyre

2 one layer of tyre

3 RFID MSOP

4 package and support

5 antenna

6 embedding

NOTE Both the “package and support” and the “embedding rubber” are purposely shown “cloudlike” to indicate that although performance standards do apply, no specific shape or dimensions are required by this International Standard.

Figure A.4 — The basic conceptual arrangement of parts in a tyre tag

A.7.4 RFID assembly size and shape

For passenger tyres and larger, the RFID chip with its package and support (not counting antennas) form a rigid structure that should fit within a “box” no more than 12 mm by 6 mm by 2 mm. Sharp corners are to be avoided, as they concentrate stress in the surrounding rubber. In most cases the smallest structure that can meet the other requirements for strength and interface with the antennas will be the best structure. It is also conceivable that a rigid core could be surrounded by a more flexible extended structure that is larger in one or two dimensions than the specified box.

A.7.5 Flexure of the RFID transponder and antenna

RFID transponders mounted in tyres will undergo three types of flexure:

— tyre shipping, handling and mounting flexure;

— continuous, cyclical flexure as the tyre rotates;

— shock flexure caused by the tyre rolling over or being impacted by bumps, potholes or road debris.

The antenna shall be capable of sustaining repeated cycles of flexing suitable for the specific tyre application intended. “Flexing” includes extension, compression, bending, and twisting. The number and severity of the cycles depends on the particular target tyre.

Depending on the materials and methods used in production of the transponder antenna and the chip bonding method, every transponder has a minimum allowed bending radius. Flexing or bending the finished RFID transponder to a radius smaller than this during the application process to the tyre, or during usage may result in RFID failure from fracture of antenna, chip or the chip-antenna bond.

The zone where the flexible antennas approach the rigid RFID package and support assembly is an area of particular concern for antenna fatigue failures. Suitable design features shall be employed to manage stress concentration.

A.7.6 Strength of electronic chip assemblies

It is impossible to give a single specification for mechanical strength that will be satisfactory in all cases. The RFID manufacturer shall coordinate with the customer for specific information. For example, during the rubber curing cycle, the RFID chip and its associated packaging and support components will be subjected to a combination of pressure, heat and time that is determined by the needs of the patch or tyre manufacturer. Depending on the particular application, there may be some rubber flow or deformation during curing that would tend to exert lateral forces on the surface of the assembly and may cause the antennas to tend to pull away from the package and support. In use, the RFID assemblies will be subjected to mechanical stresses arising from tyre deformation. There is a statistical component to the in-use deformations: a baseline deformation occurs on every revolution of the tyre, and more severe deformations occur when the tyre runs over a bump. It can be noted that copper component leads are not capable of sustaining even tiny amounts of repeated strain or bending without fatigue failure.

A.7.7 Antenna electrical properties

The antenna shall be configured in conjunction with the RFID chip to achieve at least the minimum read range needed for the particular application. Generally, this means the assembly shall be tuned to resonance in the target environment and shall not have significant resistive losses relative to the needs of the application. Note that the antenna will not be resonant at the operating frequency until it is placed in its target environment. The RFID supplier may ship the assemblies with antennas longer than needed, so that the customer can trim them to the specific length needed in a particular environment.

While this International Standard makes no specific prescription, it can be noted that

— a resonant antenna surrounded by a dielectric material is shorter than one in air,

— a conductor in the form of a helix has inductance, which further shortens the resonant length of an antenna,

— steel is a very poor conductor at UHF frequencies, but it can be plated with conductive metal, and

— the “skin depth” of conductive metals at UHF frequencies is measured in units of micrometres.

A.7.8 Tag insulation from tyre rubber

To work properly, a dipole antenna must be insulated from contact with conductive rubber. Most of the rubber compounds used in tyres are “conductive”, that is, their carbon black concentration exceeds the “percolation threshold.” In general, the antenna must be insulated from electrical contact with most of the normal rubber compounds used in tyres. A usual formulation for this would be to employ rubber of similar composition to the tag's nearest neighbour only at a significantly reduced carbon loading (reduce by typically 30 % to 60 %).

