

BS ISO/IEC 18000-3:2010



BSI Standards Publication

# Information technology — Radio frequency identification for item management

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

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**Information technology — Radio  
frequency identification for item  
management —**

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

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

*Partie 3: Paramètres de communications d'une interface d'air à  
13,56 MHz*



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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.

ISO/IEC 18000-3 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 31, *Automatic identification and data capture techniques*.

This third edition cancels and replaces the second edition (ISO/IEC 18000-3:2008), which has been technically revised.

ISO/IEC 18000 consists of the following parts, 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*

## Introduction

ISO/IEC 18000 has been developed in order to

- provide a framework to define common communications protocols for Internationally useable frequencies for radio frequency identification (RFID), and, where possible, to determine the use of the same protocols for all frequencies such that the problems of migrating from one to another are diminished;
- minimise software and implementation costs;
- enable system management and control and information exchange to be common as far as is possible.

This part of ISO/IEC 18000 was prepared in accordance with the requirements determined in ISO/IEC 18000-1.

ISO/IEC 18000-1 provides explanation of the concepts behind this part of ISO/IEC 18000.

This part of ISO/IEC 18000 has 3 MODES of operation, intended to address different applications. The detailed technical differences between the MODES are shown in the parameter tables.

This part of ISO/IEC 18000 relates solely to systems operating at 13,56 MHz.

The International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) draw attention to the fact that it is claimed that compliance with this document may involve the use of patents.

The ISO and IEC take no position concerning the evidence, validity and scope of these patent rights.

The holders of these patent rights have assured the ISO and IEC that they are willing to negotiate licenses under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statements of the holders of these patent rights are registered with the ISO and IEC. Information may be obtained from the following companies.

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# Information technology — Radio frequency identification for item management —

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

### 1 Scope

This part of ISO/IEC 18000 provides physical layer, collision management system and protocol values for RFID systems for item identification operating at 13,56 MHz in accordance with the requirements of ISO/IEC 18000-1.

This part of ISO/IEC 18000 provides definitions for systems for each MODE determined in Clause 6 below.

This part of ISO/IEC 18000 defines three non-interfering MODES.

- The MODES are not interoperable.
- The MODES, whilst not interoperable, are non-interfering.

### 2 Conformance

In order to claim conformance with this part of ISO/IEC 18000, it is necessary to comply with all of the relevant clauses of this part of ISO/IEC 18000 except those marked “optional”. It is also necessary to operate within the local national radio regulations (which may require further restrictions).

Relevant conformance test methods are defined in ISO/IEC TR 18047-3.

### 3 Normative references

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

ISO/IEC 13239, *Information technology — Telecommunications and information exchange between systems — High-level data link control (HDLC) procedures*

ISO/IEC 7816-6, *Identification cards — Integrated circuit cards — Part 6: Interindustry data elements for interchange*

ISO/IEC 15693 (all parts), *Identification cards — Contactless integrated circuit cards — Vicinity cards*

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

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

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

ISO/IEC 18000-1, *Information technology — Radio frequency identification for item management — Part 1: Reference architecture and definition of parameters to be standardized*

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

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

ISO/IEC 19762 (all parts), *Information technology — Automatic identification and data capture (AIDC) techniques — Harmonized vocabulary*

EPCglobal *Tag Data Standards (Version 1.3 and above)*

## 4 Terms and definitions

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

### 4.1

#### **cover-coded text**

information that is cover-coded

### 4.2

#### **cover-coding**

method by which an interrogator obscures information that it is transmitting to a tag

### 4.3

#### **full-duplex communications**

communication of data while the transceiver transmits the activation field

### 4.4

#### **half-duplex communications**

data transmission in either direction, one direction at a time

### 4.5

#### **handle**

16-bit random number (RN16) that is used to authenticate tags in the open or secured state

### 4.6

#### **PacketCRC**

16-bit cyclic-redundancy check (CRC) code that a tag with nonzero-valued XPC indicator (XI) dynamically calculates over its protocol control (PC), extended protocol control (XPC), and unique item identifier (UII), and provides by loadmodulation during inventory

cf. **StoredCRC**

### 4.7

#### **PacketPC**

protocol-control information that a tag with nonzero-valued XPC indicator dynamically calculates and provides by loadmodulation during inventory

cf. **StoredPC**

#### 4.8

##### **phase jitter modulation**

##### **PJM**

modulation technique that transmits data as very small phase changes in the powering field

#### 4.9

##### **physical layer**

data coding and modulation waveforms used in interrogator-to-tag and tag-to-interrogator communication

#### 4.10

##### **pivot**

average length of an interrogator-to-tag data symbol

NOTE See 6.3.3.3.1.2.8.

