TECHNICAL REPORT

# ISO/IEC TR 18001

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# Information technology — Radio frequency identification for item management — Application requirements profiles

*Technologies de l'information — Identification par radiofréquence (RFID) pour la gestion d'objets — Profils de conditions d'application*

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# Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

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

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

In exceptional circumstances, the joint technical committee may propose the publication of a Technical Report of one of the following types:

— type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

— type 3, when the joint technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights.

ISO/IEC TR 18001, which is a Technical Report of type 3, was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 31, *Automatic identification and data capture techniques*.

# Introduction

The Air Interface Standards of ISO/IEC JTC 1/SC 31 are contained in the various Parts of ISO/IEC 18000, under the general title *Information technology — Radio frequency identification for item management*:

*Part 1: Reference architecture and definition of parameters to be standardized*

*Part 2: Parameters for air interface communications below 135 kHz*

*Part 3: Parameters for air interface communications at 13,56 MHz*

*Part 4: Parameters for air interface communications at 2,45 GHz*

*Part 6: Parameters for air interface communications at 860 MHz to 960 MHz*

*Part 7: Parameters for active air interface communications at 433 MHz*

If antenna design, power levels, and the active/passive nature of the implementation design are held equal, each of these technologies have differing performance and operating parameters, including the distance achievable between tag and interrogator.

Specific implementations of the various Parts above may result in different performance and operating parameter trade-offs. Such trade-offs may include the ability to operate as intended under adverse environmental conditions such as noise or interference or other physical environment variations.

To understand the applicability of each frequency or technology it is necessary to understand the applications within which this technology will be used. A profile of the application requirements must be developed.

This Technical Report addresses these Application Requirements Profiles, providing the application detail from which one should be able to assess the applicability of the various technologies.

Seven distinct and separate efforts are included within this Technical Report.

AIM circulated a questionnaire in late 1998 to which 29 responses were received.  These responses serve as the primary basis for this Technical Report.

In early 1999, a United States application standards committee, ANSI MH 10/SC 8, circulated another questionnaire to which 19 responses were received. These responses are included as validation of the AIM survey.

— In 1999, a German University study was released covering RFID in the retail supply chain from manufacturer to transporter to retailer, involving 82 responses. These responses are consolidated in this ARP report.

— In early 2000, Japan’s contribution on RFID tags study.

— In 2000, Sweden’s contribution on 2,45 GHz RFID tags study.

— In 2001, Australia’s contribution on UHF.

— In 2001, AIM’s contribution on UHF.



# Information technology — Radio frequency identification for item management — Application requirements profiles

## 1 Scope

This Technical Report provides:

— The result of three surveys identifying the applications for radio frequency identification (RFID) in an item management environment, and the resultant classification of these applications based on various operational parameters, including operating range and memory size.

— An explanation of some of the issues associated with the parameters of distance and number of tags within an RFID interrogator's field-of-view.

— A means by which classification of RF tags may be accomplished based on the application requirements defined in the survey results.

— Recommendations for areas of standardization to the parent committee (ISO/IEC JTC 1/SC 31/WG 4) based on the results of these surveys.

## 2 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/IEC 19762 (all parts), *Information technology — Automatic identification and data capture (AIDC) techniques — Harmonized vocabulary*[1)]

## 3 Terms and definitions

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

## 4 Symbols and abbreviated terms

| | |
|---|---|
| ARP | Application Requirements Profile |
| EAS | Electronic Article Surveillance |
| FA | Fixed Asset |
| RFID | Radio Frequency Identification |
| WORM | Write Once Read Many |



1) To be published.

## 5 ARP survey and questionnaire

In the preparation of this Technical Report three surveys were conducted: one by AIM, one by the U.S. Accredited Standards Committee (ASC) ANSI MH 10/SC 8, and one by Dortmund University, Germany.

### 5.1 AIM Survey

The AIM Survey was circulated through ISO/IEC JTC 1/SC 31 national bodies asking potential respondents to access the survey form at the web site: http://www.rfid.org. The survey that was circulated (SC 31/WG 4 N0046) is attached as Annex A to this Technical Report.

To define the application requirements for standardization, the questionnaire that was circulated by AIM consisted of three categories:



#### 5.1.1 Application selection

a. Baggage Handling (includes airline)

b. Factory Automation

c. Warehouse Logistics / Inventory Control

d. Distribution

e. Security / Article Surveillance

f. Asset Tracking

g. Container Control

h. Pallet Control

i. Door to door delivery services

j. Others

#### 5.1.2 Tag characteristics

a. Are tags re-usable or disposable?

b. What is the tag's memory size?

c. Is there a requirement for a unique tag ID?

d. Is the memory requirement read only, write once read many, or read and write?

e. Is there a requirement for physical size or thickness?

#### 5.1.3 Application characteristics

a. Does the application employ a single antenna or multiple antennae?

b. Does the application use hand-held or fixed position reader / writer / antenna?

c. What are the required maximum read and write distances?

d. What is the maximum speed in front of reader / writer?

e. What amount data is transferred during read and write operations?

f. What is the minimum separation distance between tags?

g. Does the packaging or container have metallic materials?

h. Is the tag orientation controlled or not controlled?

i. Will one or multiple tags be in the field of view at one time; is an anti-collision protocol required?

j. Does the application require the encryption, authentication, or another security system?

k. What are the environmental requirements, e.g., temperature, vibration, water proof, chemical.

The results of the AIM Survey are included as Annex A.

### 5.2 ANSI MH 10/SC 8

The ANSI MH 10/SC 8 Survey was circulated to ANSI MH 10 members asking potential respondents to complete the survey and returning it to the administrator of ANSI MH 10/SC 8. The survey that was circulated is attached as Annex B to this Technical Report. Annex D provides a summary of the responses to the ANSI MH 10/SC 8 Survey.

### 5.3 Dortmund University

The Dortmund University Survey was circulated to a select group of German companies involved in the retail trade as either retail goods manufacturers, transporters, or retailers. Annex F provides a summary of the responses to the Dortmund University Survey.



## 6 ARP survey results and its analysis

From the circulation of the AIM ARP Survey, 29 responses were received from 8 countries. These results are shown in Annex C. Figure 1 shows an application table relating memory size and operating range based on the response Questionnaire. Eight key items were selected from 27 items in the Questionnaire (N0046).

The 8 items are

a. Application,

b. Memory size,

c. Read/Write,

d. Reuse/Disposal,

e. Tag Frequency,

f. Operating Range,

g. Multiple Tag Read (Anti-collision), and

h. Encryption.

### 6.1 Classification of application

For the RFID tag system, tag memory size and operating range are key factors. Figure 1 shows the summary of the applications assembled by read range and tag memory requirements. Figure 2 shows the classification of the two parameters in 3 categories.

## 6.2 Operating range

The operating ranges are different in each application, ranging from 0.1 m and up to 100 m. See Annex A and Tables 1 and 2. Even in applications named identically, it may be difficult to find identical operating ranges.

The operating range is a key factor for users when implementing RFID systems. For users, it is helpful that the operating range is classified in three ranges, e.g., short range, medium range and long range.

There are different approaches to propose the operating ranges. One aspect is the take into account the desired compatibility with the application requirements of contactless IC cards, the ARP group proposed the ranges within ISO/IEC 14443 and ISO/IEC 15693. The ARP Rapporteur Group has therefore defined operating ranges as follows.

**Table 1 — Operating Range Classifications**

| | | |
|---|---|---|
| | **short range** | ≤ 0.1 m |
| 0.1 m ≤ | **medium range** | ≤ 0.7 m |
| 0.7 m ≤ | **long range** | |

**Table 2 — Typical Operating Range Requirements by Application**

| | | **< 10 cm** | | **10 – 70 cm** | | **70 cm – 5 m** | |
|---|---|---|---|---|---|---|---|
| | 11 | Pallet ID (FA) | 3 | Asset Tracking | 25 | Vehicle Management | |
| | | | | | 30 | Pallet Control | |
| **1 kbyte** | | | | | | | |
| | | | 23 | FA Auto Warehouse | 2 | Toll Collection | |
| | | | 24 | FA Logistics Pallet | 4 | Warehouse/Logistics | * |
| | | | | | 8 | Pallet Control | * |
| | | | | | 10 | Asset Tracking | * |
| | | | | | 16 | Gasoline | |
| Memory Size | | | | | 21 | Waste Management | |
| | | | | | 22 | Inventory Control | |
| | | | | | 5 | Log Tracking | |
| | | | | | 6 | Log Tracking | |
| | | | | | | MR TAG | |
| **128 byte** | | | | | | | |
| | | | 7 | Access Control | 9 | Access & Tracking | |
| | | | 14 | Library | 12 | Baggage Handling | * |
| | | | 26 | Pallet Control | 13 | Baggage Handling | * |
| | | | | | 15 | Waste Management | * |
| | | | | | 18 | Video Tape Rental | * |
| | | | | | 27 | Container Control | * |
| | | | | | 28 | Luggage | * |
| | | | | | 29 | Asset Tracking | |
| | | | | | 31 | EAS | |

Note – * is the target application. The numbers of Figure 1 correspond to the numbers in the table of Annex C.



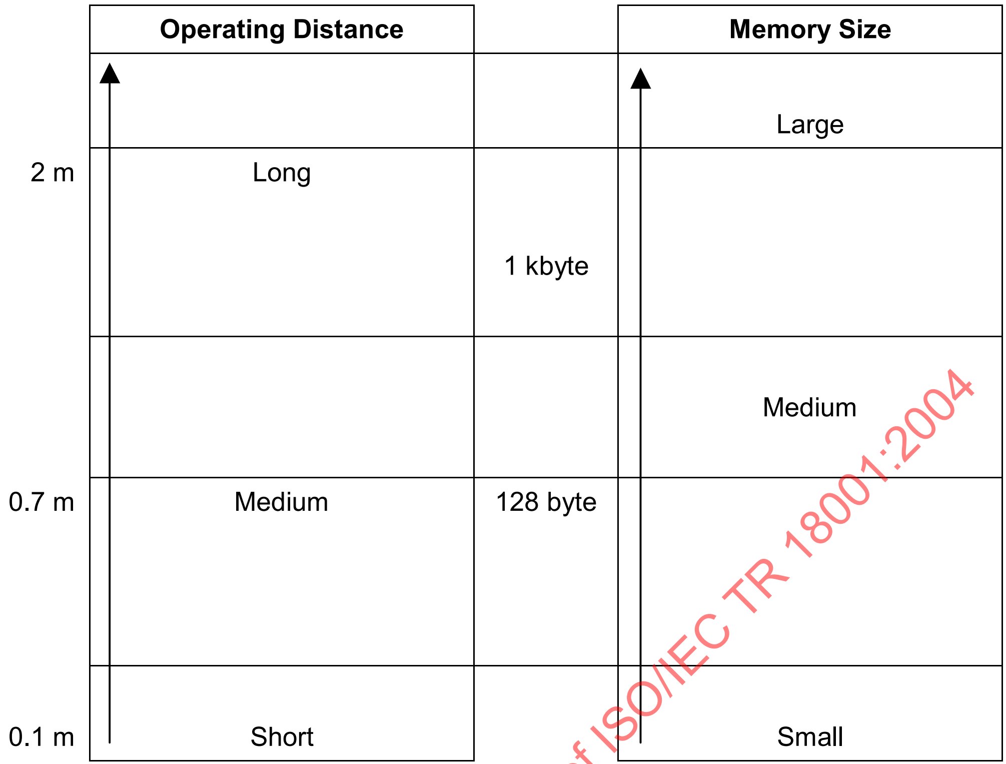



**Figure 1 – Definition of Operation Distance and Memory Size**

## 6.3 Memory size

The memory size of RF tags (see Annex A and Tables 2 and 3) differs in each application. They extend from 8 byte to 128 kbyte. This report provides classification to three sizes: small, medium, and large. They are defined as follows.

**Table 3 — Classification of Memory Size**

| | | |
|---|---|---|
| | **small size** | ≤ 128 byte |
| 128 byte ≤ | **medium size** | ≤ 1 kbyte |
| 1 kbyte ≤ | **large size** | |

## 6.4 Initial work for the first target application

Based on the responses received, the ARP Rapporteur Group has determined that the initial application focus work should be based on the pallet and /or a container (crate, returnable plastic container etc), and not the contents of containers.

The work should concentrate in two specific areas of the matrix (Operating Range – Memory size – Application) in Table 2.

### 6.4.1 Memory size < 128 byte

Operating range > 70 cm
WORM
Application:

- Waste (domestic),
- Baggage Handling
- Books / Videos (libraries)
- Container Control

### 6.4.2 128 byte < memory size < 1 kbyte

Operating range > 70 cm
Read / Write
Application:

- Warehouse Logistics.
- Pallet Control (returnable plastic container)
- Asset tracking

## 7 Technical subjects for standardization (Common items for applications)

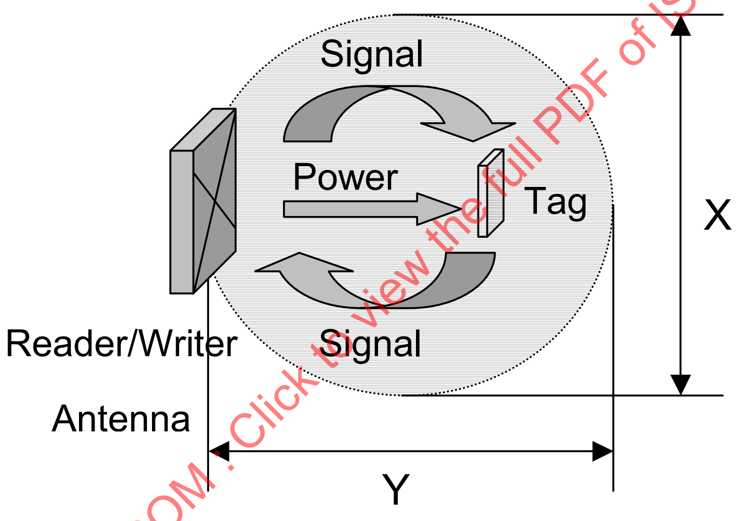



**Figure 2 – The Principal of RF Tag Communications**

### 7.1 The variation of operating range

The reader/writer antenna transmits power and signals to the tags by propagated electromagnetic waves or inductive coupling, and tags emit the response signal to the reader/writer antenna. At inductive frequencies, the operating range (X, Y, Z directions) is affected to a greater extent by the antenna size of the reader/writer and the antenna size of the tag, than are systems operating at UHF or microwave frequencies.

The operating range when writing is less than reading due to current dissipation. The tags with battery cell have a greater operating range than tags without a battery cell.

In general, an extended operating range requires a significantly larger antenna for both the reader/writer and the tag. The interference level in the environment can also have a significant effect on operating range.

Further, there are many factors that affect the operating range including tag orientation, overlap with other tags environmental noise, absorption, reflection, shadowing and the effects caused by the presence of metallic material etc.

#### 7.1.1 Influence of tag orientation

Contrasted to bar codes systems, RFID systems have an advantage of a wider operating range. Like bar codes, the RFID tags can be attached to various surfaces, e.g., the side of the container.

When the orientation (polarization) of tag is changed, the operating range is changed. For example, the 90-degree change of orientation may cause the 20-100% deterioration of the operating range. These are shown in Figure 3.

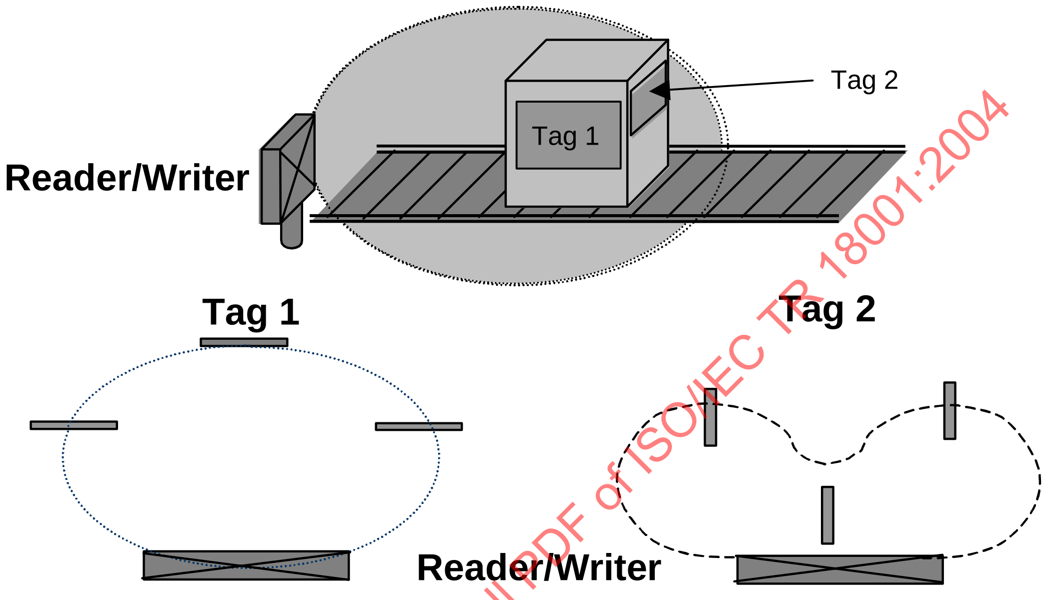



**Figure 3 – The Influence of Tag Orientation**

Tags can be read from one side or from both sides, where the former type gives better reading range at a certain output power. If the tag cannot be oriented during the reading process, dual-sided reading adds value to the application.

The tag can be freely oriented around the interrogator's radiation axis if circular polarization is used in the system. It is possible to read the tag horizontally as well as vertically, without consideration of how the interrogators are installed.

The tag can be freely oriented in relation to the interrogator if circular polarization is used and if the tag is designed for omni-directional reading. This configuration is of value if the objects are completely unaligned, such as various items on a conveyor belt or where people use the tag for personal access and find it difficult to orient the tag in a special way.