Typically, provision of the insulating layer of rubber will be the responsibility of the tyre maker or patch maker who buys the RFID assemblies, and not the RFID manufacturer. An adequate insulation layer is critical to the performance of the unit, and the tyre or patch maker must understand that the RFID manufacturer is not responsible for poor results caused by inadequate insulation. Although specific compounds may vary, in general insulating rubbers can be defined as rubbers with resistivity $> 10^5$ ohm·cm. However, the best way to evaluate candidate rubber compounds is to measure the dielectric permittivity (ε') and dielectric loss (ε''). Successful RFID transponders have been made using materials characterized at 915 MHz to have $\varepsilon' < 5$ and $\varepsilon'' < 0{,}2$, although higher values might work.

A.7.9 Bonding components to rubber or elastomer

The RFID package and support assembly and the antennas shall all be bonded to the embedding rubber that surrounds them. This bonding can be accomplished with a suitable adhesive system that acts during the rubber curing cycle. One of the reasons for this requirement is that the RFID assembly shall “do no harm to the tyre”; the other reason is to achieve a long lifetime of the assembly. Either the RFID manufacturer or the patch or tyre maker may apply the adhesive system, according to their specific needs. At least one suitable adhesive system can be applied to the assembly at the point of manufacture; it dries to a paint-like film that is not tacky and is relatively stable during gentle handling.

A.7.10 Attachment of patches

If the RFID transponder is cured into a patch for later application to a tyre, the patch maker shall demonstrably master the adhesive technology for attachment of the patch to the tyre. The tyre-repair industry is able to supply candidate adhesive systems.

A.8 Transponder testing and qualification

The ultimate customer will determine the numerical criteria necessary to specify a successful product. A minimum set of criteria will include specifications for the following:

- read range, or percentage of successful reads under conditions of actual use;
- expected lifetime, expressed in distance travelled, assuming normal tyre operating conditions;

  NOTE It might not be practical to test this directly, but laboratory tests or highway tests can be used as indicators.

- required minimum operational lifetime under laboratory test conditions, such as
  - low-pressure endurance (test with high flexing and high temperature conditions),
  - high-speed endurance (test with high temperature and high stresses in the tyre), and
  - endurance with cleats (test with high flexing but relatively normal temperature);
- the ability to survive recapping operations (if applicable);
- verification of manufacturability in the target application;
- verification of integrity after manufacture, including bonding of components to rubber.

  NOTE Generally, a good bond is a “rubber-tearing” bond; the specific force required to separate a part from the rubber is less important than the nature of the break.

In addition, the customer may require the supplier to meet other quality-control practices such as certifications that raw materials meet specifications or controls on process steps that cannot be easily tested non-destructively on the completed product.

A.8.1 Environmental considerations

Both extreme limits and cycling of environmental conditions can reduce RFID transponder operating life. Failure modes include chip-bonding failure, antenna fracture, antenna corrosion and electrostatic discharge damage to the chip. Accelerated life testing is recommended before deployment when unusual environmental conditions are expected to determine any limitations on working life of the transponder as mounted. These conditions may include outdoor storage, desert heat, arctic cold, nuclear or electromagnetic radiation exposure, usage underwater, chemical wash-down, etc.

A.8.1.1 Temperature range

For full-range military and commercial usage, the following recommendations apply.

Reading temperature range: –40 °C to +70 °C

Storage range (non-reading): –51 °C to +95 °C

Tyre fabrication temperature range (non-reading)

A.8.1.1.1 Tyre manufacturing conditions

The transponders shall survive these conditions

— 175 °C for 20 minutes or

— 160 °C for 45 minutes

— Max moulding pressure > 5 000 kPa

A.8.1.1.2 Tyre operational conditions

Transponder shall be operational at a temperature between –40 °C and +85 °C.

Transponder shall survive indefinitely between –40 °C and +110 °C.

Transponder shall survive up to 8 hours between 110 °C and 125 °C.

Transponder shall be operational under maximum tyre inflation pressures, e.g. passenger/light truck up to 413 kPa.

A.8.1.2 Humidity, underwater usage and the like

It is assumed that the transponder is embedded in or attached to the tyre. Therefore, humidity and water or chemical contact are not anticipated to be issues. Extreme cases of heat and humidity noted to affect the tyre itself could similarly affect the electronic. However, note that the transponder may not be readable when the portion of the tyre on which it is mounted is underwater, in snow, in mud, in soft sand, in gravel, etc., due to absorption of the R reader RF signal by the intervening foreign material.