#### 4.11

##### **plaintext**

information that is not cover-coded

#### 4.12

##### **recommissioning**

significant altering of a tag's functionality and/or memory contents, as commanded by an interrogator

NOTE Recommissioning is typically in response to a change in the tag's usage model or purpose.

#### 4.13

##### **StoredCRC**

16-bit cyclic-redundancy check (CRC) code that a tag calculates over its StoredPC and unique item identifier (UII) and stores in UII memory at power-up, and can backscatter during inventory

cf. **PacketCRC**

#### 4.14

##### **StoredPC**

protocol-control information stored in unique item identifier (UII) memory that a tag with zero-valued XPC indicator provides by loadmodulation during inventory

cf. **PacketPC**

#### 4.15

##### **Tari**

reference time interval for a data-0 in interrogator-to-tag communication

## 5 Symbols and abbreviated terms

For the purposes of this document, the symbols and abbreviated terms given in ISO/IEC 18000-1, ISO/IEC 19762 and the following apply.

### 5.1 Symbols

|                      |                                                                              |
|----------------------|------------------------------------------------------------------------------|
| <b>DR</b>            | ASK Method: divide ratio<br>PJM Method: bit 0 of the reply channel selection |
| <b>F<sub>c</sub></b> | carrier frequency                                                            |
| <b>M(ASK)</b>        | tag reply modulation type                                                    |
| <b>M<sub>h</sub></b> | RF signal envelope ripple (overshoot)                                        |
| <b>M<sub>l</sub></b> | RF signal envelope ripple (undershoot)                                       |
| <b>M(PJM)</b>        | bit 1 and bit 2 of the reply channel selection                               |

|                                              |                                                                                                                                |
|----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| <b>M<sub>s</sub></b>                         | RF signal level when OFF                                                                                                       |
| <b>Q</b>                                     | slot-count parameter<br>(parameter that an interrogator uses to regulate the probability of tag response)                      |
| <b>R</b>                                     | interrogator (also sometimes called reader)                                                                                    |
| <b>R=&gt;T</b>                               | interrogator-to-tag                                                                                                            |
| <b>RTcal</b>                                 | interrogator-to-tag calibration symbol                                                                                         |
| <b>T</b>                                     | tag                                                                                                                            |
| <b>T<sub>1</sub></b>                         | time from interrogator transmission to tag response                                                                            |
| <b>T<sub>2</sub></b>                         | time from tag response to interrogator transmission                                                                            |
| <b>T<sub>3</sub></b>                         | time an interrogator waits, after T <sub>1</sub> , before it issues another command                                            |
| <b>T<sub>4</sub></b>                         | minimum time between interrogator commands                                                                                     |
| <b>T<sub>f</sub> or T<sub>f,10-90%</sub></b> | RF signal envelope fall time                                                                                                   |
| <b>T<sub>pri</sub></b>                       | link pulse-repetition interval (T <sub>pri</sub> = 1/LF)                                                                       |
| <b>T<sub>r</sub> or T<sub>r,10-90%</sub></b> | RF signal envelope rise time                                                                                                   |
| <b>TRext</b>                                 | ASK Method: chooses whether the T=R preamble is prefixed with a pilot tone<br>PJM Method: bit 3 of the reply channel selection |
| <b>T<sub>s</sub></b>                         | RF signal settling time                                                                                                        |
| <b>T=&gt;R</b>                               | tag-to-interrogator                                                                                                            |
| <b>TRcal</b>                                 | tag-to-interrogator calibration symbol                                                                                         |
| <b>X<sub>fp</sub></b>                        | floating-point value                                                                                                           |
| <b>xxxx<sub>2</sub></b>                      | binary notation                                                                                                                |
| <b>xxxx<sub>h</sub></b>                      | hexadecimal notation                                                                                                           |
| <b>≈</b>                                     | MODE 1 - the value is a rounded value (e.g. ≈ 75,52 µs)                                                                        |