#### 7.1.2 Influence of overlap of inductive tags

When the RFID tags are attached to the smaller size items, such as books or letters, the distance between tag to tag may become very short. For example, at inductive frequencies when the two tags are overlapped at 50% of the tag size, the operating range may be reduced by about 30% compared to the case of one tag. The degree of reduction is different in each tag system, particularly for different carrier frequencies and tag size. The influence is caused by the variation of resonance frequency $f_0$ that expressed in formula below,

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$



$L$ [H]:Inductance of tag antenna coil

$C$ [F]: Capacity of tag's tuning capacitor

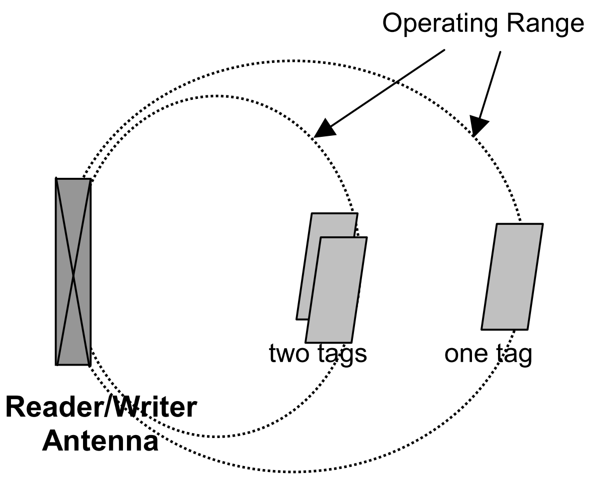


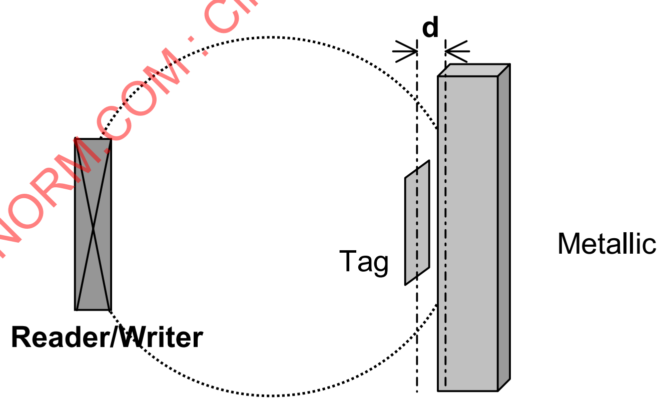

**Figure 4 – The Influence of Tag Orientation**

### 7.1.3 Influence of metallic materials

In the RFID tags system, if the tags are attached to the surface of metallic material, particularly ferrous material, the operating range is affected and in worst case tags cannot be accessed by reader/writer.

The presence of liquids, which include ions in solution, affects operating range as well as metal. The influence of liquid presence increases with the frequency.

The minimum distance between tag and metallic material should be required to ensure the access of tag.




Note: "d" is the gap between tag and the metallic material

**Figure 5 – The Influence of Metallic Material**

## 7.2 Determining the access time of RFID tags

In RFID systems, the reader/writer antenna may need to access moving tags. The communication time "TC" between reader/writer and tags can be estimated, not considering the internal processing time of both the reader/writer and tag, as follows,

$$Tc = \frac{Dc}{Dr} \times A_{CN}$$

The tag moves distance "L" at the velocity Vtag, in the operating range of the reader/writer. TR is the time that the tag remains within the operating range of the reader/writer antenna field, would be estimated:

$$T_R = \frac{L}{Vtag}$$

For successful communications,

$T_R$ = (TC + Tdct) is required

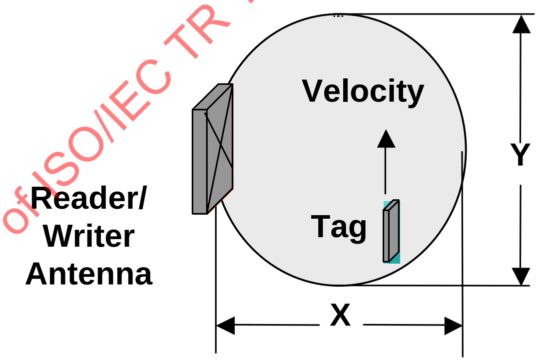



**Figure 6 – Access Time Variation**

If multiple tag access is required, and the number of tags is " Ntag", then

$$T_R > (T_C + T_{dct}) \times N_{tag}$$

| | |
|---|---|
| TR (sec): | time within the operating range |
| TC (sec): | communication time between reader/writer and tag |
| Dr (bps): | data transmission rate where reading rate = writing rate |
| DC (bit): | data capacity of communications |
| ACN (times): | average communication time between reader/writer and tag |
| Vtag (m/sec): | velocity of tag |
| L (m): | distance the tag moves through the operating range |
| $N_{tag}$: | number of tags |
| Tdct (sec): | maximum time to detect a tag |

The access time of each tag is a function of the capacity of data for communication. The total access time for all tags within the operating range is a function of the number of tags within the operating range and the data capacity of communications.

To design a sorting system using RFID tags, the following conditions should be considered:

— Number of tags within the operating range.

— Access time of each tag.

— Operating range of reader/writer antenna and orientation insensitive design of tags and-or reader/writer antenna.

— Velocity of the tags (equal to the velocity of the conveyor).

Since these conditions can vary in individual applications, those integrating the RFID system should ensure that the end users understand these the variations of RF tag access time.

### 7.3 Detecting and reading numerous tags from significant distances

Anti-collision devices work efficiently – meaning a low probability of missing detection and time of identification compatible with present duration of items in reading field – when the number of items remains low enough. In other words, multi-items identification as defined in Normalization works is well fitted to sequential needs (simultaneous shift of few items in detection field).

Another approach of multi-items identification was extended to solve problems generated by simultaneous presence of very numerous items forming a large volume. In order to sharpen the application profile, identification of a hundred of any sized items, located in hazardous positions, forming a few cubic meter volume: as example, a pallet filled up with cardboard boxes, bottles, non-metallic supply caddies, postal bags, hostel-linen bags and so on.

The main technologic solutions elected are directly issued from the application profile's definition.

First, about frequency carrier selection.

Many physical features must be taken in account:

— Size of identification volume.

— Radio Frequency Noise regulations.

— Antennas coupling, first within reader and tags, and then within close tags.

— Physical characteristics of items to be identified: liquids, solids, diamagnetic metallic conductors and so on.

— Technological build up feasibility.

The above may determine the minimum and maximum values for magnetic induction within reader and tags and to select low frequency carriers (below 135 kHz) rather than High Frequencies (13,56 MHz).

Secondly, the completely random positioning of items to be identified enforces specific technical issues:

— Tags may be affixed to items and positioned in any angle to the reader’s antenna axis. So, in order to get acceptable magnetic coupling, reader antennas are multi-axes antennas.

— Tags may be very close to each other, like stamps on letters in postal bags, stacked, like casino chips, head to tail, and so on. Thus, magnetic coupling within tag can induce fading in a reader's receptor, and mutual inductance between two close tags can rise to double, making uncertain a good tuning of tags antennas on back frequency carrier.



These observations provide two important technological features

First, tags do not respond to the resonance frequency of their antenna coils and return signals will not realize any Q-Factor benefit. Second, signals emitted by tags may be fully synchronized and carefully set in the same phase to prevent fading.

Communication between reader and tags is able to become more simplified by above design.

The reader sends requests to tags and all tags are answering in a manner in which each tag's response is added to the response of the tag population.

So no complex anti-collision loops are needed to determine simultaneous tag responses, and no anti-collision algorithms are needed, saving long duration multiple request and response communication between reader and tags. The saving in the duration of the process increases as the number of tags increases.

In order to get the unique identification of each tag, a simple enumeration method is used, ensuring total reliability. The communication algorithms determines, element by element, the tag's UID by simultaneous interrogation of all tags present in active volume. The algorithms tests in succession the possible values (for example 0 to 9 if the elements are numbered as decimal values) of the first element of the UID with a predetermined slot of time, then the same operation is repeated for all subsequent elements of the UID' within predetermined slots of time. When the UID of tags have similarities like common prefix or sequential code numbers, the system is even more efficient because of the optimization of the algorithm.

The system described above ensures reliable identification of numerous items arriving simultaneously, like batches of goods. Identification time duration is a function of items number and is an adaptable parameter depending on family application requested.

# 8 2,45 GHz RFID tags

## 8.1 Variation of operating range

In addition to range, a most important standardization criterion is speed. Both are influenced by tag orientation, overlap of tags, metallic materials, amount, and direction of data transfer (i.e. if the system is R/O or R/W), multiple interrogators near each other and the acceptable substitution error level. Parameters of indirect concern are data security, emission considerations and tag cost/disposal.

### 8.1.1 Influence of tag orientation

When large objects are to be conveniently identified, the long reading range of 2,45 GHz systems also needs a directed field of view in order to avoid unintentional reading of "wrong" objects, such as in adjacent driving lanes. Microwave antennas can provide this directionality.

The tags can be readable from one side or from both sides, where the former type gives better reading range at a certain output power. If the tag cannot be fixed to an object, or if the objects are not oriented during the reading process, dual-sided reading adds value to the application.

The tag can be freely oriented around the interrogator's radiation axis if circular polarization is used in the system. It becomes possible to read the tag horizontally as well as vertically, without consideration of how the interrogators are installed. This is of great interest in most applications.

The tag can be completely freely oriented in relation to the interrogator if circular polarization is used and if the tag is designed for omni-directional reading. This configuration is of value if the objects are completely unaligned, such as various items on a conveyor belt or where people use the tag for personal access and find it difficult to orient the tag in a special way.



#### 8.1.2 Influence of overlap of tags

2,45 GHz RFID systems, usually used for large objects, can identify these safely also in a group. However, the bigger the object, the fewer to identify at a time since only a limited number of big objects can be roomed in the field of view. At 2,45 GHz, this number is typically < 5 and such requirements are typically found when loading a transport vehicle or moving a container through a portal.

#### 8.1.3 Influence of metallic materials

Properly designed, 2,45 GHz tags can be placed, without range degradation, directly on a metal object such as a container, a railcar or a truck. Some tags however use dipole antennas that are short-circuited by the metal and need spacing from the metal to be readable at full distance.

2,45 GHz penetrates most non-metallic materials, e.g. a car window, without significant attenuation. Thin, sun-protecting metal layers used in some windshields can have considerable range-reduction effect, but such windows are usually only used in bus windshields (not side-windows) and in some vans. It is unlikely that metal layer side-windows will be used extensively, since they are expensive and also block the function of mobile phones.

Panels are seldom used in front of the interrogator, if it is not to be a hidden installation such as for corporate asset protection from employee theft. Here the interrogator can be placed out of sight above the ceiling and oriented downwards. It reads through the ceiling, that usually does not reduce the range (if not in metal). It is not recommended to locate the interrogator behind concrete walls, e.g. for garage access, since this will have significant range reduction effect.

#### 8.1.4 Influence of R/W vs. R/O

2,45 GHz systems can without considerable cost increase be designed to allow tag programming via the microwaves. This allows for convenient and safe formatting of the tags (e.g. memory size, multiplicity, and data speed) and for programming with data in decentralized, stand-alone, systems.

The theoretical writing distance at 100 mW EIRP is in the order of five meters for active tags. Commercially available passive tags demonstrate a writing distance of between 1 and 2 meters at 4 W EIRP. The tag memory size to use depends on the application, but the trend over the five years has been towards smaller memories. It makes the tags cheaper and Internet and other networks have made centralized data easy to manage.

A long writing distance is not always good, and many applications write the tag only once or a few times during its life. Writing with microwaves is however very convenient when issuing tags “en masse”, since no galvanic connecting is needed. Hence, systems with write distances <0,5 m become increasingly popular. In long-distance writing systems, it must be secured that tags are not unintentionally written since this will lead to system confusion.

Regardless of R/W or R/O, both systems need a unique and non-alterable code in the tag for increased security. The distribution, use and maintenance of tags are then much easier.

### 8.2 Determining the access time of RFID tags

#### 8.2.1 General

The nature of microwaves allows for high passage speeds.

#### 8.2.2 Influence of multiple interrogator operation

Congestion reduces the communication speed because of message collisions. 2,45 GHz RFID installations sometimes comprise up to 100 interrogators inside a radius where interference can occur if not protective measures, such as channel selection are taken. Reader density varies between the applications and can be as little as 2 at the entrance/exit of a remote car park, while in most commercial garages, automatic cargo handling terminals and automatic factory lines up to 25 interrogators or more are installed inside the interference zone.

A consequence is that a standardized system should be able to roam at least 25 channels in a frequency band that is allocated by the frequency authorities. UHF tag systems use low data speed in the microwave link and typically need a channel spacing of only 300 kHz or less, implying that an 8 MHz band would allow for 26 channels. In most cases, this would be enough.

#### 8.2.3 Influence of substitution errors

The passage speed is limited by safety requirements; a train application might require a substitution error likelihood in the region of $10^{-9}$, and with the relatively high bit rate available in all 2,45 GHz systems there is no reason to lower this requirement in other applications. Using 32 bit CRC is one method to meet said requirement.

### 8.3 Indirect parameters

#### 8.3.1 Security

For most applications, adequate security can be achieved by factory coding of the tag, i.e. using tags where an identifier is included in each message from the tag and where the identifier is unique to the tag and non-alterable by the user. If One Time Programming (OTP) tags are used, it must be ensured that unauthorized access to programming equipment and virgin tags is impossible. A higher security is achieved if the tags are programmed already at chip manufacture, since it is hard to duplicate the chips. In both cases, a standard may imply that a numbering management organization is established.

If the tag makes use of both a fixed and writeable memory, it can be encrypted e.g. according to DES to protect against unauthorized viewing and duplication of the tag data. For easy key distribution, an asymmetrical encryption algorithm such as RSA can be used. Key distribution, e.g. with PGP, secures confidentiality of communication, reliability of source of information and integrity of messages and has become widely used over the Internet for transfer of protected information.

#### 8.3.2 Emission

The emission from a 2,45 GHz system (that is not beam powered) is orders of magnitude below what is permitted from health aspects. To simplify, the emission is only about 1/10 of that from a mobile phone, permitted to use with its antenna close to the human body.

The emission from beam powered 2,45 GHz systems, e.g. in the 4 W range, must be regulated to avoid that other services, including RFID, are harmed. Technically, there is no need for signal modulation of the powering signal, e.g. to stay in a 100 kHz spectrum down to noise. Many readers, close to each other, without interference, can use the same powering channel. This solution significantly frees up the spectrum for RFID communication.

Operating with many channels, narrow-band 2,45 GHz systems of the same make are tolerant to electrical interference from one another. Thanks to synthesizer technology, different channels can be electronically selected and the interference to/from adjacent interrogators of the same make is zero.

Spread-spectrum RFID have a merit in that that there is less need to plan the channels, but must take interference between interrogators into account. For systems with fast objects (such as a trains) or factory lines (such as in automotive with large tag data) no “second chance” to identify exists. This also goes for systems where multiple tags (such as with people rushing out of a mine under fire) are to be read and no margin exists for slowing-down interference from adjacent interrogators that may cause failed ID. Such interference may also be harmful for RFID systems within the interference zone, i.e. typically 0,1 to 1 km away (at power levels below 100 mW EIRP).

Awake tags with low data speed and close-to-carrier modulation give very little interference to 2,45 GHz tags that have their base band at a higher distance from the carrier. When formatted for multiple tag reading, the tag-to-tag interference from such tags is virtually eliminated, since most of the time they do not modulate at all. Mass installations verify this.

Wake-up tag systems are more sensitive to interference than Awake tag systems because they make use of both forward link and a return link and need a protocol that slows the system down. Unintentional waking, e.g. by other RFID systems, surveillance radars or microwave ovens, can quickly drain the batteries. If awake, the wide backscatter spectrum of high data-speed tags might interfere with other tags; otherwise they are harmless in this respect.

Because of their expected use “en masse”, certain RFDC systems - like Bluetooth - can be an interference threat to 2,45 GHz RFID. Interference tests and theoretical studies have verified that interference exists, but also that many RFID applications have enough functional margins and are unaffected in practice. Interference protection methods are also under development.

An area of concern is applications where a glitch from a Bluetooth device blocks out an ID message and no “second chance” exists, such as for fast trains. This potential problem would be solved if a narrow (1 MHz or so) protected RFID band could be arranged for.

Interference from other 2,45 GHz systems is well known. A widespread source is microwave ovens, but, although there can be a problem with waking up “wake-up” tags and battery depletion; this source is usually no problem for the function. Thanks to the health regulations, the leakage from microwave ovens has been gradually reduced over the years. High power 2,45 GHz ovens, e.g. for industrial drying, are sometimes worse than household ovens. ICNIRP, CENELEC ENV 50166-2, NRBP/UK, and IEEE C95.1 address the safety issues associated with various frequencies at various power levels.

### 8.3.3 Lithium cells

Lithium cells have the highest energy content per gram among batteries and a two gram cell typically lasts for 10 years taking into consideration the number of times data is read from or written to the tag. They also have low cost (50 cent or less) thanks to mass production (a typical lithium coin cell factory can produce in 100 million cells per annum). Lithium cells can normally be freely disposed of (no heavy metals, no mercury or other harmful chemicals), except for certain types that are designed for special, e.g. military, applications.

## 9 400 MHz to 1000 MHz UHF RFID-systems

### 9.1 Introduction

The operating range of a UHF tag system influenced by many factors:

— how range is defined in relation to interrogator positioning;

— interrogated radiated power;

— how such power is specified;

— the sharpness of the tuning of the tags;

— the frequency of the interrogator carrier versus the tag center frequency;

— the type of detector specified within the regulations;

— whether the regulations specify EIRP or antenna power and antenna gain;

— the tag antenna size,

— the tag environment, in three respects:



— the possible interposition of lossy materials,

— beneficial reflections for metallic surfaces, and

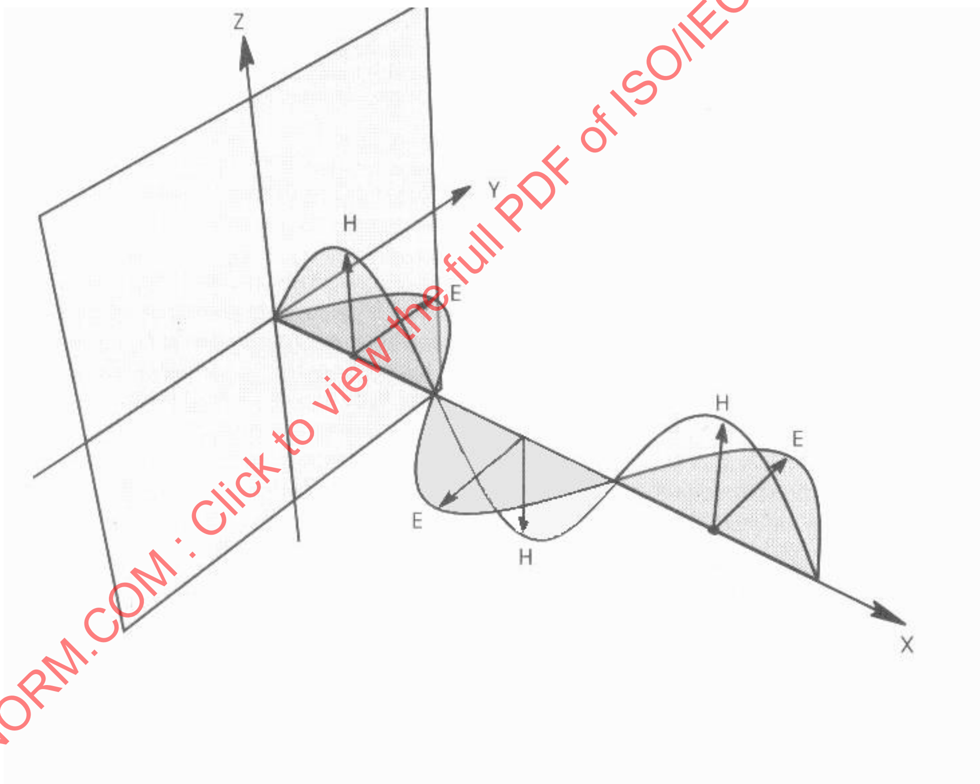
— metallic screening and tag orientation.