A.8.2 Electrostatic discharge (ESD) compliance

Many processes can easily generate static electricity, including tyre flexure. It is especially a problem in low-humidity environments as found in desert, winter or high-altitude conditions. Discharge of static electricity through the transponder antenna into the RFID chip can cause permanent chip failure or loss or corruption of the stored data. Antenna designs can help mitigate ESD.

The ESD resistance of the transponder in free air shall be at least 2 kV. Compliance shall be verified by a standard test such as MIL-STD-331, or simply by discharging a 500 pF capacitor charged to 2 kV DC through a 500 Ω resistor.

The 500 pF capacitor and 500 Ω resistor simulate the characteristics of a human body discharge.

During testing, circuit inductance should be limited to 5 µH.

The discharges shall be applied in both polarities at various points on the RFID-enabled label as applied to the ends of the transponder antenna.

A minimum of five RFID transponders shall be tested to provide a scientific basis for concluding that the requirement is met.

A.8.3 Dealing with defective transponders

Systems shall test each embedded transponder to verify that the transponder is both functional and the data properly encoded. Tyres with defective transponders shall have a functional transponder applied as a patch and vulcanized onto the inside side wall, not closer than 10cm to the defective transponder, and programmed with the same data that would have been programmed into the embedded transponder.

A.8.4 Temporary label transponder — Specific considerations

For the purposes of this International Standard, an RFID label is defined as an RFID inlay or transponder laminated to an adhesive based label stock attached to a release paper carrier web. Some of the important requirements of the RFID label are:

The label is used to store tyre manufacturer's information and identification. The end receiver may also request manifest information or unique product identification (i.e. UII or EPC).

Insert will be adhered to a label, which will in turn be adhered to a tyre.

Label/tyre combination are expected to stay intact through

— tyre manufacturing processes of inspection, shipping, storage, and loading onto trailers for transportation to vehicle assembly plants, tyre distributor or direct retailer,

— transportation from the tyre manufacturer to the automotive manufacturer, distributor or direct retailer, and

— processing in the vehicle plant or similar application facility including but not limited to receiving inspection, tyre/wheel assembly, wheel vehicle assembly, wheel balance/rotation final assembly, and final assembly inspection and data gathering.

Tyre applications not requiring permanent tagging are expected to employ RFID labels. While these labels are not expected to be “life of tyre”, they are expected to survive traditional manufacturing, logistics and tyre mounting applications. Some of these requirements of use are listed below.

A.8.5 Tyre RFID label's test requirements

a) The label shall not lose any more than 20 % of its original strength (do a 90° pull test after the label has been applied for 1 hour) after being applied to a tyre and placed in an oven at 71,5 °C for 6 weeks (tyre is allowed to cool for 1 hour before testing).

b) The label shall not loose any more than 20 % of its original strength (do a 90° pull test after the label has been applied for 1 hour) after being applied to a tyre (cross terrains) and placed in a refrigerator at –40 °C for 1 week (tyre is allowed to warm for 1 hour before testing).

c) The original strength of the label shall exceed the current 2D label employed for AIAG B-11 standard applications.

d) 99,6 % of the labels and RFID tags shall be readable after being applied to a tyre, maximized, shipped to LA, shipped back to Detroit, unloaded, mounted with an automatic tyre mounter and place through a simulator.

e) 99,6 % of the RFID labels shall be readable when applied to a tyre and placed on a conveyor (label up) moving at a speed of 0,61 mps. The tyre shall be able to be placed in any orientation on the conveyor (1 m wide) and be read with a single antenna mounted 1 m above the conveyor.

f) 99,6 % of the RFID labels shall be able to be written to (128 characters) when placed on a conveyor (label up and any orientation) moving at 0 speed within 5 sec with a single antenna mounted 1 m above the conveyor.

g) Logistics and shipping shall include as a minimum 1 000 tyres stacked in a dense packing configuration and shipped an extended distance without loss of any labels.

h) The labels on the tyres in f) shall survive wheel assembly and mounting without loss.

i) Finally, the same labels on the tyres [f) and g)] shall survive transport through the vehicle assembly facility to tyre vehicle mounting.

j) Optionally, the label should be removed at final shipping preparation of the vehicle or at the landing point of vehicle distribution.

A.8.6 Adhesive residue (label designed to be removed after mounting)

Adhesive residue on tyre after label is removed should be minimized as much as possible (goal is less than 10%) and should be easily cleaned with a heptane solvent or citric-based cleaner.