## 5.2 Abbreviated terms

|             |                                                     |
|-------------|-----------------------------------------------------|
| <b>ARIB</b> | Association of Radio Industries and Businesses      |
| <b>AFI</b>  | application family identifier                       |
| <b>AM</b>   | amplitude modulation                                |
| <b>ASK</b>  | amplitude shift keying                              |
| <b>BPSK</b> | binary phase shift keying                           |
| <b>CEPT</b> | Conference of European Posts and Telecommunications |
| <b>CFR</b>  | Code of Federal Regulations                         |
| <b>CRC</b>  | cyclic redundancy check                             |

NOTE: This specification uses two CRC algorithms: CRC-5 (5-bit CRC) and CRC-16 (16-bit CRC) and three different logical CRC-16s: StoredCRC, PacketCRC and CRC-16c.  
For the UII bank word 0 or ACK the following two logical CRC-16s are used:

- StoredCRC = CRC-16 calculated at startup and mapped to UII word 0
- PacketCRC = CRC-16 calculated over the response data of the tag in case of the ACK command

For all other cases and commands the following logical CRC-16 is used:

- CRC-16c = CRC-16 calculated over the response data of the tag

|                |                                                                      |
|----------------|----------------------------------------------------------------------|
| <b>CW</b>      | continuous wave                                                      |
| <b>dBch</b>    | decibels referenced to the integrated power in the reference channel |
| <b>DSB</b>     | double sideband                                                      |
| <b>DSB-ASK</b> | double-sideband amplitude shift keying                               |

|               |                                                                                        |
|---------------|----------------------------------------------------------------------------------------|
| <b>DR</b>     | divide ratio                                                                           |
| <b>ERC</b>    | European Radiocommunications Committee                                                 |
| <b>ERM</b>    | electromagnetic compatibility and radio spectrum matters                               |
| <b>ETSI</b>   | European Telecommunications Standards Institute                                        |
| <b>FCC</b>    | Federal Communications Commission                                                      |
| <b>FT</b>     | frequency tolerance                                                                    |
| <b>ITF</b>    | interrogator talks first (reader talks first)                                          |
| <b>LF</b>     | link frequency ( $LF = 1/T_{pri}$ )                                                    |
| <b>MFM</b>    | modified frequency modulation                                                          |
| <b>N/A</b>    | not applicable                                                                         |
| <b>NSI</b>    | numbering system identifier                                                            |
| <b>PIE</b>    | pulse-interval encoding                                                                |
| <b>PJM</b>    | phase jitter modulation                                                                |
| <b>ppm</b>    | parts-per-million                                                                      |
| <b>PC</b>     | protocol control                                                                       |
| <b>RF</b>     | radio frequency                                                                        |
| <b>RFU</b>    | reserved for future use                                                                |
| <b>RN16</b>   | 16-bit random or pseudo-random number                                                  |
| <b>RNG</b>    | random or pseudo-random number generator                                               |
| <b>SRD</b>    | short range devices                                                                    |
| <b>TDM</b>    | time-division multiplexing or time-division multiplexed (as appropriate)               |
| <b>TID</b>    | tag identification or tag identifier, depending on context                             |
| <b>UII</b>    | unique item identifier                                                                 |
| <b>UMI</b>    | user-memory indicator                                                                  |
| <b>XI</b>     | XPC indicator                                                                          |
| <b>XPC</b>    | extended protocol control                                                              |
| <b>XPC_W1</b> | XPC word 1                                                                             |
| <b>XPC_W2</b> | XPC word 2                                                                             |
| <b>XTID</b>   | extended TID indicator (see version 1.3 and above of the EPCglobal Tag Data Standards) |

### 5.3 Notation

Mode 3 of this specification uses the following notational conventions:

- States and flags are denoted in bold. Example: **ready**.
- Commands are denoted in italics. Variables are also denoted in italics. Where there might be confusion between commands and variables, this specification shall make an explicit statement. Example: *BeginRound*.
- Procedures are shown as **italics underline**
- Command parameters are underlined. Example: Pointer.
- For logical negation, labels are preceded by '~'. Example: If **flag** is true, then **~flag** is false.
- The symbol,  $R \Rightarrow T$ , refers to commands or communications signal air interface from an interrogator to a tag (reader-to-tag).