These matters are dealt with in the paragraphs below.

### 9.2 Operating principle

Radio Frequency Identification systems operating in the UHF frequency range make use of conventional electromagnetic wave propagation to communicate their data and commands, and in the case of battery-less tags also to power the RFID transponders. This is in contrast to low frequency RFID systems, which operate on the induction principle, much like a transformer.

In EM field systems, the interrogator (or reader) transmits an EM wave, which propagates outwards with a spherical wave front. Transponders placed within the field are immersed in this propagating wave and collect some of the energy as it passes. The amount of energy available at any particular point is related to the distance from the transmitter and may be expressed as 1/d2 where d is the distance from the transmitter.






Note: The electric “E” component is at right angles to, but in phase with the magnetic (H) component

**Figure 7– Electromagnetic wave propagation.**

EM energy propagates through the atmosphere or any other material by exciting electrons, which in turn reradiate energy at the same frequency which then excite nearby electrons which reradiate and so on.

Induction systems rely on the magnetic coupling between the interrogator and transponder and therefore the field strength of the transmitted signal drops at between 1/d3 and 1/d4 depending on the orientation of the tag to the reader transmitter loop.

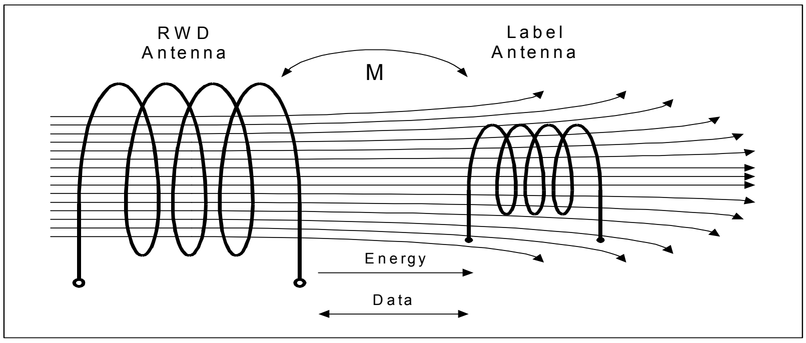



**Figure 8 – Basic operating principle, induction technology (drawing by 1356 FF)**

Passive tags need energy to power them, this energy is realized from the reader's transmit field.

Power density is not influenced by frequency, however, received power is dependent on antenna size that in turn is dependent on frequency.

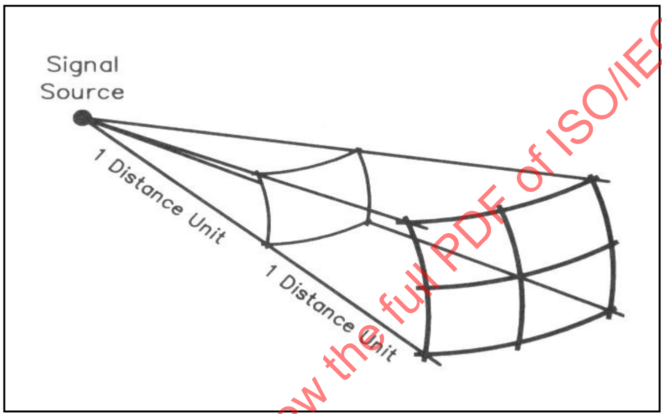



**Figure 9**

The amount of energy collected is a function of the aperture of the receiving antenna, which in simple terms is related to the wavelength of the received signal of a propogative technology.

Consider for a moment a simple wave-receiving antenna that is 0,5 meters long at 300 MHz and 0,25 meters at 600 MHz. The electrically active area around the antenna is roughly an ellipse in shape

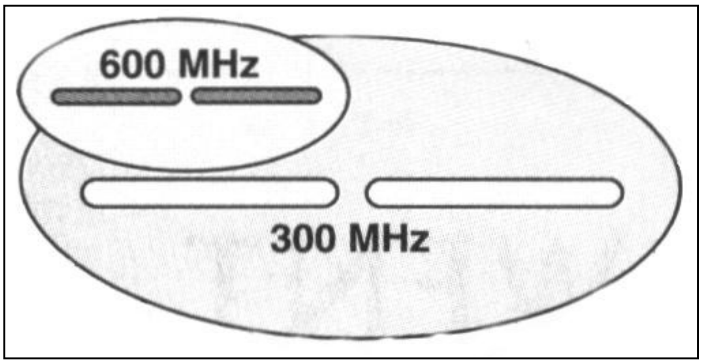



**Figure 10**

The area enclosed by the ellipse at 300 MHz is approximately 4 times the area enclosed at 600 MHz. Therefore, at 300 MHz the effective energy collection area is four times that at 600 MHz.



The receiving antenna may be made physically smaller and still have the same aperture, but there are trade-offs to reducing the antenna size, such as reduced bandwidth and critical tuning. In practice, operating range is dependent on the radiated power of the reader, the operating frequency and the size of the tag antenna.

In order for passive RFID technology to be properly exploited, the reader must produce an adequate energy field to power tags at a usable distance. Under current radio regulations, enforced in much of Europe, radiated power is limited to 500 mW ERP, which translates to a read range of approximately 0.7 meters at 870 MHz. In the USA and Canada and some other countries, license free regulations permit a radiated power of 4-watts ERP that will yield a read range in the order of 2 meters. An RF output of 30-watts ERP under USA site license conditions will yield a read range in the order of 5.5 meters.

## 9.3 Typical tags

### 9.3.1 Regulations

Until recently, frequencies in the UHF range were scarce almost everywhere except in North America. Australia and South Africa permit RFID and Europe’s ERO DSI III working group has recommended the allocation of additional bands for RFID. These recommendations have been based on the USA model of a common shared band with FHSS as the basis for sharing and frequency re-use, including adaptive frequency agile systems. The shift to UHF reduces the spectrum requirements as the propagation characteristics at 900 MHz increases the ability to re-use frequencies.

#### 9.3.1.1 Interrogator radiated power

In various jurisdictions, interrogator radiated powers varying in the range of 4 watts down to half a watt may be allowed. Power levels lower than may not be practical or of interest.

The true effectiveness of such power is strongly influenced by the structure of the regulations as described in the below two sections.

In a small number of jurisdictions an average detector is allowed to be used, with the result that the effective power available is up to a hundred times greater than that which appears within the regulation.

From another regulatory aspect, in some situations antenna power and antenna gain are specified, and in others equivalent isotropic radiated power is specified. For regulations, which appear to specify powers, there is approximately fourfold increase in the power density available to a tag when power is specified in terms of antenna gain and terminal power instead of through an equivalent isotropic radiated power specification.

#### 9.3.1.2 Detector specification

In one USA regulation for the 900 MHz band, an equivalent isotropic radiated power of 500 milliwatts with an average detector is specified. When an interrogator system is operated in a pulse-energized mode under such a regulation, the properties of the average detector are such that the interrogator peak power can be increased by an amount up to 20 dB above that appearing in the regulations. 900 MHz tags operating under these regulations can have ranges of many meters.

#### 9.3.1.3 Antenna power versus EIRP regulations

When interrogator power is limited by an equivalent isotropic radiated power regulation, the requirement is that compliance measurements must be carried out in the presence of a ground plane. The ground plane causes reflections, and the approximate doubling of the measured signal amplitude in certain conditions. The regulations are required to be enforced at points at which such doubling takes place. The result is that the interrogator power must be reduced by a factor of four below that which would be allowed if the ground plane were not present.

When, however, the interrogator power is limited by a terminal power and antenna gain regulation, the measurement is supposed to take place in the absence of a ground plane and this enforced reduction of interrogator power does not occur.

#### 9.3.1.4 Power appearing in the regulations

Looking at regulations throughout the world, it may be observed that in some jurisdictions an antenna power of 4 watts with an antenna gain of 6 dBi is allowed. In other jurisdictions an equivalent isotropic radiated power of 1 watt enforced in the presence of a ground plan is required.

If one compares the effectiveness of those two systems just described in might be concluded that the former permits 16 times as much power to be radiated as the latter.

Since the range of a system in the far field region is proportional to the square root of the interrogator power, we would expect a four-fold superiority in range for the former system as compared with the latter.

#### 9.3.1.5 Human safety (to protect people)

The safe limits of human exposure are a function of conducted power, antenna gain, exposure time and body mass. For most recommendations, the exposure is averaged over a 6-minute period at pulse duration time not exceeding 30 µS.

**Table 4 — Human Exposure Limits**

| Organization | Power Density W/m² | Averaging time In minutes | Peak Power Energy Density |
|---|---|---|---|
| ICNIRP | 10 | 6 | 20mJ/m²<<30µs pulse |
| CENELEC ENV 50166-2 | 10 | 6 | 20mJ/m²<<30µs pulse |
| NRBP/UK | 100 | 6 | 10mJ/m²<<30µs pulse |



Calculation of protection distance.

Power density is a function of the conducted power into the antenna and the exposure area at a distance from the antenna.

As an example it can be calculated that for a worst case scenario with:

1. A conducted power of 1,25 W,
2. An effective duty cycle of 10%,
3. An antenna gain of 6 dB, and
4. An exposure limits of 10 W/m², or for a radiated power of 6 watts, that the protection distance would be 6,2 cm.

This distance would only be of relevance if a person's head or trunk was 6,2 cm away from the antenna for a continuous 6-minute period, RF interrogations are made during the full 6 minutes and the duty cycle is averaged over 6 minutes. In the event that the exposure time, or the duty cycle is less, the resultant required protection distance would be less.

However, the interrogation rate is dependent of the number of tags in the read area. A person present in this area would absorb RF energy in tissue. This, due to the reader not seeing the tags, will result in a reduced interrogation rate. A lower interrogation rate will reduce the duty cycle with a major reduction in the required protection distance. Conversely, for a higher duty cycle rate, the required protection distance would be increased.

It can therefore be seen that the required protection factor varies with radiated power and the duty cycle, which in turn is a function of the number of tags being interrogated.

#### 9.3.1.6 Radiation (to ensure proper use of the spectrum)

The table below shows the frequencies available at the time of this report or proposed for UHF RFID.

**Table 5 — Regional Availability of Spectrum and Permitted Power Output**

| Band | Region | Max. Power | Duty Cycle |
|---|---|---|---|
| 433,05-434,79 MHz | Europe | 10 mW ERP | <10% |
| 433,05-434,79 MHz | Europe | 1 mW ERP (-13 dBm/10 kHz) | Up to 100% |
| 425-435 MHz | USA | 11 mV/M (110 peak) @ 3 M | 120 seconds on/10 seconds off |
| 868,00-868,60 MHz | Europe | 25 mW ERP | <1.0% |
| 869,30-869,40 MHz | Europe | 10 mW ERP | No Restriction |
| 869,40-869,65 MHz | Europe | 500 mW ERP | <10% |
| 869,70-870,00 MHz | Europe | 5 mW ERP | Up to 100% |
| 902-928 MHz | USA/Canada | 50mV/m at 3 meters (Single freq. Systems) | 50mV/m at 3 meters (Single freq. Systems) |
| 902-928 MHz | USA/Canada | 4W using spread spectrum | 4W using spread spectrum |
| 902-928 MHz | USA/Canada | 30W FCC Part 90, LMS (3W conducted) | 30W FCC Part 90, LMS (3W conducted) |
| 918-926 MHz | Australia | 1W all new equipment designs | 1W all new equipment designs |
| 915,3-915,6 MHz | South Africa | 15W (5 Watt conducted) | 15W (5 Watt conducted) |
| 915-921 MHz | Europe | 4 Watts FHSS (proposed by ETSI for Europe | 4 Watts FHSS (proposed by ETSI for Europe |
| 2446-2454 MHz | Europe | 500 mW EIRP (inside/outside) | Up to 100% |
| 2446-2454 MHz | Europe | 4 W EIRP (inside only) | <15% |
| 2400-2483,5 MHz | USA/Canada | 4 W EIRP (FHSS) | 50 channels: 0.4 s/20 s/λ |
| 2400-2483,5 MHz | USA/Canada | 50mV/m at 3 meters (Single freq. Systems) | 50mV/m at 3 meters (Single freq. Systems) |

### 9.3.2 Performance

Most UHF RFID (300 MHz – 3000 MHz) systems operate with what are known as electrically small antennas. Such antennas are efficient at extracting the available source power from the surrounding electromagnetic field only over a narrow bandwidth determined by the antenna quality factor, which is inescapably linked to antenna size.

It is also true that the proper utilization of the extracted power is, to a significant extent, in the servicing the reactive power required in the junction capacitance of a diode of the rectification process required in a passive tag. This requirement also tends to reduce the width of the frequency band at which the tag operates efficiently, but is less stringent that the former.

The result of an analysis of these considerations is an electrically small UHF tag can be expected to operate at optimum performance over an approximately 25 MHz band. Operation over larger bandwidth is practicable if the antenna physical size is increased, and the degree to which the tag can be regarded as electrically small is diminished.

These considerations are relevant to worldwide operation, because the licensed or potentially available frequency bands in the vicinity of 800-900 MHz vary in different parts of the world. It is desirable that this frequency variation is not too extreme, but as indicated already, physically larger tag antennas, can be permit greater variation of operating frequency.

#### 9.3.2.1 Absorption

When electromagnetic energy passes through any substance other than a vacuum, some of the energy is absorbed and is converted to heat. Attenuation of radio signals (by absorption) depends on the characteristics of the material through which the EM wave propagates. Absorption of energy is caused by some of the energy being dissipated in material that poses a resistance to the wave and being converted to heat.

At 900 MHz, electromagnetic waves are more substantially attenuated by lossy materials, which might be interposed between the tag and interrogator, than are the fields at the frequencies of inductive operation. This comment excludes metallic materials which have their special properties considered in below sections.

#### 9.3.2.2 Reflection, refraction and diffraction

UHF EM waves are related to light and behave in a similar manner. They can be reflected off radio conductive reflective surfaces, they can be refracted as they pass across the barrier between dissimilar dielectric media or they can be diffracted around a sharp edge.

Whereas induction systems have a long wavelength relative to objects such as people, pallets, boxes etc, UHF waves have much shorter wavelengths and so are more prone to these phenomena. This phenomenon can be both a benefit and a disadvantage.

For an EM wave to pass through an aperture in a conductive object, its wavelength must be shorter than at least one dimension of the aperture. At 900 MHz the wavelength is 0,3 meters, therefore a 900 MHz system will read through a 1 meter.

#### 9.3.2.2.1 Reflection

EM waves can be reflected off any conductive or partially conductive surface, such as metal, water, concrete etc. Reflection can work for us by causing the waves to be reflected around objects that would normally act as a barrier to radio waves.

Reflection can also cause a problem in that should a direct wave meet at some point with an opposite phase reflected wave, a cancellation or null occurs at that point, resulting in a no-read situation. Should the waves reach the same point in phase, the signal strength is enhanced. The use of multiple antennae, easily configured at 900 MHz wavelengths, can reduce the effects of this problem. It should be noted that nulls are far more prevalent than enhancements.

Operation of a 900 MHz tag can be greatly aided by the presence of beneficial reflections from metallic plates that are somewhere near, but not between the interrogator and the tag and are not immediately behind the tag. In brief, the more such reflections the better.

What happens in this case is that waves for the direct and reflected paths can show constructive interference with an approximate doubling of field amplitude in certain regions, at the expense of field reduction in others. Since tags are normally moving, or the field can be stirred, and since tags have an operating threshold, the augmentation is more important that the reduction.

When the tag is operated immediately adjacent to metallic material it must be specifically designed for it. Most 900 MHz tags are designed for operation in an environment free of such metal. However it is possible to design tags with substantial coupling to magnetic field and not electric field, and to exploit that fact that when electromagnetic waves are reflected from a backing metal surface, although the electric field is extinguished, the magnetic field immediately adjacent the surface is doubled. Such specifically designed tags are capable of high performance.



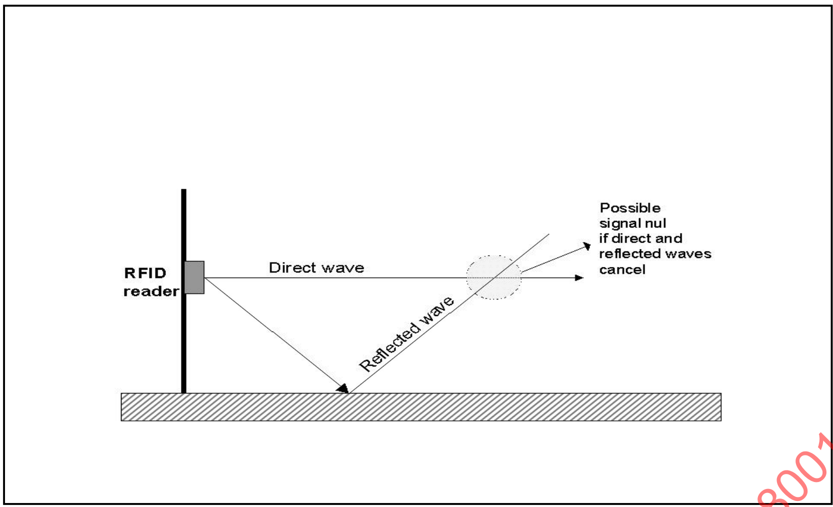



**Figure 11 – The effects of multi-patch signals**

#### 9.3.2.2.2 Refraction

Refraction is caused by the change in velocity of an EM wave when it crosses a boundary between one propagating medium and another. If this crossing is at an angle, then one part of the wave front will change speed before the other so changing the direction of the wave.

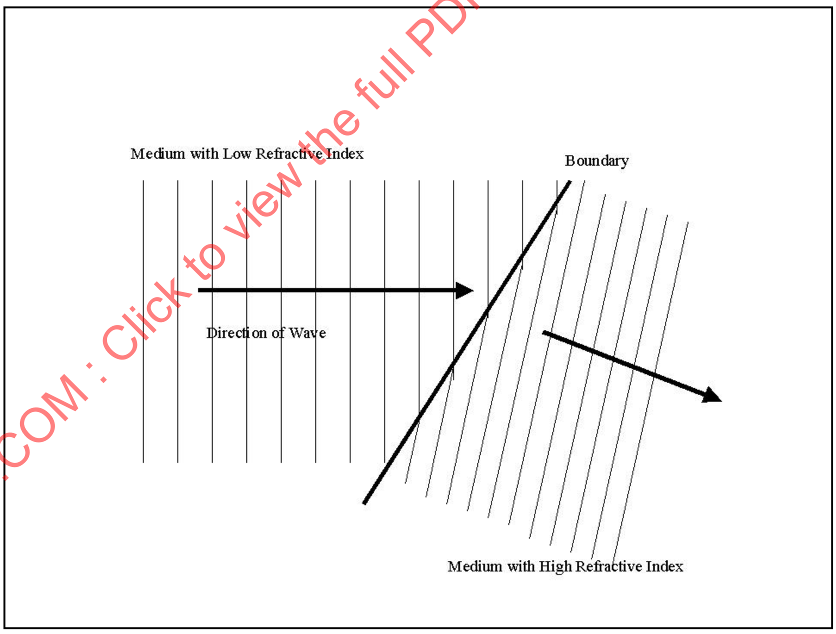



**Figure 12 - Example of refracted wave**



This may be illustrated by the apparent bending of a stick when partially immersed in a pond. The amount of bending is dependent on the ratio of the refractive indices of the two media. (Refractive index is the velocity of a wave in free space divided by its velocity in the medium).