A.8.7 Tyre RFID label placement specification

A.8.7.1 Dielectric variations

The final feature that is a key feature of this specification is the fact that the tyre has generally a very lossy dielectric value for the rubber, due to the carbon content of the tyre as well as the presence of metal in parts or most of nearly all tyres. The reading distance for tyres can vary tremendously based on carbon content as well as the proximity to metal such as tyre tread steel. For example, a label designed for a passenger tyre can read at 0,76 m, while the same label attached to an earthmover tyre would read at only 0,127 m. This example emphasizes the impact of carbon. In addition, a tyre with shallow tread results in more interference from the steel in the belts. The same drop in performance can occur in a single passenger car tyre when the identical label from the sidewall that has no steel cords is moved to the tread that has a significant number of steel cords. Finally, the fact that tread by design is a series of blocks or bands with features means that there are air spaces that would have a different dielectric and result in variability in tuning. Sidewall areas tend to lack steel or have lower density of steels cords (truck tyres), thus reducing or eliminating one source of interference. Sidewall areas inherently have lower carbon content than tread areas and therefore are more RF friendly.

A.8.7.2 Label location

The RFID label requires placement on the sidewall of the tyre. Factory automation dictates that the side read be available without the need to specially orientate the tyre. For example, as the tyre moves on a conveyor or is suspended on a hook the label would be read from the side. A tread label would cause undue cost in finding the RFIS due to specific orientation.

Wheel assembly and vehicle assembly also dictate the need for a sidewall label to allow for reading tyre, tyre/wheel assembly and tyre/vehicle while on production lines.

Tyres with sidewall tags can be read when in a retail display, provided an air space of one inch exists between tyres. This has the advantage of assuring that the exact tyre desired is being read. The challenge with a tread label is that one cannot be assured that a particular tyre is being read and not its direct neighbour. A sidewall label being read from the tread side assures isolation and high quality read reliability.

A.8.7.3 Label size specification

The label size should be a minimum of 101,6 mm in length by 35,56 mm in height. The maximum should be 190,5 mm in length by 50,8 mm in height. Variations between 101,6 mm and 190,5 mm for length and between 35,56 mm and 50,8 mm for height are acceptable. The shape can be curved, rectangular, elliptical or other shape with the limits of the maximum length and height.

The transponder shall not represent more that 60 % of the area of the entire label (transponder plus over-label).

A.8.7.4 Label read distance

The label read distance is similar to that required by the AIAG B-11 standard for tyre and wheel identification which requires a minimum distance of 609,6 mm (as measured between the tyre surface and the reader antenna) for passenger tyres. Heavy truck tyres that have steels cords in the sidewall and can vary in design from one manufacturer to another shall have a minimum distance of 304,8 mm.

A.8.7.5 Insert specification

The insert should be designed to sustain the shipping and handling requirements.

An example set of guidelines is given in Table A.1.

Table A.1 — Insert specification guidelines

Substrate	The tag is printed on a PEN flexible substrate with laminate thickness of 0,050 8 mm (2 mil) (typical).
Physical characteristics	The label shall comprise an RF insert and an thin layer of solder mask as a cover layer. The RF insert will comprise an ASIC with an appropriate package and a substrate and an antenna attached to the package.
ASIC package	Wire bond glob top package.
Cover layer	Nominal thickness 0,025 4 mm (1 mil) (typical) over the plated copper, excluding chip attach area. Can be photo imagible or screen-printed and can be transparent.
Maximum package thickness	The overall package thickness is 1,27 mm (maximum).
Twist	The insert shall withstand ten 180° twists from one end to the other.

A.8.7.6 Adhesive type

Typically, pressure sensitive or heat seal adhesive is used; rubber based adhesive is preferred. If a heat seal adhesive is used, then its green tack shall be sufficient to hold the label in place while curing.

The ambient minimum application temperature for the label and the tyre surface should be at least 4,4 °C.

A.8.7.7 Bend radius

The RFID label shall be capable of withstanding without degradation a minimum bend radius of 12 mm.

A.8.7.8 ESD limits

The label shall withstand electrostatic air discharge of 2 kV.

A.8.7.9 Survival rate

The survival rate of the label through the defined process will be greater than 99,9 %.

A.8.7.10 Operating life (label on tyre)

The expected life of an RFID label applied to a tyre sidewall will be one year when stored at operating temperature and humidity.

A.8.7.11 Operating temperature

The RFID label shall operate at the temperature range –40 °C to +71,1 °C.