- The symbol, T=>R, refers to commands or communications signal air interface from a tag to an interrogator (tag-to-reader).

## 6 Requirements: Physical layer, collision management system and protocol values for 13,56 MHz systems

### 6.0 General and applicable to All Modes

#### 6.0.1 Presentation as determined in ISO/IEC 18000-1

The context, form and presentation of this part, which provides physical layer, collision management system and protocol value definitions for RFID systems for item identification operating at 13,56 MHz are in accordance with the requirements of ISO/IEC 18000-1.

#### 6.0.2 ISO/IEC 18000-3 Interoperability

This part of ISO/IEC 18000 specifies three MODES of operation at 13,56 MHz. These MODES are not interoperable, but they are expected to operate without causing any significant interference with each other. Any known causes of interference are listed in Annex O.

NOTE 1 It is recommended that users select one MODE for any specific application.

NOTE 2 Local national regulations may further limit either power, frequency or bandwidth allocations and such limitations may reduce the capability of a system within that country. Users shall have the responsibility to ensure that they use only systems that comply with these regulations. This implies a user responsibility to obtain proofs from manufacturers, and where appropriate have adequate tests carried out to assure that systems are in compliance.

NOTE 3 At the time of preparation of this part of ISO/IEC 18000, the interrogator to tag link and tag to interrogator link physical layer emissions may be subject to type approval or certification. It is therefore necessary to make reference to local or regional radio regulations and radio standards in addition to this part of ISO/IEC 18000. All systems are required to comply with local radio regulations, which may affect performance.

#### 6.0.3 ISO/IEC 18000-3 interrogator conformance/compliance

To claim compliance with this part of ISO/IEC 18000, an interrogator/ reader shall support either MODE 1, MODE 2, or MODE 3. The interrogator may support any or all modes as an option (the modes are not interoperable).

#### 6.0.4 ISO/IEC 18000-3 tag compliance

To claim compliance with this part of ISO/IEC 18000, a tag shall support either MODE 1, MODE 2, or MODE 3. The tag may support any or all modes as an option (the modes are not interoperable).

#### 6.0.5 Command structure and extensibility

Clauses 6.1, 6.2, and 6.3, include definition of the structure of command codes between an interrogator and a tag and indicate how many positions are available for future extensions. Command specification clauses provide a full definition of the command and its presentation. Each command is labelled as being “mandatory” or “optional”. In accordance with ISO/IEC 18000-1, the clauses of this part of ISO/IEC 18000 make provision for “custom” and “proprietary” commands.

The types of permitted command options are defined in subclauses 6.0.6 to 6.0.9.

#### 6.0.6 Mandatory commands

A mandatory command shall be supported by all tags that claim to be compliant. Interrogators which claim compliance shall support all mandatory commands.

### 6.0.7 Optional commands

Optional commands are commands that are specified within the International Standard. Interrogators shall be technically capable of performing all optional commands that are specified in the International Standard (although need not be set up to do so). Tags may or may not support optional commands.

If an interrogator or a tag implements an optional command, it shall implement it in the manner specified in this standard.

### 6.0.8 Custom commands

Custom commands may be enabled by an International Standard, but they shall not be specified in that International Standard.

A custom command shall not solely duplicate the functionality of any mandatory or optional command defined in the International Standard by a different method. An interrogator shall use a custom command only in accordance with the specifications of the tag manufacturer.

### 6.0.9 Proprietary commands

Proprietary commands may be enabled by an International Standard, but they shall not be specified in that International Standard.

A proprietary command shall not solely duplicate the functionality of any mandatory or optional command defined in the International Standard by a different method. Vendors shall not provide proprietary means to circumvent the protocol. Proprietary commands are intended for manufacturing purposes and shall not be used in field-deployed RFID systems.

## 6.1 Physical layer, collision management system and protocols for MODE 1

MODE 1 is not interoperable with any other MODES defined within this International Standard.

### 6.1.1 Read/Write system

MODE 1 describes a read/write system using a "interrogator talks first" technique.

### 6.1.2 Normative Aspects

The physical, collision management and transmission protocols determined in this MODE are defined in ISO/IEC 15693. Clauses 6.1.3 – 6.1.8 provide normative parts of MODE 1 by reference.