#### 9.3.2.2.3 Diffraction

Diffraction of an EM wave occurs as it passes a sharp corner. The sharp edge (or knife-edge) slows a portion of the wave front thus allowing some of the energy to appear behind an otherwise solid object. At lower frequencies, typically within the medium to short wave frequencies, this effect is virtually non-existent with the angle increasing into the vhf and uhf bands. The higher the frequency, the greater the angle and consequentially the smaller the shadow

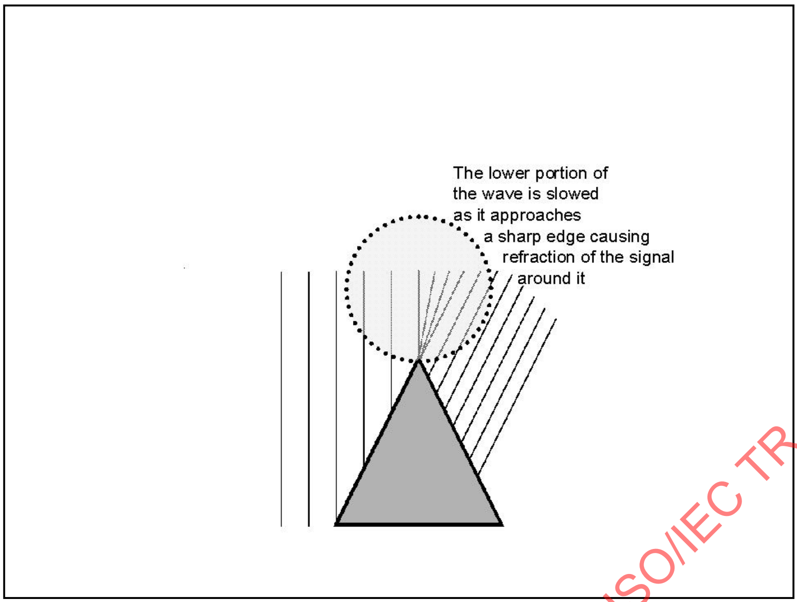



**Figure 13 - Effect of knife edged object in wave path**

### 9.3.2.3 Penetration into liquids

Radio Waves will penetrate into different liquids depending on the electrical conductivity of the liquid. For example, water has a high electrical conductivity and will therefore tend to reflect and absorb EM energy, whereas oil and petroleum based liquids with low conductivity will allow EM energy to pass with relatively low levels of attenuation.

### 9.3.2.4 Read range

Read range is dependent on the transmitter power output and in the case of passive tags, on the energizing requirements of the tags. The effective read range would also depend on the absorption factor of the type of material to which the tag is affixed.

Tag size plays a major role in determining read range. The smaller the tag, the smaller the energy capture area, therefore the shorter the read range. Proper design of the system and optimization of reader power, antenna positioning and optimum tag placement will help to overcome many of these limitations.

The recommended definition of read range applicable for UHF systems is to use only one interrogator and define the range as the workable interrogator to tag separation.

### 9.3.2.5 Interference

Electrical noise from motors, fluorescent lights, etc. is minimal at UHF frequencies. At the higher UHF frequencies (around 900 MHz) there is very little electrical noise.

Of most concern is the effect of other RFID systems, mobile phones, ISM etc. Most of these sources of radio signals are relatively narrow band.

Frequency hopping spread spectrum. (FHSS) is one of the most effective ways to avoid the effects of interference and to avoid causing interference to other users of shared spectrum. This way the transmitted energy is distributed, reducing the potential for interfering with other systems, and because the receiver frequency is continually changing it avoids the effects of other users blocking the reader's receiver.

#### 9.3.2.5.1 Concurrent operation of adjacent systems

In the 900 MHz band, adjacent RFID systems require either time multiplexing to ensure non-interference, or frequency hopping.

Time multiplexing is the feasible option when only narrow frequency range is available. The rate at which tags can be read by the competing systems is obviously reduced.

It is not necessary for there to be the overt cooperation between the competing systems. It is easily possible to design systems to sense the presence of one another, and to move their operation into a cooperative mode.

Commonly, however non-interference between adjacent systems is achieved by operating under frequency hopping spread spectrum operations. In this situation neither overt nor automatic cooperation is required, as frequency-hopping regulations are such as to minimize but not extinguish interference between physically adjacent systems.

In such a situation it is essential that the systems be designed so that missed tags reads due to interference can be recovered in subsequent reading periods.

#### 9.3.2.5.2 Environmental noise

It is characteristic of 900 MHz systems that they suffer much less from man made noise such as power system interference than do the low frequency systems. However, the regulations under which they operate frequently insist upon frequency sharing, so interference from other users of the system will in some situations occur. Such interference is tolerable if those other users are also subject to similar regulations as to the statistics of their signalling, and the RFID systems are designed to be fault tolerant.

#### 9.3.2.6 Tag read and tag selection

Generally speaking tag reading in 900 MHz systems can be faster than in the inductively coupled systems. This result comes about from the fact that regulations often allocate broader bandwidths per channel, but if this is not the case in a particular jurisdiction, the general statements made here will not be true. It is also true that tag tuning characteristics allow the use of greater bandwidths and hence greater signalling speeds.

Although the data rates (referred to below) vary significantly between manufacturers, it might be said that the tag read out of data per interrogation is commonly of the order of 100 bits, and such data read at a data rate of 50 kilobits per second or greater, leading to tag read times of about 2 milliseconds, although shorter is possible.

As both uplink and downlink data rates can be made similar, and the data transmission in tag selection resembles that just mentioned, the selection of an individual tag in a multiple read situation may take a similar amount of time. However multiple reading algorithms that do not require elaborate tag selection to precede high speed reading of the multiplicity of tags in single environment exist.

#### 9.3.2.7 Directional reading capability

The nature of UHF radio allows the use of relatively small directional antennas. This permits the reader beam to be directed towards a particular area and so selectively read a group of tags or discriminate against other tags. This directional capability has an additional benefit, in that it allows the reader to discriminate against potential interference from other readers or transmitter sources.

As much, as 20 to 30dB of discrimination is possible (100 to 1000 times discrimination). High directivity may permit lower conducted power levels with a resultant reduction of the possibility of causing harmful interference as well as enhanced possibilities for frequency re-use.

#### 9.3.2.8 Tag orientation

The orientation of the tag antenna with respect to the reader antenna will impact on the range. Linear polarization is normal with a simple antenna, such as a dipole or yagi. With linear polarization, the tag's antenna must be in the same orientation as the reader antenna to be able to receive maximum energy. It is possible and highly undesirable, for the polarization of reader and tag antennas to occur at right angles, with a resultant signal null occurring. If non-linear polarization of the reader antenna is used then it is not important which way the tag is oriented Circular polarization of the reader antenna, easy achievable at 900 MHz, allows any tag antenna orientation.

#### 9.3.2.9 Who talks first

##### 9.3.2.9.1 Tag Talks First (TTF)

Once activated, a TTF system continues to transmit its beacon over a given duty cycle during the time it senses the presence of a reader. Works very well with longer read ranges to capture and record fast moving objects such as motor vehicles, cyclists, sporting event competitors, objects moving along conveyor belts, (baggage, parcels etc) Best suited for applications where a single tag is in the field-of-view at one time.

##### 9.3.2.9.2 Reader Talks First (RTF)

Under reader control, an RTF system transmits only when instructed to do so by the reader/interrogator. Useful where there is a large volume of items where collision avoidance is required and unique identification of individual tags is needed. Best suited for applications where multiple tags are in the field-of-view at one time.

##### 9.3.2.9.3 Issues

Most systems within the ISO 18000 series are RTF systems. This is because a high number of TTF tags transmitting its beacon periodically will saturate the air space and potentially interfere with RTF systems.



## 10 RFID system and bar code system

RF tags will be used in various applications, some of which will be complementing the use of bar code labels in the same system. Consequently, the data structure of the RF tags should be compatible with the similar types of bar code labels, specifically individual fields of data should share the same semantics and a message of multiple fields should share the same high capacity data syntax. The data semantics are described in ISO/IEC 15418:1999, *EAN.UCC Application Identifiers and FACT Data Identifiers* and the high capacity data syntax is described in ISO/IEC 15434:1999, *Transfer Syntax for High Capacity ADC Media.*

Two standards that are not found in bar code systems but do provide some syntactical recommendations for RFID includes ISO/IEC 15961, *Information technology — Radio frequency identification for item management — Data protocol: application interface* that provides information interface based on ASN.1 (commands) and ISO/IEC 15962, *Information technology — Radio frequency identification for item management — Data protocol: data encoding rules and logical memory functions* that provides process definition for the generation of a logical memory map in a binary form.

Users have come to expect high reliability in automatic data capture techniques, specifically with the error correction capabilities of two-dimensional symbols. RF tag manufacturers and systems integrators should consider such error correction techniques to support the 100% reading reliability expectations of the end users.

### 10.1 Sorting systems using bar code labels

When baggage on a belt conveyor is sorted using bar code labels, the bar code reader must be able to precisely locate and read the baggage tag. The bar code labels are then read consecutively.

If a reading error occurs (mis-read or no-read), the sorting system will detect the error and the baggage to which the bar code label creating the reading error is attached will be diverted and handled as an exception at a recovery line.

### 10.2 Sorting system using RFID tags

Many RFID systems have the benefit of a greater operating range than bar code systems. Since data on the tags are read using radio frequency, operating range is affected by various reasons, as described in the Clause 7.

When multiple tags are scanned with an anti-collision protocol as shown in Figure 14, if a tag cannot be read, it is required that the erroneous tag be identified. In this respect, the reading system of RF tags is fundamentally the same as the bar code labels system, though systems integrators will need to design systems in such a way that the erroneous tag can be positively identified. However, the RF tag systems provide additional capabilities that are not possible with bar code systems, e.g.:

a) effective scanning over a wider operating range

b) improved data management capabilities due to larger data capacity of the RF tags

c) others ( read/write, security, etc.)

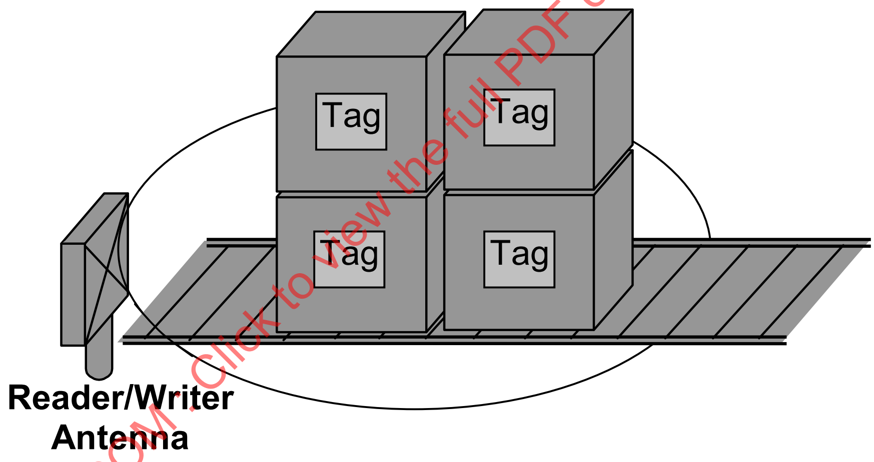





**Figure 14 – Scanning Multiple Tags**

## 11 Proposals for individual application

### 11.1 Application: returnable plastic containers

a) The dimensions of the container for this application (see Annex E) are:

X: 437-600 mm

Y: 329-405 mm

Z: 234-386 mm

b) The minimum distance between tags (tag separation) is 200 millimeters.

c) The tag is attached to the surface of the container (assumption of no metal or similar material).

d) The tag's maximum velocity in front of the reader/writer is 2 meters per second (conveyor speed of 400 fpm).

e) The tag's orientation is controlled

f) Number of characters transferred: ~1k byte / ~4k byte

g) Number of tags within a field of view: ~10

## 11.2 Typical parameter for application

**Table 6 — Typical Parameters for Various Applications**

| Parameters \ Application | Plastic returnable container | Baggage handling | Video tape rental |
|---|---|---|---|
| Distance (X,Y) between tags | 200 mm~ | 30 mm~ | 10 mm~ |
| Orientation | controlled | not controlled | not controlled |
| Number of characters transferred | ~1 kbyte<br>~4 kbyte | ~128 byte | ~128 byte |
| Speed of movement in front of reader/writer | ~2 m/sec | ~10 m/sec | ~1 m/sec |
| Number of tags within a field of view | ~10 | ~10 | ~20 |

## 12 Conclusions

The aim of this Technical Report is to define the Application Requirement Profile for item management.

RF tag systems are used in a variety of applications and the requirements for RF tags are different in individual applications.

For standardization, the requirements should be limited to minimum requirements and the works regarding to system integration should be separated.

The reliability of RF tag systems is very important.

The RF tag systems have various benefits over bar code label systems, but there are several issues that need to be resolved in systems integration for highly reliable system's operation.



# Annex A
(informative)

## AIM / SC 31 Survey



ISO/IEC JTC 1/SC 31/WG 4/ARP

Questionnaire to SC 31/WG 4 Members

Radio Frequency Identification for

Item Management

Application Requirements Profile

1998 / 10 / 6

version 1.2

Rapporteur - Toshihiro Yoshioka

# SC 31/WG 4/ARP

Questionnaire to SC 31/WG 4 Members

To Define the Application Requirements for Standardization

1. Choose Application (The applications are focused mainly on supply chain model)

2. Operation Requirements (How do you use the Tag?) (The requirements that are determined by other standards are exempted.)

3. Required Specification (How do you access the Tag?)

Others

1. Application

Choose one from this list

Luggage Handling (airline)

Factory Automation

Warehouse Logistics / Inventory Control

Distribution

Security / Article Surveillance

Asset Tracking

Containers Control

Pallets Control ( small plastic pallets )

Door-to-Door Delivery Service

If any others

Briefly describe on your application

2. How do you use the Tag?

2.1 Is Tag re-used or disposable?

re-used

disposable

If you have any comments

2.2 How much raw data needs to be stored on Tag?

maximum ________ bytes

minimum ________ bytes

2.3 Does Tag need unique ID number?

Yes

No

If Yes, how do you use the unique ID number?

2.4 How will the data on your Tag be used ?

Read only

Write once / Read many

Read and Write

2.5 Is there any constraint to the physical size or thickness of Tag?

Yes

No

If Yes, describe briefly your comments

3. How do you access (read or write the Tag ?

3.1 Single Antenna

Yes

No

3.2 Multi Antenna

Yes

No

3.3 Do you use a Hand-held type reader / writer with antenna?

Yes

No

If Yes, describe briefly how to use it.

3.4 What is the maximum read / write distance for your application?

Read mode _______ m

Write mode _______ m

If you have any comments

3.5 What is the maximum speed of Tag going through the field of view?

Read mode _______ m/sec

Write mode _______ m/sec

If you have any comments

3.6 What is the amount of data transferred during read operation?

maximum / typical _____/_____ bytes

3.7 What is the amount of data transferred during write operation?

maximum / typical _____/_____ bytes

3.8 What is the minimum separate distance from Tag to Tag?

_______ mm / cm / m

3.9 Does the item (packaging or container) have any metallic content ?

Yes

No

If Yes, what is the minimum separate distance from Tag to metal surface?

_______ mm / cm / m

3.10 What is Tag orientation ?

Controlled

Random

3.11 Does more than 1 tag need to be read simultaneously? (Is Anti-collision required?)

Yes

No

3.12 Do you need an encryption, authentication, or another security system?

Yes

No

If Yes, what kind of security system do you need?

3.13 What are the environment requirements for this application?

Briefly describe the requirement conditions for metal / temperature / vibration / water / and chemical.

## 4 Others

If you have any other comments,

# Annex B
(informative)

# ANSI MH 10/SC 8 Survey

**User Application Requirements for
Shipping, Receiving, and Warehouse Management Applications Using RF Tags**



**General:**

Subcommittee 8 of the American National Standards Accredited Standards Committee MH 10 is in the process of developing an application standard for RF tags. As such it is attempting to secure user input on existing or potential uses of RF as a precursor to developing this standard. It is essential to obtain user input in order to establish the application and technology requirements of this standard. ANSI MH 10/SC 8 has previously developed marking standards for shipping containers and pallets using linear bar code and two-dimensional symbol technologies. MH 10/SC 8 also maintains the Data Application Identifier standard, data structure and syntax standards for high capacity media, and serves as the U.S. Technical Advisory Group to ISO TC 122 (Packaging).

Your response to this questionnaire is being requested in order to determine **actual or anticipated** user requirements for applications using radio frequency (RF) tags in the shipping, receiving, and warehouse management of containers, packages or unit loads. Responses to this questionnaire should be considered in terms of any RF application that is extended deep into the supply chain, having a broad and universal functionality.

Responses should be sent to Dr. Mike Ogle at MHIA via email no later than 22 March 1999. Dr. Ogle's email address is:

mogle@mhia.org (Michael K. Ogle)

**Multiple applications:**

If you have identified multiple applications with separate and distinct requirements, please specify that application and submit a separate response for each application.

**Types of Applications:**

While this list is not exhaustive, the survey addresses the following applications:

- For returnable containers:

  a) asset tracking of the container

  b) a method of tracking the contents of the container

  c) maintenance of the container

Identify places that these returnable containers might be read from or written to in either a stationary or handheld manner, including:

d) location where the container is filled

e) location from where the container is shipped

f) locations during the carrier's handling process (in-transit visibility)

g) location where the container is received

h) internal warehouse locations for inventory control and other affiliated applications

i) materials management functions within the production cycle (work-in-process, kanban, and shop floor control)

j) locations in support of automated handling equipment

- Consideration should be given within these applications for high value contents, special handling of contents such as

  – hazardous materials,

  – shipping container management,

  – trailers and vans,

  – and high value equipment tracking (e.g., rentals).