A.8.7.12 Operating humidity

The RFID label shall operate at a relative humidity range of 5 % to 95 % (non-condensed).

A.8.7.13 Surface interaction

Labels shall not introduce any surface cracks or damaging marks on sidewall that might impact functional performance of the tyre.

A.8.7.14 Label colour/marking

To assure no interference by optical scanners in OE automotive factories as well as assure visibility, the label shall be principally cyan in colour (Pantone or SWOT Process Cyan).

For labels intended for commercial tyres, the colour may be Process Black or Pantone Black 2U.

A.9 RFID transponder testing methods

While the visual inspection methods may be used to guide RFID-enabled label placement, a more quantitative method is useful in both confirming results and in determining the best transponder selection, polarization and placement on the transport package in terms of reader performance. Use of this method will help ensure that the labelled transport package or unit load will meet the minimum read range requirements.

The method described here requires a minimum of equipment and gives relative (not absolute) measurements of read range performance (not conformance) that may be easily compared between transponders and labelled packages made in the same test lab. By testing the same transponders and packages in multiple laboratories, meaningful correlations of test results between labs may be made.

For standardized performance measurement, the methods of ISO/IEC TR 18046 should be followed. Conformance measurement should be performed utilizing the methods of ISO/IEC TR 18047-6.

A.9.1 Equipment

A.9.1.1 Facility

An indoor or outdoor facility capable of maintaining a fixed relationship at a defined distance between an RFID reader system and the device under test is used. A range of 1 m with the device under test (DUT) on direct line to the reader transmit antenna is recommended; however, if the size of the package makes this difficult to achieve, an increase to 2 m is possible, but absorber material may be required on the floor between the DUT and reader system to suppress reflections. The centre of the transmit antenna should be located approximately 1,5 m above the floor. If indoor, the ceilings should be as high as possible, and the floor should be non-metallic. If available, an anechoic chamber can be used; if not, environmental adsorptions can be suppressed using suitable RF absorber panels.

A.9.1.2 RFID interrogator and antenna mounting

The UHF RFID reader will be of the appropriate frequency, designed for fixed-mount applications and will be used together with a fixed-mount UHF RFID antenna having a linear polarization, with a facility to rotate the antenna through 90° to measure tag devices designed to be dual polarized. The antenna used should be of a patch type and orientated so that the peak radiation direction is towards the device under test; the operator should always stay behind the antenna, or at least 4 m away from the test system, during testing.

A.9.1.3 RFID interrogator and antenna type approval

Both the reader and antenna should be types approved for use on conveyors in Defense Logistics Agency depots, and compliant with the appropriate radio regulations.

The reader shall have either programmable or manually step-adjustable output power; the power should be controllable in 0,25 dB steps or less.

Either a single port, receive and transmit on the same connector, or a dual port, separate receive and transmit, reader can be used; in the case of a dual port system, external attenuation should be placed in the transmit path, and, as noted above, the DUT should be on direct line to the transmit antenna.

Readers having integral antennas may be used.

A.9.1.4 Computer

A computer with appropriate reader driver software is connected to the reader. If the computer has a wireless LAN link, it should be disabled.

A.9.1.5 Antenna set-up

For a 1 m test range, it is suggested that the centre point of the transmit antenna be 1,5 m above the floor.

The transport package under test shall be set up on a plastic or wooden table. It shall be strong enough to support the heaviest transport package (24,6 kg). A moulded plastic or structural foam patio table is a good choice. Preferably, replace any metal fasteners with nylon fasteners.

A.9.1.6 Cabling

The set-up shall include computer and RF coaxial cabling, as required.

A.9.1.7 Facilities set-up

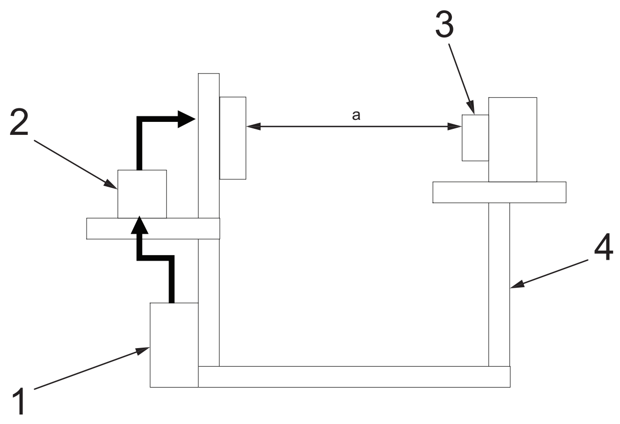
Ideal test environments are specified in ISO/IEC TR 18046:2006, Annex A. While such facilities are necessary for accurate absolute measurements, the simplified method described is much less costly and adequate for the purpose of guiding transponder selection and placement.