### 6.1.3 Conformance and performance measurement aspects

The performance and conformance measurement aspects for MODE 1 are given in the relevant clauses of Technical Reports (ISO/IEC TR 18046 and ISO/IEC TR 18047-3, respectively).

### 6.1.4 Physical Layer

The Physical layer for the MODE 1 air interface at 13,56 MHz shall be compliant with ISO/IEC 15693-2.

### 6.1.5 Protocol and collision management operating method

The collision management operating method for the MODE 1 air interface at 13,56 MHz shall be compliant with ISO/IEC 15693-3.

### 6.1.6 Commands

The commands for the MODE 1 air interface at 13,56 MHz shall be compliant with ISO/IEC 15693-3. Annex A shows the commands that are necessary to support encoding to ISO/IEC 15962, which is required for RFID for item management.

### 6.1.7 Parameter tables for interrogator to tag link

The parameter tables for interrogator to tag link for the MODE 1 air interface at 13,56 MHz shall be compliant with ISO/IEC 15693-2. See Table 1 — Parameter Tables for interrogator to tag link for details.

**Table 1 — Parameter Tables for interrogator to tag link**

| Ref.       | Parameter                                                                                                             | Description/limits                                                                                                                                                                                                                                                                                                                                           | Options/Comments                                                                                                                                                                                                                                                                                                                            |
|------------|-----------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| M1-Int: 1  | Operating frequency range                                                                                             | 1 interrogator to tag link channel at (centre frequency) 13,56MHz $\pm$ 7 kHz                                                                                                                                                                                                                                                                                |                                                                                                                                                                                                                                                                                                                                             |
| M1-Int: 1a | Default operating frequency                                                                                           | 13,56 MHz                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                             |
| M1-Int: 1b | Operating channels (for spread spectrum systems)                                                                      | N/A                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                             |
| M1-Int: 1c | Operating frequency accuracy                                                                                          | +/- 100 parts per million<br>+/- 50 parts per million in Japan                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                                                                                                                                             |
| M1-Int: 1d | Frequency hop rate (for Frequency hopping [FHSS] systems)                                                             | N/A                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                             |
| M1-Int: 1e | Frequency hop sequence (for Frequency hopping [FHSS] systems)                                                         | N/A                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                             |
| M1-Int: 2  | Occupied channel bandwidth                                                                                            | 13,56 MHz $\pm$ 7 kHz<br>with modulation as defined in 6.1.4                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                             |
| M1-Int: 2a | Minimum receiver bandwidth                                                                                            | 13,56 MHz $\pm$ (423,75 $\pm$ 40 kHz)<br>13,56 MHz $\pm$ (484,28 $\pm$ 40 kHz)                                                                                                                                                                                                                                                                               | Centred at the sub carrier frequency.                                                                                                                                                                                                                                                                                                       |
| M1-Int: 3  | Interrogator transmit maximum Magnetic Field Strength<br><br>Magnetic Field Strength limits within communication zone | The interrogator shall not generate a field higher than 12 A/m in any part of the volume where a tuned ISO card sized tag may be present<br><br>Maximum operating field strength:<br><br>5 A/m for ISO card sized tags, as defined in ISO/IEC 7810. For other label form factors, the label manufacturer shall specify the maximum operating field strength. | (Inductive coupling)<br><br>Where Local regulations restrict the Magnetic Field Strength Limits below those determined in this Clause, a degradation of local performance may be expected.<br><br>Test methods for determining the interrogator operating field are defined in relative clauses of the Technical Report ISO/IEC TR 18047-3. |