**(Survey Follows on Next Page)**

1. From what distance between tag and reader (feet or inches) do you anticipate the RF tag will be read?

2. Are the requirements for read-only or read/write tags?

3. Is the tag moving or stationary at the time of reading? If moving, at what speed (mph or ft/sec) does the tag need to be read?

4. Is the tag moving or stationary at the time of writing to the tag?
If moving, at what speed (mph or ft/sec) is the object on which a tag is affixed moving in front of the reader?

5. What is the amount of data (in number of characters) that will transferred during a read operation?

6. What is the amount of data (in number of characters) that will transferred during a write operation?

7. What would you anticipate to be the number of characters required being stored on the tag for your application?

8. What are the environmental conditions in which the tag is being used?

   a) - Temperature

   b) - Humidity

   c) - Shock

   d) - Vibration

   e) - Battery life

   f) - Chemical resistance

   g) - Dirt, dust, precipitation

   h) - Rough handling (susceptible to physical damage other than from shock or vibration)

   i) - Electromagnetic interference (from other RF, microwave or electronic devices in proximity)

9. Will there be a presence of metal in the working environment, in close proximity of the tag or the reader?

10. Will the tag be presented to the reader in a specific orientation (e.g., in a plane perpendicular to the reader), or will omni-directionality be required of the reader?

11. Regarding the data on the tag,

   j) - Will a specific field (s) need to be identified without reading the entire tag?

   k) - Within the life of the data on the tag, will the data need to be changed or appended?

   l) - Will encryption or security be required?

12. What if any obstructions will exist, e.g., walls, racks, between the reader and the tags?

13. Do you currently or do you anticipate using a fixed position or a hand-held reader? If handheld, is the terminal a batch device or is communicating via radio-frequency back to the host computer?

14. Will multiple items (on the tag or container?) need to be read at the same time? If yes, how many?

15. Will the tag be reclaimable / reusable?

16. Will the tag require and will the application use a unique tag ID?

17. Will the tag be visible or embedded in a material? If embedded, what will the material be?

    m) - Plastic

    n) - Cardboard

    o) - Wood

    p) - Metal

    q) - Other

18. Is there a requisite mounting method such as rivet, sheet metal screw, bolt, adhesive, or magnet? (If yes, please specify??)

19. Is there a specific requisite tag size (height, width, thickness)?

20. Is there a specific requisite reader size (height, width, depth)?

21. Do you have any other requirements or comments regarding your use or anticipated use of RF tags?

**THANK YOU FOR TAKING THE TIME TO COMPLETE THIS SURVEY!!!**

# Annex C
(informative)

## ARP Questionnaire Responses



**Table C-1 — ARP Question Response**

| No. | Application | Memory Size | Read/Write | Reuse | Tag/freq | Operating Distance (Read) | Multi-tag Read | Encryption | Country |
|---|---|---|---|---|---|---|---|---|---|
| 1 | FA Semiconductor Line | | Read | Reuse | Tirus | 0,6 m | No | No | USA |
| 2 | Transport Tolls | 256 byte | R/W | Reuse | | 7 m | Yes | Yes | USA |
| 3 | Asset Tracking | 16 kbyte to 128 kbyte | R/W | Reuse | | 0,2 | Yes | No | USA |
| 4 | Warehouse Logistics | 512 byte to 1024 byte | R/W | Reuse | | 3 – 5 m | | Yes | USA |
| 5 | Tracking logs in forestry | | WORM | Dispose | | 100 m | | | NZL |
| 6 | Tracking logs in forestry | | R/W | Dispose | | 100 m | | | NZL |
| 7 | Access Control | 8 – 128 byte | R/W | Both | | 0,5 m | Yes | Yes | DEU |
| 8 | FA Logistics Distribution Pallet Control | 10 – 32 kbyte | R/W | Reuse | | 1,0 m | No | Yes | SWE |
| 9 | Access and Tracking Airport truck, cars, buses, trolleys, harbours: car | 80 byte | WORM | Reuse | 2,45 GHz | 6 m | Yes | Yes (DES) | FIN |
| 10 | Asset Tracking | 64 byte – 512 byte | WORM | Dispose | | 2 m | Yes | No | DEU |
| 11 | FA Pallet Identification | 2 kbyte – 32 kbyte | R/W | Reuse | | 0,025 m | No | No | GBR |
| 12 | Luggage Handling | 10 byte | R/W | Dispose | | 1 m | Yes | No | USA |
| 13 | Luggage Handling | 4 byte | WORM | Dispose | | | | Yes | AUS |
| 14 | Library | 16 byte | R/W | Reuse | ISD | 0,65 m | Yes | Yes | |
| 15 | Domestic Waste Management | 8 byte | Read | Reuse | ISD | 3,5 m | No | No | USA |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 16 | Identify/payment vehicle (gasoline) | 9 – 256 byte | R/W | Reuse | | 2,5 m | Yes | Yes | |
| 17 | Luggage Handling | | | | | | | | |
| 18 | Asset Tracking Video Tape Store | 10 byte | Read | Reuse | | 1,5 m | Yes | No | |
| 19 | Warehouse Logistics | | | | | | | | |
| 20 | Asset Tracking: Tracking Vehicle | | Read | Reuse | | | No | No | |
| 21 | Waste Management | 256 byte | R/W | Reuse | | 1 m | No | No | JPN |
| 22 | Inventory Control | 512 byte | R/W | Reuse | | 1 m | No | No | JPN |
| 23 | FA Automatic Warehouse | 128 byte – 256 byte | R/W | Reuse | 125 kHz | 0,2 m – 0,4 m | Yes | No | JPN |
| 24 | FA Logistics Distribution Pallet | 128 byte | R/W | Reuse | 125 kHz | 0,5 m | Yes | No | JPN |
| 25 | Distribution (Vehicle Management) | 1K byte | R/W | Reuse | 2,45 GHz | 3 m | No | No | JPN |
| 26 | Pallet Control | 128 byte | R/W | Reuse | | 0,7 m | Yes | No | JPN |
| 27 | Container Control | 128 byte | R/W | Reuse | 2,45 GHz | 5 m | No | No | JPN |
| 28 | Luggage Handling | 64 byte | R/W | Reuse | | 1 m – 1,5 m | Yes | No | JPN |
| 29 | Asset Tracking | 12 byte | R/W | Reuse | | 1 m | Yes | No | JPN |

# Annex D
(informative)

## ANSI MH 10/SC 8 Questionnaire Responses



**Table D-1 — ANSI MH 10/SC 8 Question Response**

| Question / Respondent | Air Force | Ameritech | Bell Atlantic | Caterpillar | DLA/SmLbl | Dow |
|---|---|---|---|---|---|---|
| 1. Tag to Reader Distance | 40-50 feet | 10 feet | .5-10 feet | .5-50 feet | 1-3 meters | 3 - 4 feet |
| 2. Read-only / Read-write | read/write | read/write | r/o - r/w | r/o - r/w | r/o - r/w | r/o - r/w |
| 3. Tag stationary or moving when read | both | moving | both | both | both | stationary |
| 3a. If moving, what speed | 10 mph | 10 mph | 2-5 mph | <25 mph | 350 fpm | |
| 4. Number of characters transferred during read | < 50 | 44 | 16+ | 150 | 61-170 chars | 60/100/300 |
| 5. Number of characters transferred during write | < 50 | 9 | n/a | 150 | 61-170 chars | 20 to 40 |
| 6. Number of characters being stored on tag | 10 K | 44 | 8 | 150 | 61-170 chars | 100 to 300 |
| 7. Environmental Conditions | | Upper MW | | | Extr Harsh | Extr Harsh |
| 7a. Temperature | -20-120 F | | 10 - 90 F | -15 to 150 F | -15 to 140 F | -15 to 140 F |
| 7b. Humidity | 10-90% | | yes | 0 to 100% | ≤100 % | up to 100% |
| 7c. Shock | forklift | yes | | | extreme | extreme |
| 7d. Vibration | forklift | yes | yes | yes | extreme | extreme |
| 7e. Battery life | no battery | 5 years | | 10 years | no bat/10 yrs | |
| 7f. Chemical Resisitance | unknown | | | yes | extreme | extreme |
| 7g. Dirt, dust, precipitation | unknown | | yes | yes | extreme | extreme |
| 7h. Rough handling | unknown | | yes | yes | extreme | extreme |

| | | | | | | |
|---|---|---|---|---|---|---|
| 7i. Electromagnetic interference | 0,9&2,45 GHz | | | yes | yes | yes |
| 8. Presense of metal | yes | yes (cable) | yes (cable) | yes | yes | yes |
| 9. Orientation (perpendicular / omni-directional) | omni pref but | omni | both | omni | omni/both | omni/both |
| 10. Tag data | | | | | | |
| 10a. Read specific field without reading entire tag | yes | yes | no | yes | yes | yes |
| 10b. Data changed or appended during tag life | yes | yes | no | yes | yes | yes |
| 10c. Encryption | no | no | no | sometimes | none | yes |
| 11. Obstructions | no | cable reel | cable reels | racks | racks | none |
| 12. Handheld / Fixed position | both | both | both | both | both | handheld |
| 12a. Batch or RFDC | RFDC w/bc2D | RFDC | | both | RFDC | RFDC |
| 13. Multiple tags read at same time? | yes, 100 | no | no | yes mxd load | yes, 100 | yes, 5 |
| 14. Reclaimable / reusable tag | some | no | ro-no/rw-yes | yes/no | no | yes |
| 15. Unique tag ID | yes | yes | yes | sometimes | yes | yes |
| 16. Visible / embedded (plastic, cardboard, wood, metal | visible | visible | visible | both | visible | visible/both |
| 17. Requisite mounting apparatus | all | no | | yes per appl | label adhesive | any secure |
| 18. Requisite tag size (height, width, thickness) | pro w/h | no | on reel | appl specific | | no |
| 19. Requisite reader size (height, width, thickness) | no | no | | | | no |
| 20. Comments | 2 type tags<br>Disposable UID<br>&<br>∑ bar code &<br>disposable tag<br>data | | | cost-eff<br>autodscrm<br>AIs / DIs<br>chng batry | | none |

**Table D-2 — ANSI MH 10/SC 8 Question Response (continued)**

| Question / Respondent | IATA 1640 | Innov Insights | JPN RPSC | Lucent | Marine W/H | Marine Trans |
|---|---|---|---|---|---|---|
| 1. Tag to Reader Distance | 5 meters | 3-15 feet | > 70 cm | 4-5 feet | ≤6 feet | 200-300 yds |
| 2. Read-only / Read-write | read/write | r/o - r/w | | r/w | r/o - r/w | Read-write |
| 3. Tag stationary or moving when read | both | both | both | stationary | both | Both |
| 3a. If moving, what speed | 10 mps | <15 mph | | stationary | 20 mph | 20 mph/sta |
| 4. Number of characters transferred during read | 64 | 8-100 (32K) | | 9-14 chars | n13 | Per oth svcs |
| 5. Number of characters transferred during write | 64 | 92 (32K) | | 33-27 chars | n13 | Per oth svcs |
| 6. Number of characters being stored on tag | 64 | 100 | <1kB & 1-4 kB | 33-27 chars | n13 | Per oth svcs |
| 7. Environmental Conditions | | | | | | |
| 7a. Temperature | -50 to 70 C | -40 to 160 F | | 10 - 90 F | 0 - 130 F | -25 to 120 F |
| 7b. Humidity | 0,95 | | | 50 - 90% | ≤100% | ≤100% |
| 7c. Shock | 30 g (68) | | | Yes | 2 ft drop | |
| 7d. Vibration | yes | | | Yes | Minimal | |
| 7e. Battery life | na passive | if req, 10 yrs | | | | 3 years |
| 7f. Chemical Resisitance | yes | yes | | No | Oil/Solvents | Oil/Solv/Salt |
| 7g. Dirt, dust, precipitation | yes | yes | | Yes | | |
| 7h. Rough handling | yes (3.3 m) | yes (5' drop) | | Probable | | |
| 7i. Electromagnetic interference | 1,2-2,8 GHz | | | Probable | | |
| 8. Presense of metal | yes | mount on mtl | | yes/steelreel | yes | yes |
| 9. Orientation (perpendicular / omni-directional) | mount on mtl | perp | | omni | omni | omni |
| 10. Tag data | | | | | | |
| 10a. Read specific field without reading entire tag | yes | nice not req | | yes | yes | yes, TCN |

| | | | | | | |
|---|---|---|---|---|---|---|
| 10b. Data changed or appended during tag life | no / yes | yes | | yes | yes/ea cntnr | yes |
| 10c. Encryption | yes | no | | no | no | ideally, yes |
| 11. Obstructions | none | none | | racks/reels | no | yes |
| 12. Handheld / Fixed position | both | both | | both | both | both |
| 12a. Batch or RFDC | both | batch | | RFDC | | |
| 13. Multiple tags read at same time? | yes | yes 20-30/s | | no | yes, 50 | yes |
| 14. Reclaimable / reusable tag | yes | yes | | yes | yes | yes |
| 15. Unique tag ID | yes | yes | | no | no | yes |
| 16. Visible / embedded (plastic, cardboard, wood, metal | both | both | | visible | both | both |
| 17. Requisite mounting apparatus | fstnts/adh | rivet/bolt | | mag/bolt | adh/scr/brk | bolt/rivet |
| 18. Requisite tag size (height, width, thickness) | | 8x2x.5" | | 3"x2"x0.5" | 2" x 1" | smaller |
| 19. Requisite reader size (height, width, thickness) | | | | ForkLiftMount | none | hendheld |
| 20. Comments | 20K reads<br>30mm btw tgs | no | WG 4 N0099 | | n9 Contnr ID<br>n13 NSN<br>Written while<br>stationary | Accurate<br>Reliable<br>Hardy<br>Long shelf<br>life |

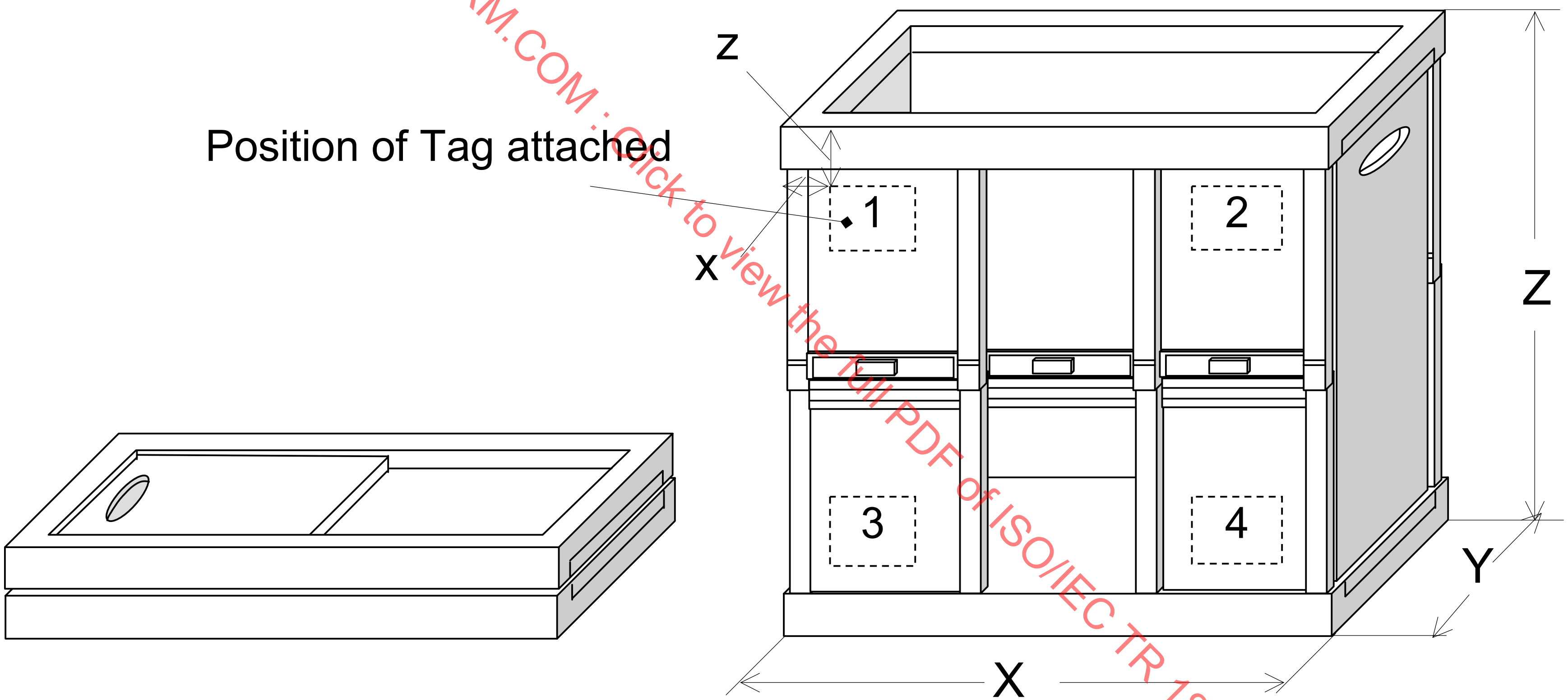
**Table D-3 — ANSI MH 10/SC 8 Question Response (continued)**

| Question / Respondent | MR TAG | MTMC | TI | Upjohn | USN | VICS |
|---|---|---|---|---|---|---|
| 1. Tag to Reader Distance | 4 meters | < 400 feet | 1 meter | 0,5-5 feet | per oth svcs | 0,1-16 feet |
| 2. Read-only / Read-write | read/write | read/write | read/write | r/o - r/w | read/write | r/o - r/w |
| 3. Tag stationary or moving when read | both | both | both | stationary | stationary | both |
| 3a. If moving, what speed | 1,8mps/10km/h | < 40 mph | 10 fps | | | |
| 4. Number of characters transferred during read | | ≈100 bytes | 256 bits | 15-50 | | 20 |
| 5. Number of characters transferred during write | | < 128 kB | 256 bits | 15-50 | | |
| 6. Number of characters being stored on tag | +107 | 10-20 kB | per appl | 15-50 | | 1000 |
| 7. Environmental Conditions | | | | | | |
| 7a. Temperature | -40 to 100 C | -40 to 120 F | -25 to 70 C | 0 to 120 F | | |
| 7b. Humidity | ≤100 % | up to 100% | | | | |
| 7c. Shock | yes | veh mount | | | | |
| 7d. Vibration | yes | veh mount | | | | |
| 7e. Battery life | 10 years | 5000 RF hits | na passive | 2 years | | |
| 7f. Chemical Resistance | yes | yes | | possibly | | |
| 7g. Dirt, dust, precipitation | yes | | | warehouse | | warehouse |
| 7h. Rough handling | yes | | | no | | yes |
| 7i. Electromagnetic interference | yes | | per regulates | yes | | |
| 8. Presence of metal | yes | yes | per appl | metal shlvng | yes | metal shlvng |
| 9. Orientation (perpendicular / omni-directional) | omni | omni | omni (tunnel) | omni | omni | omni |
| 10. Tag data | | | | | | |
| 10a. Read specific field without reading entire tag | yes | yes | tag id | yes | | yes |

| | | | | | | |
|---|---|---|---|---|---|---|
| 10b. Data changed or appended during tag life | yes | yes | yes | no / yes | yes | yes |
| 10c. Encryption | no | no | possible | no | no | no |
| 11. Obstructions | none | yes | per appl | none | no | none |
| 12. Handheld / Fixed position | both | both | per appl | handheld | both | both |
| 12a. Batch or RFDC | both | | per appl | RF laptop | | RFDC |
| 13. Multiple tags read at same time? | yes 60 simul | yes 400-500 | yes 50/s | yes | no | yes |
| 14. Reclaimable / reusable tag | yes | no | yes | yes | yes | yes |
| 15. Unique tag ID | | yes | yes | yes | probably | yes |
| 16. Visible / embedded (plastic, cardboard, wood, metal | vis/emb | both | per app no mtl | visible | visible | embedded |
| 17. Requisite mounting apparatus | permanent | any secure | adh pref | adh / screw | no | adhesive |
| 18. Requisite tag size (height, width, thickness) | | low profile | 45x76 mm | 2 qtrs | low profile | |
| 19. Requisite reader size (height, width, thickness) | | low weight | 220x120x90 mm | handheld | no | |
| 20. Comments | 15K reads<br>4 inter/day<br>≥99% FRR | Coml ƒ<br>Atten Pwr<br>0-400<br>Int-Int<br>Network Com<br>w/o addl equip | | no | | |

# Annex E
(informative)

## Example of plastic returnable container in Japan




NOTE In Japan the specifications of "Plastic returnable containers" are provided by Japanese Industrial Standards JIS Z 1655, Z 0105. The typical sizes of these containers, as used in convenience stores, are (X, Y, Z) (mm)=(437,329,234), (530, 360, 325), (600, 405, 307), (600, 405, 386).