A suggested structure is shown below; more details of one implementation of this structure are currently being used for carrying out this test.

The system consists of a suitably rigid frame supporting a reader antenna at 1,5 m above the floor, a shelf mounted behind the antenna for carrying the reader equipment, external attenuator (if used) and computer system. Optionally, a layer of absorber material can be placed behind the reader antenna system to suppress reflections between the operator and computer equipment and device being tested.

A suitable low dielectric constant mount holds the device being tested.

Ensure that there are no active RFID readers within 30 m of the test in any direction, even if there are intervening walls, ceilings or floors. As a general practice, cellular telephones, cordless telephones, cordless earphones or speakers, Bluetooth-connected devices and 802.11 wireless LANs should not be used within that same 30 m radius. This is because certain transponder antennas are resonant at multiple frequencies, causing the chip to be activated by an external RF source rather than the test reader and antenna, therefore resulting in false readings of activation power threshold for the transponder under test.



Key

1 host computer system with suitable software

2 reader system with controllable output power

3 device under test (DUT) on boresight to the transmit path at 1 metre

4 low dielectric constant support

[a] 1 metre test path.

Figure A.5 — Nominal package test facilities layout

A.9.1.8 Equipment set-up

A.9.1.8.1 RF cabling considerations

The RF cabling used to connect the reader to the external attenuator (if used) and reader antenna should be of a good quality and the RF connectors should be tightened to a defined torque in accordance with the manufacturer's recommendations. It is recommended that the cable used be dedicated to the test system and not moved or used for other purposes to avoid inducing variations in test results.

A.9.1.8.2 Reader set-up

Ideally, the test software used should allow direct control of both reader frequency and reader output power.

If this is not available, a number of companies provide utility software for their products that can set the output power.

Ideally, power should be measured using a real time spectrum analyser for each individual channel in the output frequency range of the reader, or a calibration technique, using a calibrated tag, should be used.

If this cannot be done, an average power measurement, with a defined command sequence being executed, integrated over a large enough time to allow the reader to fully exercise all channels, can be used to indicate if the relative performance of a system has altered.

A.9.1.8.3 Empirical testing

Since tyre RFID has a specification read distance of nominally one metre or less, it is possible and convenient to establish an empirical test method and procedure.

The procedure is to find a space no less than 4,57 m by 4,57 m with no sources of interferences in proximity to the centre of the room.

Place the tyre to be tested on a spacer (a wooden table is ideal) approximately 0,61 m to 0,91 m above the ground. Rotate the tyre so that the area to be read is at 12 o'clock with the tyre facing the reader sideways sitting otherwise upright.

Hold or place the reader antenna [fixed or even handheld, for example an Intermec 1555[2)] or a Psion 7535[2)]] perpendicular to the tyre with only clear space between. Only non-metallic rules shall be used for any attempts to measure read distance.

These empirical techniques can provide adequate baseline and directional information.

2) The Intermec 1555 and Psion 7535 are examples of suitable products available commercially. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of these products.

Annex B
(informative)