| Ref.       | Parameter                                                                          | Description/limits                                                                                                                                                                                                                                                 | Options/Comments |
|------------|------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| M1-Int: 3a | Minimum operating field strength                                                   | Minimum Operating Field Strength: 150 mA/m for tuned ISO card sized tags.<br><br>Application requirements may result in a different minimum operating field strength. In that case the minimum operating field strength shall be declared by the tag manufacturer. |                  |
| M1-Int: 4  | Interrogator transmit spurious emissions                                           | compliant with regulations                                                                                                                                                                                                                                         |                  |
| M1-Int: 4a | Interrogator transmit spurious emissions, in-band<br>(for Spread spectrum systems) | N/A                                                                                                                                                                                                                                                                |                  |
| M1-Int: 4b | Interrogator transmit spurious emissions, out-of-band                              | N/A                                                                                                                                                                                                                                                                |                  |
| M1-Int: 5  | Interrogator transmitter spectrum mask                                             | The modulation technique and bit coding enable maximum tag powering within the following regulations:<br>US Jurisdictions : FCC 47 Part 15<br>EU : EN 300 – 330<br>Japan : ARIB STD – T82                                                                          |                  |
| M1-Int:6   | Timing                                                                             | See below.                                                                                                                                                                                                                                                         |                  |
| M1-Int: 6a | Transmit to receive turn around time                                               | $\leq 4320/f_c$                                                                                                                                                                                                                                                    |                  |
| M1-Int: 6b | Receive to transmit Turn around time                                               | $\geq 4192/f_c$                                                                                                                                                                                                                                                    |                  |
| M1-Int: 6c | Dwell time or Interrogator transmit power on ramp                                  | See 6.1.4                                                                                                                                                                                                                                                          |                  |
| M1-Int: 6d | Decay time or Interrogator transmit power down ramp                                | See 6.1.4                                                                                                                                                                                                                                                          |                  |
| M1-Int: 7  | Modulation                                                                         | Carrier amplitude modulation<br>(ASK 100%, ASK 10%....)                                                                                                                                                                                                            |                  |
| M1-Int: 7a | Spreading sequence<br>(for Frequency hopping [FHSS] systems)                       | N/A                                                                                                                                                                                                                                                                |                  |
| M1-Int: 7b | Chip rate<br>(for Spread Spectrum systems)                                         | N/A                                                                                                                                                                                                                                                                |                  |
| M1-Int: 7c | Chip Rate Accuracy<br>(for Spread spectrum systems)                                | N/A                                                                                                                                                                                                                                                                |                  |

| Ref.       | Parameter                                 | Description/limits                                                                                                                                                                                                                            | Options/Comments                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|------------|-------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| M1-Int: 7d | Modulation index                          | Two level amplitude modulation:<br>100% and 10%<br>Modulation Index: $(a - b) / (a + b)$<br>(NOTE Modulation Depth $(a - b) / a$ )                                                                                                            | Either option at determination of the interrogator (See 6.1.4). Two modulation indexes are permitted and are determined by the interrogator. The RF tag shall decode both. Modulation shall use the principle of ASK. Depending on the choice made by the interrogator.                                                                                                                                                                                                                                                       |
| M1-Int: 7e | Duty cycle                                | See 6.1.4                                                                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| M1-Int: 7f | FM deviation                              | N/A                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| M1-Int: 8  | Data coding                               | Data coding shall be implemented using pulse position modulation.<br><br>Two data coding modes shall be supported by the RF tag. The selection shall be made by the interrogator and indicated to the RF tag within the Start of frame (SOF). | <b>Data coding mode:</b><br><b>1 out of 256</b><br><br>The value of one single byte shall be represented by the position of one pulse. The position of the pulse on one of 256 successive time periods of 18,88 $\mu$ s (256/fc), determines the value of the byte.<br><br><b>Data coding mode:</b><br><b>1 out of 4</b><br><br>Pulse position modulation shall be used where the position determines two bits at a time. Four successive pairs of bits form a byte.<br><br>The resulting data rate is 26,48 kbit/s (fc/512). |
| M1-Int: 9  | Bit rate                                  | 1 out of 256 Data coding mode:<br>1,65 kbit/s (fc/8192)<br><br>1 out of 4 Data coding mode:<br>26,48 kbit/s (fc/512)                                                                                                                          | Either mode at the determination of the interrogator                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| M1-Int: 9a | Bit rate accuracy                         | Synchronous to the carrier frequency                                                                                                                                                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| M1-Int: 10 | Interrogator transmit modulation accuracy | N/A                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

### 6.1.8 Parameter tables for tag to interrogator link

The parameter tables for tag to interrogator link for the MODE 1 air interface at 13,56 MHz shall be compliant with ISO/IEC 15693-2. See Table 2 — Parameter Tables for tag to interrogator link for details.