# Annex F
(informative)

# Dortmund Study

## F.1 Retailer's Responses to Questionnaire

Replies were received from 14 respondents representing 65 billion DM sales revenue and 7000 retail outlets.

### A1 Which type of retail outlets do you have?

| | |
|---|---|
| Department store without food | 7% |
| Department store with food | 43% |
| Specialist store >1000 sq. m | 21% |
| Food | 29% |
| Discount store | 43% |
| Supermarket | 29% |
| DIY | 29% |
| Cash & Carry | 29% |
| Specialist store <1000 sq. m | 43% |
| Mail order | 14% |

### A2 What type of goods do you sell?

| | |
|---|---|
| Audio/Video/Music/Photography | 29% |
| DIY / Garden | 43% |
| Drugs/Cosmetics/Perfume | 43% |
| Office/Computer | 29% |
| Household & electrical | 57% |
| Food | 64% |
| Gifts | 57% |
| Furniture | 36% |
| Optician | 14% |
| Jewellery | 7% |
| Shoes | 29% |
| Toys | 36% |
| Sports | 29% |
| Clothing | 71% |
| Books | 29% |

### A5 How do goods reach the store?

| | |
|---|---|
| Wholesaler | 36% |
| Manufacturer | 71% |
| Delivery service | 71% |
| Self collection | 7% |

**A6 Which sales method is most common?**

| | |
|---|---|
| Service | 57% |
| Mostly self-service | 29% |
| Self-service | 29% |

**A12M Where do you collect data manually in the logistic chain?**

| | |
|---|---|
| Receiving | 71% |
| Warehouse | 71% |
| Transport within the company | 29% |
| Transport outside the company | 57% |
| Order packing | 14% |
| Order Picking | 43% |
| Shelf care | 36% |
| Point of Sale | 21% |
| Outgoing | 29% |

**A12B Where do you collect data with bar-codes in the logistic chain?**

| | |
|---|---|
| Receiving | 29% |
| Warehouse | 43% |
| Transport within the company | 21% |
| Transport outside the company | 14% |
| Order packing | 0% |
| Order Picking | 50% |
| Shelf care | 0% |
| Point of Sale | 43% |
| Outgoing | 57% |

**A13 Which bar-codes do you use?**

| | |
|---|---|
| EAN 8 | 43% |
| EAN 13 | 57% |
| EAN 128 | 29% |
| Others | 15% |

## F.2 Retailers' Requirements to Transponder Systems

### B1.1 Which data is received with the goods, which is of interest and which do you make available?

| | Received | Of interest | Available |
|---|---|---|---|
| Shipping unit number | 71% | 21% | 7% |
| EAN Shipping unit | 71% | 14% | 29% |
| Lot number | 29% | 0% | 21% |
| Quantity | 93% | 7% | 43% |
| Manufacturing date | 29% | 29% | 14% |
| Packing date | 57% | 14% | 36% |
| Best before date | 43% | 0% | 14% |
| Customer order number | 64% | 21% | 43% |
| Area | 14% | 43% | 0% |
| Net Volume | 14% | 29% | 0% |
| Net weight | 50% | 7% | 29% |
| Customer Int. Loc. Number | 29% | 14% | 0% |
| Product type | 7% | 21% | 7% |
| Serial number | 14% | 29% | 0% |
| Expiry date | 43% | 0% | 14% |



### B1.3 How do you exchange data with the manufacturer and shipper?

| | Manufacturer | Shipper |
|---|---|---|
| EDI | 43% | 29% |
| Post/Fax | 86% | 57% |
| Telephone | 43% | 43% |

### B1.5 Do you work principally with EAN128?

| | |
|---|---|
| Yes | 80% |
| No | 20% |

### B1.6 b Dependence of smallest tagged unit on tag cost.

| Tag Cost | 5DM | 1DM | 0.5DM | 0.2DM |
|---|---|---|---|---|
| Individual items | 21% | 14% | 29% | 57% |
| Pack | 14% | 0% | 36% | 43% |
| Carton | 21% | 7% | 21% | 29% |
| Pallet | 0% | 0% | 14% | 36% |
| Load | 14% | 0% | 0% | 0% |

### B1.7 In which area is it important to be able to write data?

| | Very important | Important | Less important | Unimportant |
|---|---|---|---|---|
| Receiving | 29% | 43% | 0% | 21% |
| Ticketing | 0% | 29% | 0% | 14% |
| Price marking | 0% | 36% | 14% | 14% |
| Warehouse storage | 29% | 21% | 0% | 7% |
| Stock taking | 0% | 29% | 0% | 21% |

| | | | | |
|---|---|---|---|---|
| Picking | 29% | 14% | 0% | 14% |
| Quality control | 0% | 71% | 0% | 7% |
| Waste handling | 7% | 0% | 14% | 14% |
| Point of Sale | 0% | 14% | 14% | 14% |
| Shipping | 14% | 50% | 0% | 7% |

### B2.1 How often are different reading distances needed?

| Read distance | Frequency |
|---|---|
| <50 cm | 23% |
| <100 cm | 8% |
| >150cm | 69% |

### B2.2 How large must the memory capacity be?

| Capacity | Frequency |
|---|---|
| <256 bits | 20% |
| <2k bytes | 30% |
| >2k bytes | 50% |

### B2.4 How suitable are different transponder forms?

| | Disks | Buttons | Glass | Labels |
|---|---|---|---|---|
| Most suitable | 0% | 0% | 0% | 43% |
| Suitable | 29% | 29% | 29% | 14% |
| Less suitable | 14% | 36% | 7% | 7% |
| Unsuitable | 36% | 7% | 14% | 0% |

### B2.5 Have you already discussed transponder applications, if yes where?

| Yes | No | Logistics |
|---|---|---|
| 50% | 50% | 100% |

### Do you need anti-collision, if so, what is the min, average and max number of tags?

| Anti-collision | Min. | Ave. | Max |
|---|---|---|---|
| 70% yes | 70 | 130 | 250 |

### What transponder temperature range is needed?

| Min temp | Max temp |
|---|---|
| -18 C | +57 C |

## F.3 Manufacturer's Responses to Questionnaires

Replies were received from 36 respondents representing 215 billion DM sales revenue.

### A1 Which sector do you belong to?

| | |
|---|---|
| Chemicals/Pharmaceuticals | 14% |
| Electronics | 17% |
| Plastic/rubber | 19% |
| Ceramic/glass | 0% |
| Vehicle | 11% |
| Printing/binding | 0% |
| Mechanical/metal | 17% |
| Textile | 11% |
| Food | 17% |
| Optics/precision mechanics | 0% |
| Toys | 3% |
| Furniture | 0% |
| Clothing | 22% |

### A3 How do you deliver goods to retailers?

| | |
|---|---|
| Direct | 83% |
| Central warehouse | 78% |
| Other | 22% |
| Shipper | 100% |
| Own deliveries | 17% |

### A4 Where do you collect data manually or with barcodes?

| | Manual | Barcode |
|---|---|---|
| Receiving | 78% | 53% |
| Warehouse | 42% | 72% |
| Internal transport | 36% | 44% |
| Production | 47% | 50% |
| Order Packing | 11% | 19% |
| Order Picking | 39% | 67% |
| Shipping | 42% | 56% |
| External transport | 44% | 22% |

### A5 Which bar-codes do you use?

| | |
|---|---|
| EAN 8 | 11% |
| EAN 13 | 37% |
| EAN 128 | 80% |
| 2/5 Interleave | 14% |

### B1.1 Which data do you receive and which is of interest?

| | Received | Of interest |
|---|---|---|
| Shipping unit number | 50% | 25% |
| EAN Shipping unit | 22% | 28% |
| Lot number | 61% | 19% |
| Quantity | 94% | 3% |
| Manufacturing date | 53% | 22% |
| Packing date | 39% | 6% |
| Best before date | 22% | 8% |
| Customer order number | 67% | 3% |
| Area | 11% | 6% |
| Net Volume | 25% | 14% |
| Net weight | 78% | 11% |
| Customer Int. Loc. Number | 0% | 17% |
| Product type | 42% | 8% |
| Serial number | 44% | 22% |
| Expiry date | 6% | 3% |

### B1.2 Which data do you make available and what is requested?

| | Available | Requested |
|---|---|---|
| Shipping unit number | 67% | 22% |
| EAN Shipping unit | 61% | 28% |
| Lot number | 39% | 31% |
| Quantity | 94% | 3% |
| Manufacturing date | 22% | 8% |
| Packing date | 36% | 6% |
| Best before date | 28% | 6% |
| Customer order number | 56% | 21% |
| Area | 6% | 6% |
| Net Volume | 25% | 8% |
| Net weight | 67% | 3% |
| Customer Int. Loc. Number | 22% | 17% |
| Product type | 61% | 0% |
| Serial number | 50% | 0% |
| Expiry date | 3% | 6% |



### B1.3 How do you exchange data with the retailer and shipper?

| | Retailer | Shipper |
|---|---|---|
| EDI | 61% | 56% |
| Post/Fax | 78% | 61% |
| Telephone | 44% | 39% |

### B1.5 Do you work principally with EAN128?

| | |
|---|---|
| Yes | 82% |
| No | 18% |

## B1.6 Dependence of smallest tagged unit on tag cost.

| Tag cost | 5DM | 1DM | 0.5DM | 0.2DM |
|---|---|---|---|---|
| Individual article | 11% | 17% | 17% | 56% |
| Pack | 0% | 3% | 17% | 28% |
| Carton | 6% | 11% | 11% | 19% |
| Pallet | 17% | 0% | 6% | 17% |
| Load | 8% | 0% | 8% | 0% |

## B1.7 In which area is it important to be able to write data?

| | Very | Important | Less important | Unimportant |
|---|---|---|---|---|
| Receiving | 56% | 17% | 6% | 0% |
| Warehouse storage | 39% | 22% | 3% | 0% |
| Stock taking | 33% | 14% | 14% | 3% |
| Picking | 42% | 28% | 11% | 0% |
| Production date storage | 28% | 19% | 17% | 6% |
| Assembly control | 17% | 6% | 28% | 17% |
| Material flow supervision | 36% | 17% | 22% | 3% |
| Quality control | 14% | 39% | 19% | 8% |
| Shipping | 61% | 11% | 6% | 6% |
| Disposal | 6% | 14% | 14% | 22% |

## B2.1 How often are different reading distances needed?

| Read distance | Frequency |
|---|---|
| <20cm | 3% |
| <50cm | 20% |
| <100 cm | 29% |
| <150 cm | 17% |
| >150cm | 31% |

## B2.2 How large must the memory capacity be?

| Capacity | Frequency |
|---|---|
| <64 bit | 3 % |
| <256 bit | 40% |
| <1k byte | 43% |
| <2k byte | 7% |
| >2k byte | 7% |

## B2.4 How suitable are different transponder forms?

| | Disks | Buttons | Glass | Labels |
|---|---|---|---|---|
| Most suitable | 8% | 11% | 17% | 56% |
| Suitable | 11% | 39% | 11% | 17% |
| Less suitable | 22% | 8% | 14% | 11% |
| Unsuitable | 25% | 6% | 28% | 0% |

**B2.5 Have you already discussed transponder applications, if yes where?**

| Yes | No | Logistics | Development | Sales |
|---|---|---|---|---|
| 59% | 41% | 71% | 14% | 14% |

**Do you need anti-collision, if so, what is the min, average and max number of tags?**

| Anti-collision | Ave. |
|---|---|
| 65% yes | 29 |

**What transponder temperature range is needed?**

| Min temp | Max temp |
|---|---|
| -18 C | +54 C |



## F.4 Logistics Service Provider's Responses to Questionnaires

Replies were received from 32 respondents representing 18 billion DM sales revenue.

### A1 Which services do you offer?

| | |
|---|---|
| Local transportation | 75% |
| National transportation | 81% |
| Intern. Transportation | 69% |
| Collection service | 50% |
| Warehousing | 78% |
| Cross-docking | 81% |
| Pick and pack | 63% |
| Air freight agency | 31% |
| Sea freight agency | 56% |
| Rail freight agency | 28% |
| Canal freight | 25% |
| Finishing | 22% |

### A2 In which market segment are you active?

| | |
|---|---|
| Collection service | 56% |
| Parcel and express | 13% |
| Cargo | 88% |
| Mixed goods | 38% |
| Hazardous goods | 69% |
| Temperature sensitive | 50% |
| Liquid transport | 38% |

### A4 How do you deliver goods to retailers?

| | |
|---|---|
| Direct | 44% |
| Indirect | 56% |
| Central warehouse | 19% |
| Own warehouse | 50% |

### A6 Where do you collect data manually or with barcodes?

| | Manual | Barcode |
|---|---|---|
| Receiving | 44% | 38% |
| Warehouse | 47% | 44% |
| Internal transport | 31% | 31% |
| Ext. transport | 50% | 34% |
| Finishing | 13% | 6% |
| Packing | 25% | 13% |
| Picking | 34% | 25% |
| Shipping | 28% | 41% |

### A7 Which bar-codes do you use?

| | |
|---|---|
| EAN 8 | 0% |
| EAN 13 | 0% |
| EAN 128 | 38% |
| 2/5 Interleave | 13% |

## F.5 Logistic Service Providers' Requirements to Transponder Systems



### B1.1 Which data do you receive and which is of interest?

| | Received | Of interest |
|---|---|---|
| Shipping unit number | 56% | 3% |
| EAN Shipping unit | 25% | 13% |
| Lot number | 50% | 0% |
| Quantity | 81% | 0% |
| Manufacturing date | 28% | 6% |
| Packing date | 19% | 0% |
| Best before date | 31% | 16% |
| Customer order number | 59% | 0% |
| Area | 6% | 25% |
| Net Volume | 44% | 16% |
| Net weight | 88% | 0% |
| Customer Int. Loc. No. | 22% | 3% |
| Product type | 31% | 3% |
| Serial number | 34% | 0% |
| Expiry date | 16% | 19% |

### B1.2 Which data do you make available and what is requested?

| | Available | Requested |
|---|---|---|
| Shipping unit number | 50% | 9% |
| EAN Shipping unit | 19% | 3% |
| Lot number | 53% | 3% |
| Quantity | 69% | 6% |
| Manufacturing date | 13% | 9% |
| Packing date | 28% | 0% |
| Best before date | 25% | 6% |

| | | |
|---|---|---|
| Customer order number | 38% | 6% |
| Area | 0% | 13% |
| Net Volume | 22% | 13% |
| Net weight | 69% | 3% |
| Customer Int. Loc. No. | 16% | 6% |
| Product type | 28% | 0% |
| Serial number | 31% | 0% |
| Expiry date | 6% | 9% |

### B1.3 How do you exchange data with the retailer and shipper?

| | Retailer | Manufacturer | Shipper |
|---|---|---|---|
| EDI | 25% | 69% | 56% |
| Post/Fax | 38% | 69% | 69% |
| Telephone | 34% | 59% | 53% |

### B1.5 Do you work principally with EAN128?

| | |
|---|---|
| Yes | 86% |
| No | 14% |

### B1.6 Dependence of smallest tagged unit on tag cost.

| Tag cost | 5DM | 2DM | 0.5DM | 0.2DM |
|---|---|---|---|---|
| Individual article | 0% | 3% | 6% | 13% |
| Pack | 0% | 6% | 0% | 31% |
| Carton | 0% | 9% | 19% | 22% |
| Pallet | 6% | 25% | 3% | 19% |
| Load | 25% | 19% | 0% | 6% |

### B1.7 In which area is it important to be able to write data?

| | V. important | Important | Less important | Unimportant |
|---|---|---|---|---|
| Receiving | 38% | 19% | 0% | 0% |
| Warehouse storage | 41% | 13% | 6% | 0% |
| Stock taking | 31% | 6% | 19% | 0% |
| Finishing | 13% | 3% | 9% | 25% |
| Picking | 6% | 16% | 0% | 31% |
| Packing | 25% | 25% | 6% | 13% |
| Quality control | 19% | 25% | 3% | 19% |
| Tracking of shipments | 56% | 9% | 3% | 6% |
| Cross docking | 34% | 16% | 0% | 0% |

### B2.1 How often are different reading distances needed?

| Read distance | Frequency |
|---|---|
| <50 cm | 13% |
| <100cm | 3% |
| <150cm | 19% |
| >150 cm | 65% |

## B2.2 How large must the memory capacity be?

| Capacity | Frequency |
|---|---|
| <64 bit | 17% |
| <256 bit | 22% |
| <1k Byte | 13% |
| <2k Byte | 22% |
| >2k Byte | 26% |

## B2.4 How suitable are different transponder forms?

| | Disks | Buttons | Glass | Labels |
|---|---|---|---|---|
| Most suitable | 6% | 13% | 3% | 56% |
| Suitable | 19% | 31% | 6% | 19% |
| Less suitable | 22% | 6% | 9% | 6% |
| Unsuitable | 13% | 3% | 44% | 0% |

## B2.5 Have you already discussed transponder applications, if yes where?

| Yes | No | Parcels | Sales | Customer | Direct | Tracking |
|---|---|---|---|---|---|---|
| 60% | 40% | 17% | 17% | 33% | 17% | 17% |

## Do you need anti-collision, if so, what is the min, average and max number of tags?

| Anti-collision | Ave. |
|---|---|
| 70% yes | 26 |

## What transponder temperature range is needed?

| Min temp | Max temp |
|---|---|
| -25 C | +58 C |

# Annex G
(informative)

## JEIDA Study Report

# RFID Tag Study Report

For ISO / IEC JTC1 / SC31 / WG4 / ARP



March 4, 2000

JEIDA RFID Tag Project

(Japan Electronic Industry Development Association)

# 1 Introduction

With the recent spread of information technology (IT) and economic globalization, international distribution of personnel and products should become an increasingly expanding field. Wireless identification of individuals and products using RFID technology is also on the verge of rapid expansion.