Table of useful data elements for product life cycle management

Table B.1 — Useful data elements for product life cycle management

Name	Classification	Item	Explanation	Bytes
TID	TID	TID	Tag Identification Number (ISO/IEC 15963)	(32 bits)
UII	UII	EPC	(SGTIN)	(96 bits)
	Product identification code assigned by manufactures (ISO/IEC 15459-4 or ISO/IEC 15459-6)	Issuing agency code		50
		Manufacturer code		
		Product code	Example: CF-L2M8WAXS	
		Serial number	Example: 3AKSB01019	
User memory	Internal code of manufacturers			30
	Hazardous material	Hazardous material flag	Hazardous material flag	1
		Products revision	Revision identification number of products	5
	Data for maintenance (These data are for maintenance person's use at consumer's office or home)	Maintenance contract date	Maintenance contract date between maintenance company and user (YYMMDD)	6
		Parts exchange flag	Flag that indicates some parts were exchanged for new parts	1
		Consumable supply flag	Consumable supply flag	1
		Supplies change date	Date consumable supplies put into service (YYMMDD)	6
		Durable hours	How many hours' supply is viable	1
	Data for recycling (These data are used in a recycle phase and resale)	Recycle application date	Date that recycle application form was made (Date that user delivers recycle products to recycle company or carrier) YYMMDD	6
		Recycle application ID number	Number assigned to recycle product to identify each product	11
		Product classification	Product classification flag (Classification example: desktop PC, laptop) This flag is used to pre-sort the products in recycle operation	2
		Manufacturing date	Manufacturing date YYYYMMDD	8
		Durability period	Durable years from manufacturing date	2
		Resale date	Resale date of lease products (YYMMDD), Product no longer subject to manufacturer's guarantee	6
		Resale dealer	Identification code of resale dealers	10
			Total	152 bytes

Bibliography

[1] ISO 3166-1, *Codes for the representation of names of countries and their subdivisions — Part 1: Country codes*

[2] ISO 4000-1:2007, *Passenger car tyres and rims — Part 1: Tyres (metric series)*

[3] ISO 9000, *Quality management systems — Fundamentals and vocabulary*

[4] ISO 9001, *Quality management systems — Requirements*

[5] ISO 9004, *Quality management systems — Guidelines for performance improvements*

[6] ISO 14001, *Environmental Management Systems — Specifications with guidance for use*

[7] ISO/IEC 15394, *Packaging — Bar code and two-dimensional symbols for shipping, transport and receiving labels*

[8] ISO/IEC 15417, *Information technology — Automatic identification and data capture techniques — Code 128 bar code symbology specification*

[9] ISO/IEC 15459-1, *Information technology — Unique identifiers — Part 1: Unique identifiers for transport units*

[10] ISO/IEC 15459-2, *Information technology — Unique identifiers — Part 2: Registration procedures*

[11] ISO/IEC 15459-3, *Information technology — Unique identifiers — Part 3: Common rules for unique identifiers*

[12] ISO/IEC 15459-4, *Information technology — Unique identifiers — Part 4: Individual items*

[13] ISO/IEC 15459-6, *Information technology — Unique identifiers — Part 6: Unique identifier for product groupings*

[14] ISO 17363, *Supply chain applications of RFID — Freight containers*

[15] ISO 17365, *Supply chain applications of RFID — Transport units*

[16] ISO 17366, *Supply chain applications of RFID — Product packaging*

[17] ISO/IEC 18000-2, *Information technology — Radio frequency identification for item management — Part 2: Parameters for air interface communications below 135 kHz*

[18] ISO/IEC 18000-7, *Information technology — Radio frequency identification for item management — Part 7: Parameters for active air interface communications at 433 MHz*

[19] ISO/IEC TR 18001, *Information technology — Radio frequency identification for item management — Application requirements profiles*

[20] ISO 18185 (all parts), *Freight containers — Electronic seals*

[21] ISO 19011, *Guidelines for quality and/or environmental management systems auditing*

[22] ISO 21849, *Aircraft and space — Industrial data — Product identification and traceability*

[23] ISO/IEC TR 24729-2, *Information technology — Radio frequency identification for item management — Implementation guidelines — Part 2: Recycling and RFID tags*

[24] ISO 28219, *Packaging — Labelling and direct product marking with linear bar code and two-dimensional symbols*

[25] AIAG B-11, *Tire and Wheel Label and RFID Standard*

[26] *AIM Global Standard for the use of the AIM RFID Emblem and index to identify RFID-enabled labels*

[27] ASTM F538-03, *Standard Terminology Relating to the Characteristics and Performance of Tires*

[28] EPC™, *Radio-Frequency Identity Protocols Class-1 Generation — 2 UHF RFID Protocol for Communications at 860 MHz — 960 MHz, Version 1.0.9*

[29] JEDEC MO187-E, *Registration — Plastic Low/Thin/Very Thin Shrink Small Outline Package*

[30] MIL-STD-129, *Military Marking for Shipment and Storage*

[31] MIL-STD-331, Department Of Defense, *Environmental and Performance Tests for Fuze and Fuze Components*

[32] RoHS (2002/95/EC) on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS) and WEEE (2002/96/EC) On waste electrical and electronic equipment directive (WEEE)

ICS 55.020

Price based on 41 pages