**Table 2 — Parameter Tables for tag to interrogator link**

| Ref.       | Parameter Name                                                     | Description/limits                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Options/Comments |
|------------|--------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| M1-Tag: 1  | Operating frequency range<br>Subcarrier frequencies                | One or two subcarriers may be used. The selection between either shall be made by the interrogator using the first bit in the protocol header as defined in ISO/IEC 15693-3. The RF tag shall support both modes.<br>When one subcarrier is used, the frequency $f_{s1}$ of the subcarrier loadmodulation shall be $f_c/32$ (423,75 kHz).<br>When two subcarriers are used, the frequency $f_{s1}$ shall be $f_c/32$ (423,75 kHz), and the frequency $f_{s2}$ shall be $f_c/28$ (484,28 kHz).<br>When two subcarriers are used, continuous phase shall be used, as shown in supporting diagrams |                  |
| M1-Tag: 1a | Default operating frequency                                        | 13,56MHz $\pm$ 7 kHz                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                  |
| M1-Tag: 1b | Operating channels (for Spread spectrum systems)                   | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                  |
| M1-Tag: 1c | Operating frequency accuracy                                       | 13,56 MHz synchronous to the carrier                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                  |
| M1-Tag: 1d | Frequency hop Rate (for Frequency hopping [FHSS] systems)          | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                  |
| M1-Tag: 1e | Frequency hop sequence (for Frequency hopping [FHSS] systems)      | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                  |
| M1-Tag: 2  | Occupied channel bandwidth                                         | 13,56 MHz 4 subcarriers<br>1 sub carrier: 13,56 MHz<br>$\pm$ (423,75 kHz $\pm$ 40 kHz)<br>2 sub carriers: 2 channel: 13,56 MHz<br>$\pm$ (484,28 kHz $\pm$ 40 kHz)                                                                                                                                                                                                                                                                                                                                                                                                                               |                  |
| M1-Tag: 3  | Transmit Maximum Magnetic Field Strength                           | In accordance with local regulations                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                  |
| M1-Tag: 4  | Transmit spurious emissions                                        | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                  |
| M1-Tag: 4a | Transmit spurious emissions, in-band (for Spread spectrum systems) | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                  |
| M1-Tag: 4b | Transmit spurious emissions, Out-of-band                           | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                  |

| Ref.       | Parameter Name                                                                                      | Description/limits                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Options/Comments |
|------------|-----------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| M1-Tag: 5  | Transmit spectrum mask                                                                              | In compliance with:<br>US: FCC 47 Part 15<br>EU and other EN:300-330<br>(Transmit spectrum mask is not regulated in the Japan Radio Law)                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                  |
| M1-Tag: 6  | Timing                                                                                              | See below.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                  |
| M1-Tag: 6a | Transmit to receive turn around time                                                                | $\leq 4192/f_c$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                  |
| M1-Tag: 6b | Receive to transmit turn around time                                                                | Within $4320/f_c - 4384/f_c$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                  |
| M1-Tag: 6c | Dwell time or Transmit power on ramp                                                                | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                  |
| M1-Tag: 6d | Decay time or Transmit power down ramp                                                              | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                  |
| M1-Tag: 7  | Modulation (on the carrier)                                                                         | <p>The RF tag shall be capable of communication to the interrogator via an inductive coupling area whereby the carrier frequency is modulated to generate a subcarrier with frequency <math>f_s</math>. The subcarrier shall be generated by switching a load in the RF tag.</p> <p>Test methods for RF tag loadmodulation are defined in ISO/IEC TR 18047-3.</p> <p>The loadmodulation amplitude shall be at least 10 mV for ISO card sized tags when measured as described in the test methods.</p> <p>For other label form factors, the label manufacturer shall specify the loadmodulation.</p> |                  |
| M1-Tag: 7a | Spreading sequence (for Frequency hopping [FHSS] systems)                                           | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                  |
| M1-Tag: 7b | Chip rate (for Spread spectrum systems)                                                             | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                  |
| M1-Tag: 7c | Chip rate accuracy (for Spread spectrum systems)                                                    | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                  |
| M1-Tag: 7d | On-off ratio                                                                                        | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                  |
| M1-Tag: 7e | Subcarrier frequency                                                                                | <p>if one sub carrier is used : 423,75 kHz</p> <p>if two sub carriers are used :<br/>423,75 kHz and 484,28 kHz</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                  |
| M1-Tag: 7f | Subcarrier frequency accuracy<br><br>Tolerance of direct generated tag to Interrogator link carrier | Derived from the carrier.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                  |