RFID technology has two areas of application. The first is hand-held non-contact IC cards for pay phones, commuter rail passes or the like.

The second is SCM (supply chain management), in which RFID (wireless IC) tags are used to manage the flow of products during physical distribution by being attached to containers, pallets or products.

In both these areas, the challenges are to create an international RFID standard, and develop low-cost RFID technology. In the first application area, international standards for non-contact IC cards are under review by IS/IEC, JTC1 and SC17/WG8, and are nearing finalization. International standards for the second application area have been under review by ISO/IEC, JTC1 and SC31/WG4 since 1998, and are nearly midway through completion.

As the institution in charge of ISO/IEC, JTC1 and SC31 standards in Japan, JEIDA has worked on standardization and technical research of linear bar codes and 2D codes. Since forming the RFID Tag Project in 1998, JEIDA has been actively working on RFID research, concentrating on the future development of RFID.

JEIDA's RFID Tag Project has proposed its findings to ISO/IEC/JTC1/SC31/WG4 as a midterm report for Japanese standardization. It has also submitted a draft technical report for application specification requirements to WG4/ARP. The final report on the findings of JEIDA's RFID Tag Project is being submitted to SC31/WG4/ARP in March 2000.

JEIDA's RFID Tag Project has been carried out by a specially-created working group under the leadership of a technical committee whose major members are representatives of MITI, the Japanese Standards Association, the academic world and a physical distribution industry organization. The working group consists of an RFID tag system developer, a physical distribution company and a freight user. The purpose of the study is to conduct substantive tests to investigate the problems that arise when RFID tags are introduced to physical distribution sites, and to submit Japan's first international standard proposal to SC31/WG4.

T. Yoshioka Project Editor

## 2 Study Findings

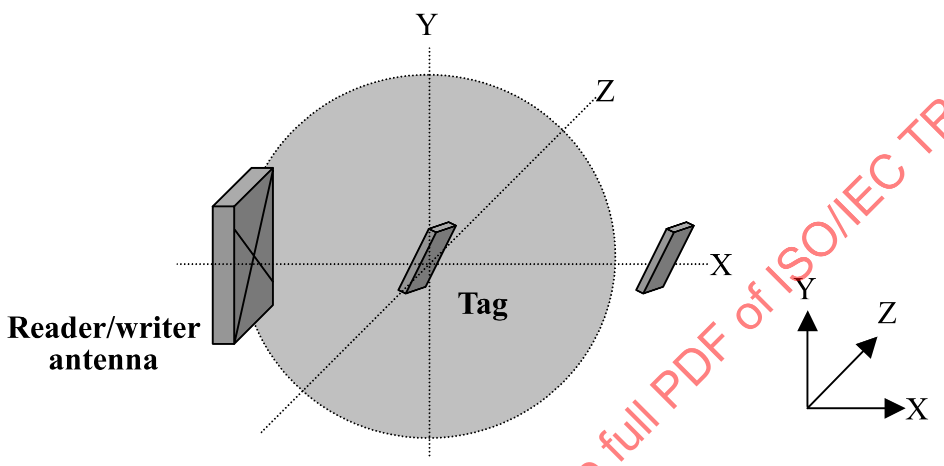
When RFID tags are used in physical distribution sites, reader/writers and tags must operate under various conditions. The tests carried out by the project confirmed the operating characteristics of the equipment under the basic conditions described.

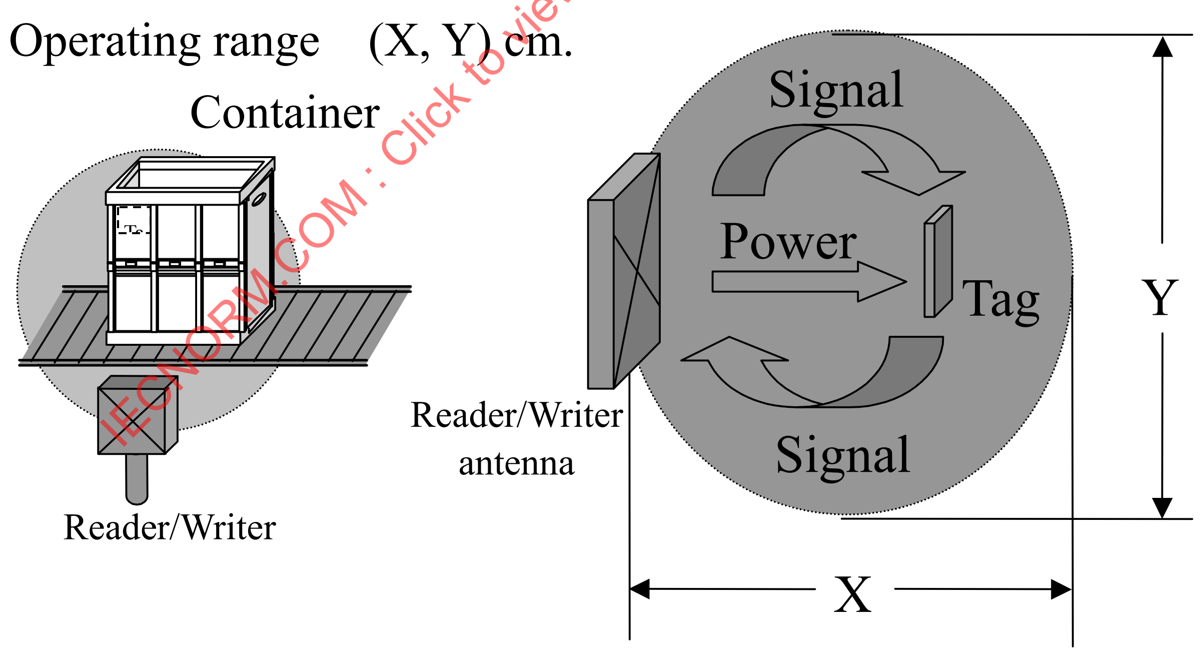
### 2.1 Single-tag operating characteristics

One reader/writer was provided for each tag. The tags were attached to the front or sides of plastic containers.

### 2.1.1 Operating range

(1) Standard model






The reader/writer antenna sent the power and signal to the tag, and the tag returned a response signal to the reader/writer.

- Ratio of reader/writers to tags: 1:1

- Effect of tag's orientation was ignored
- Effects from metallic substances were eliminated

The tag coil's magnetic field *H* (AT/m) at a position *r* (m) from the reader/writer antenna coil is given by:

$$H = K\frac{a^2}{r^3}i$$

$a$ : Radius of reader/writer antenna coil (m)

$r$ : Distance from reader/writer antenna coil to tag (m)

$i$ : Current in reader/writer antenna coil (A)

$K$ : Constant

To increase the magnetic field at the tag's position, the reader/writer antenna coil's radius (*a*) must be increased, or the current in the antenna coil (*i*) must be increased.

The strength of the magnetic field attenuated in proportion to the inverse of the distance (r) cubed.

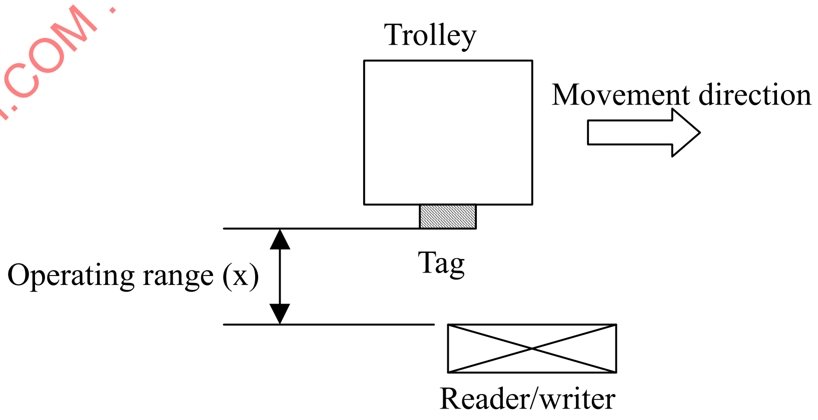
By increasing the diameter of the RFID tag's antenna coil, the signal induced in the tag's coil could be increased. Accordingly, for applications that require long range operation, the reader/writer antenna coil radius and tag antenna coil dimensions must be increased. In tests comparing coin-sized and IC card-sized tags using the same reader/writer, the IC-card sized tag had an operating area several times larger than the coin-sized tag.

(2) Test Results

1) Effect of tag size on operating range

- Test method

  A tag was attached to a trolley, and the operating range was measured while a researcher pushed the trolley in front of the reader/writer at a natural speed. The test was conducted with attached tags of various sizes, and the effect of the tag size on the operating range was measured.

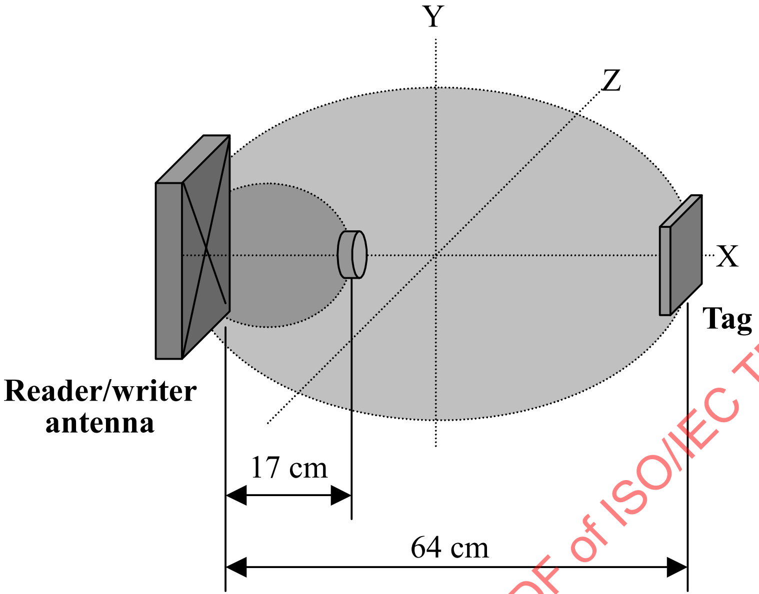



- Evaluation system

| | |
|---|---|
| Carrier frequency | : 125 kHz |
| Modulation and degree of modulation | : ASK 100% |
| Communication speed | : 5 kbps |
| Reader/writer antenna dimensions | : 65 × 20 cm |

- Test results

| | | |
|---|---|---|
| Tag dimensions | $\phi$ 2 cm | 11 × 11 cm |
| Tag surface area | 3.14 $cm^2$ | 121 $cm^2$ |
| Operating range (x) | 17 cm | 64 cm |




- Test site

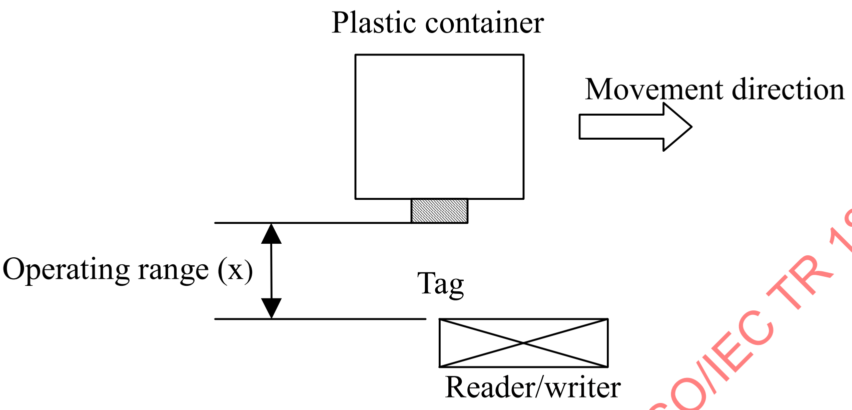
- Square tag (11 × 11 cm) mounting position


- Coin tag (ϕ 2 cm) mounting position

## 2) Effect of reader/writer antenna size on operating range

- Test method

A tag was attached to a plastic container, and the operating range was measured while the container moved in front of the reader/writer on a conveyor (at a velocity of 10 m/minute). The test was conducted with reader/writer antennas of various sizes, and the effect of the antenna size on the operating range was measured.

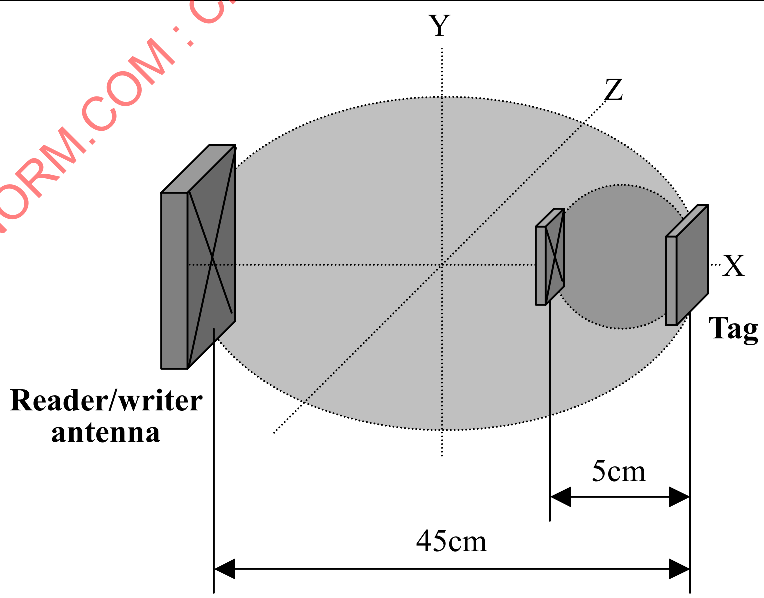



- Evaluation system

Carrier frequency: 125 kHz
Modulation and degree of modulation: PSK
Communication speed : 7.8 kbps
Tag dimensions: 9 × 7 cm

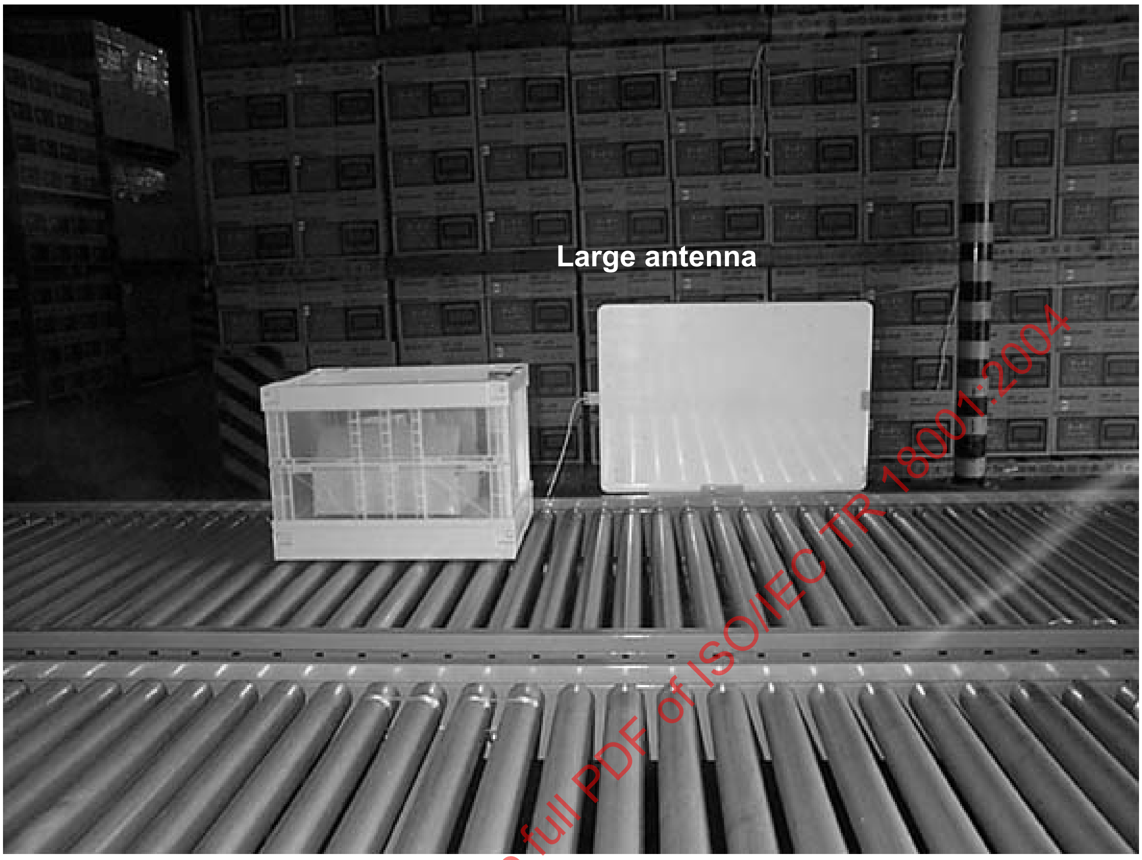
- Test results

| | | | |
|---|---|---|---|
| Antenna dimensions | 7 × 5 cm | 30 × 30 cm | 70 × 50 cm |
| Antenna surface area | 35 $cm^2$ | 900 $cm^2$ | 3500 $cm^2$ |
| Operating range (x) | 5 cm | 30 cm | 45 cm |

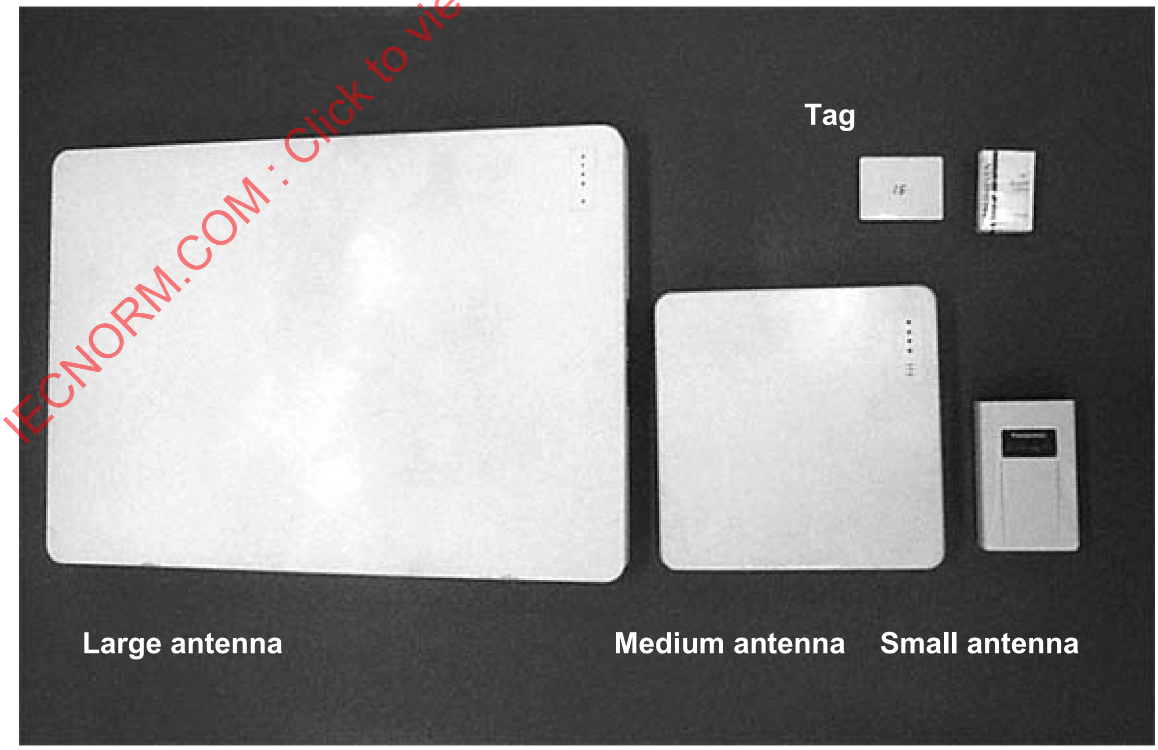



The larger the antenna was made, the longer the operating range became.

- Test site

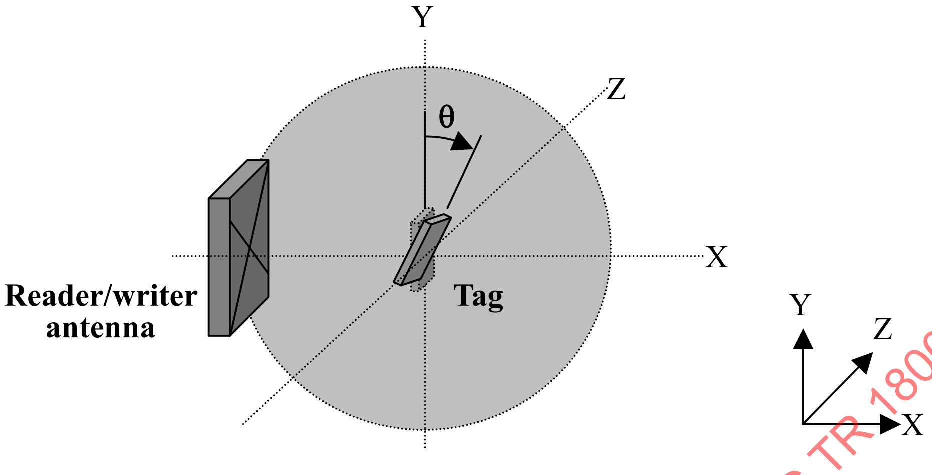



- Comparison of antennas



### 2.1.2 Tag orientation

(1) Standard model




The tag orientation characteristic also affected the tag operating range characteristic discussed in the previous section. The operating range (area) varied as the angle of the reader/writer antenna coil relative to the tag antenna coil changed.

This effect is referred to as the tag's orientation characteristic.

Below is an example for an inductive frequency band RFID tag.

When the angle of inclination from the Y-axis (parallel to the plane of the reader/writer antenna coil) is $\theta$,

$\theta = 0°$ (parallel) : Maximum operating range

$\theta = 90°$ (perpendicular) : Minimum operating range

RFID tags were attached to the front (0°) and sides (90°) of plastic containers, and the operating range was tested.

The operating characteristic was also checked with $\theta$ values of 0, 30, 60 and 90 degrees.

(2) Test results

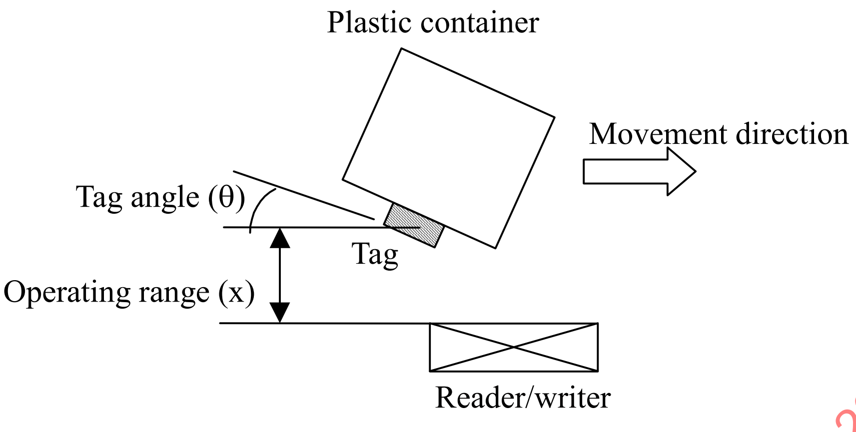
Effect of tag angle on operating range

Evaluation method

A tag was attached to a plastic container, and the operating range was measured while the container moved in front of the reader/writer on a conveyor (at a velocity of 10 m/minute). The test was conducted with the plastic container at various angles, and the effect of the tag angle on the operating range was measured.






Evaluation system

| | |
|---|---|
| Carrier frequency | : 125 kHz |
| Modulation and degree of modulation | : PSK |
| Communication speed | : 7.8 kbps |
| Tag dimensions | : 9 × 7 cm |
| Reader/writer antenna dimensions | : 70 × 50 cm |

Evaluation results

| Tag angle (θ) | 0° | 30° | 60° | 90° |
|---|---|---|---|---|
| Operating range (x) | 45 cm | 40 cm | 35 cm | 30 cm |

When the tag angle was 90°, the operating range decreased by 30%.



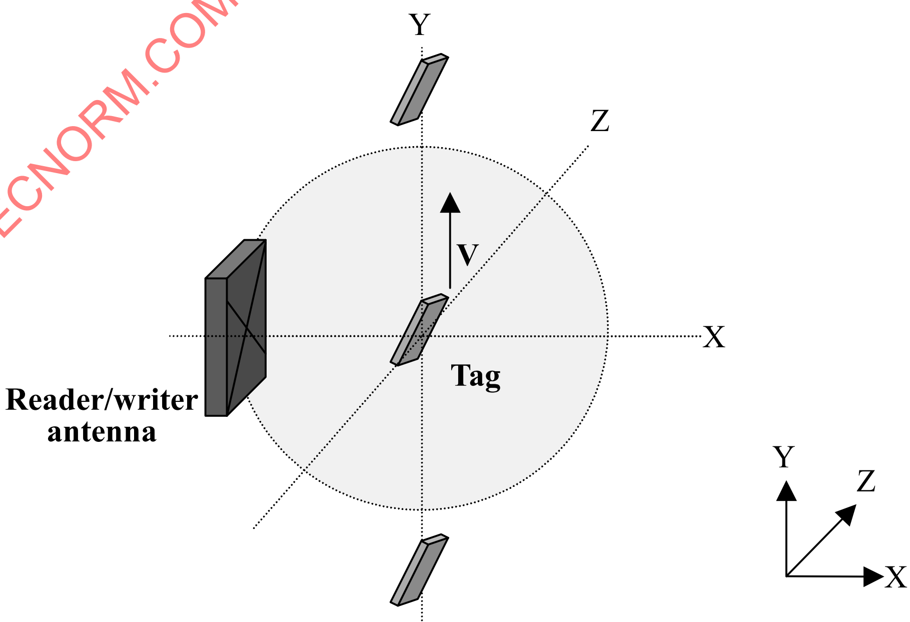
 

• Test site

### 2.1.3 Tag operating time

(1) Standard model

When containers or freight are moved on a conveyor or similar equipment in a tag reader system, the reader/writer must read and write data to and from moving tags. For successful access, the following conditions must be satisfied:



$$\mathrm{Tc} = \frac{\mathrm{Dc}}{\mathrm{Dr}} \times \mathrm{ANC} \quad \text{.......} \quad (1)$$

$$\mathrm{Tr} = \frac{\mathrm{L}}{\mathrm{Vtag}} \quad \text{.......} \quad (2)$$

$$\mathrm{Tr} \geq \mathrm{Tc} + \mathrm{Tdct} \quad \text{.......} \quad (3)$$

| | |
|---|---|
| Tr (sec) | : Amount of time tag is in operating area |
| Tc (sec) | : Tag-reader/writer operation time |
| Dr (bps) | : Data transfer rate |
| Dc (bit) | : Data transfer volume |
| Acn (count) | : Average number of tag-reader/writer operations |
| Vtag (m/s) | : Tag movement velocity |
| L (m) | : Distance tag moves within operating area |
| Ntag | : Number of tags |
| Tdct (sec) | : Amount of time for detecting existence of all tags |

Formulas (1) and (2) show that when the tag's data transfer volume (Dc (bits)) increases and the data transfer rate (Dr (bps)) decreases, the tag-reader/writer operation time (Tc (sec)) increases, and operation may fail.

Formula (2) shows that when the reader/writer operating area decreases, the distance the tag moves (L (m)) decreases, and the tag movement velocity (Vtag (m/s)) increases, the amount of time the tag is in the operating area (Tr (sec)) decreases, and operation may fail.

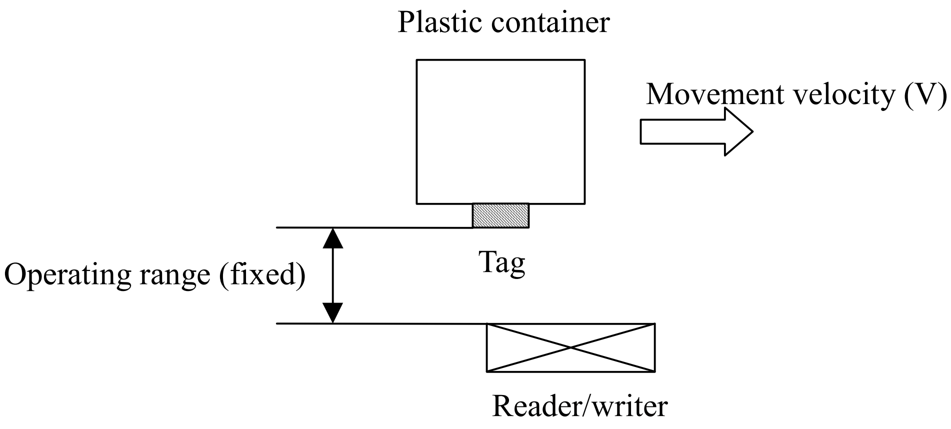
If only one type of tag can be used when reading/writing RFID tags attached to freight on a conveyor belt, the reader/writer antenna must have a large operating area to cope with the conveyor belt's speed.

(2) Test results

Effect of tag movement velocity on operating success rate

Evaluation method

A tag was attached to a plastic container, and the operating success rate was measured while the container moved in front of the reader/writer on a conveyor. The test was conducted with the conveyor moving at various velocities, and the effect of the velocity on the operating success rate was measured.




Evaluation system

| | |
|---|---|
| Carrier frequency | : 13.5 MkHz |
| Modulation and degree of modulation | : ASK 10% |
| Communication speed | : 1.65 kbps |
| Communication data volume | : 48 bytes |
| Tag dimensions | : 7 × 4.5 cm |
| Reader/writer antenna dimensions | : 40 × 30 cm |
| Operation mode | : Read |

Evaluation results

| Tag movement velocity (V) | 10 m/minute | 20 m/minute | 30 m/minute | 40 m/minute |
|---|---|---|---|---|
| Operating success rate | 100% | 100% | 100% | 100% |

Measurements were taken only for conveyor speeds of up to 40 m/minute, but operation is possible with a Vtag of up to 72 (m/minute). In this case, the operating area (L) is 0.4 m, and the amount of time for detecting the tag's existence (Tdct (sec)) is about 0.1 second for single operation:

$Tc = 48 \times 8/1650 \times 1 = 0.23$ (sec)

$Tr = 0.4/Vtag$

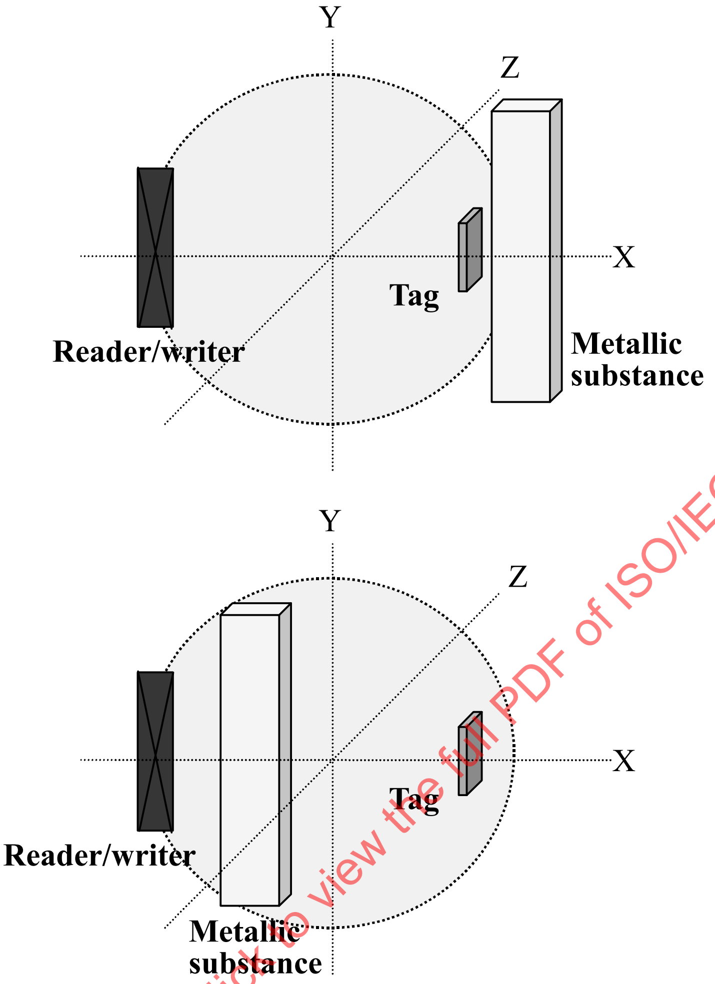
Substituting these values into $Tr \geq Tc + Tdct$:

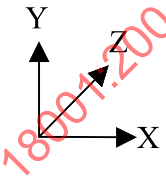
$0.4/Vtag \geq 0.23 + 0.1 = 0.33$

$Vtag \leq 0.4/0.33 = 1.21$ (m/sec) = 72 (m/minute)

### 2.1.4 Effect of metallic substances

(1) Standard model






Metallic substances in the reader/writer's operating area reduce the size of the operating area.

This effect could be caused by the metal screening the electromagnetic waves.

The top figure shows a model seen from the front of the reader/writer antenna, when a metallic substance is present at the rear of the tag. In this case, the effect of the metallic substance increases when the distance between the tag and metallic substance ($\Delta$d) decreases. However, the effect is minute when this distance is between 3 and 6 cm.

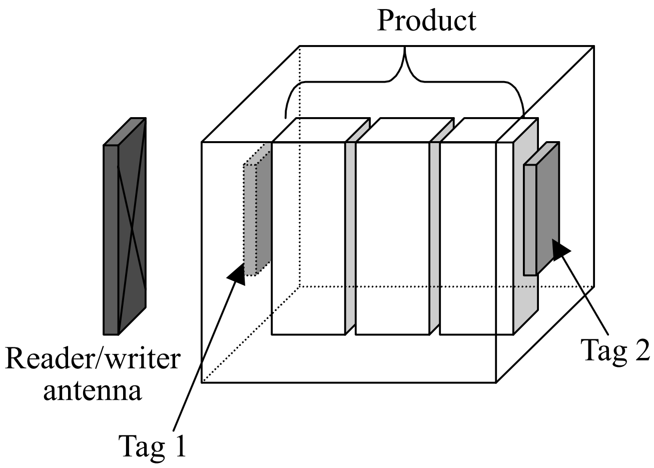
The bottom figure shows a model in which the metallic substance is present between the reader/writer antenna and tag. In this case, there is a large screening effect on the electromagnetic waves, and operation may fail completely under some conditions.

(2) Test results

a) Products were placed in a plastic container and transported. Operation was tested with the RFID tag attached on the outside of the container case (the Tag 1 position in the diagram below). Even with products that were mostly metal, (such as CD-ROM drives and electric appliances), there was almost no effect on the operating characteristic when the product was placed between 3 and 6 cm or more from the inside wall of the case. Operation was also tested with the RFID tag attached to the far side of the container relative to the reader/writer antenna, on the outside of the case (Tag 2 position).

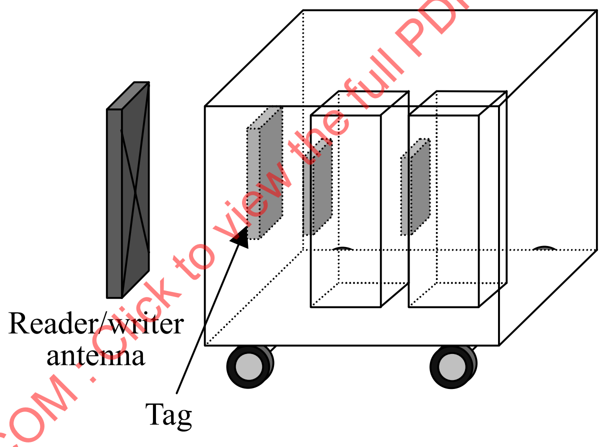
 

There was a large effect on operation for products that were mostly metal, and the operating range decreased by between about 30 and 50%.




b) RFID tags were attached directly to individual products under the conditions described in a). When the products were in cans, there was a large screening effect on the electromagnetic waves, and operation was almost impossible.

c) RFID tags were attached to a trolley (made of metal). A metal trolley affected the operating characteristic, causing a 20 to 30% decrease in operating range.




d) RFID tags were attached directly to individual products under the conditions in c). When the products were mostly metal, the screening effect on the electromagnetic waves made operation almost impossible.



Effect of metal items on operating range

Evaluation method

A tag was attached to a plastic container or trolley, and a product containing metal was placed directly behind it. The operating range was measured while the container moved in front of the reader/writer on a conveyor (at a velocity of 10 m/minute). The test was conducted with various products, and the effect of the product on the operating range was measured.