| Ref.        | Parameter Name                                                          | Description/limits                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Options/Comments                                           |
|-------------|-------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------|
| M1-Tag: 7g  | Subcarrier modulation                                                   | <p>One Subcarrier: A logic <b>0</b> starts with 8 pulses of 423,75 kHz (<math>f_c/32</math>) followed by an unmodulated time of 18,88 <math>\mu</math>s. (<math>256/f_c</math>).<br/>A logic <b>1</b> starts with an unmodulated time of 18,88 <math>\mu</math>s (<math>256/f_c</math>) followed by 8 pulses of 423,75 kHz (<math>f_c/32</math>).</p> <p>Two subcarriers: A logic <b>0</b> starts with 8 pulses of 423,75 kHz (<math>f_c/32</math>) followed by 9 pulses of 484,28 kHz (<math>f_c/28</math>).<br/>A logic <b>1</b> starts with 9 pulses of 484,28 kHz (<math>f_c/28</math>) followed by 8 pulses of 423,75 kHz (<math>f_c/32</math>).</p> | Determined by the interrogator. RF tag shall support both. |
| M1-Tag: 7h  | Duty cycle                                                              | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                            |
| M1-Tag: 7 I | FM Deviation                                                            | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                            |
| M1-Tag: 8   | Data coding                                                             | Data shall be encoded using Manchester coding, of one or two subcarriers.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                            |
| M1-Tag: 9   | Bit rate                                                                | Refer to 6.1.4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                            |
| M1-Tag: 9a  | Bit rate accuracy                                                       | Derived from the carrier                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                            |
| M1-Tag: 10  | Tag transmit modulation accuracy (for Frequency hopping [FHSS] systems) | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                            |
| M1-Tag: 11  | Preamble                                                                | <p>Framing has been chosen for ease of synchronization and independence of protocol.</p> <p>Frames are delimited by a Start of frame (SOF) and an End of frame (EOF) and are implemented using code violation.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                            |
| M1-Tag: 11a | Preamble length                                                         | See 6.1.4.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                            |

| Ref.        | Parameter Name                              | Description/limits                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Options/Comments |
|-------------|---------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| M1-Tag: 11b | Preamble waveform                           | <p><b>:SOF when using one subcarrier</b></p> <p>The SOF comprises 3 parts:</p> <ol style="list-style-type: none"> <li>1: an unmodulated time of 56,64 <math>\mu</math>s (768/fc),</li> <li>2: 24 pulses of 423,75 kHz ( fc/32 ),</li> <li>3: followed by a logic <b>1</b> which starts with an unmodulated time of 18,88 <math>\mu</math>s. (256/fc) followed by 8 pulses of 423,75 kHz (fc/32).</li> </ol> <p><b>:SOF when using two subcarriers</b></p> <p>The SOF comprises 3 parts:</p> <ol style="list-style-type: none"> <li>1: 27 pulses of 484,28 kHz (fc/28 ),</li> <li>2: 24 pulses of 423,75 kHz (fc/32 ),</li> <li>3: a logic <b>1</b> which starts with 9 pulses of 484,28 kHz (fc/28) followed by 8 pulses of 423,75 kHz ( fc/32 )</li> </ol> <p><b>:EOF when using one subcarrier</b></p> <p>The EOF comprises 3 parts:</p> <ol style="list-style-type: none"> <li>1: a logic <b>0</b> which starts with 8 pulses of 423,75 kHz ( fc/32 ),</li> <li>2: an unmodulated time of 18,88<math>\mu</math>s (256/fc)</li> <li>3: 24 pulses of 423,75 kHz (fc/32), an unmodulated time of 56,64 <math>\mu</math>s (768/fc)</li> </ol> <p><b>:EOF when using two subcarriers</b></p> <p>The EOF comprises 3 parts:</p> <ol style="list-style-type: none"> <li>1: a logic <b>0</b> which starts with 8 pulses of 423,75 kHz ( fc/32 ) followed by 9 pulses of 484,28 kHz (fc/28),</li> <li>2: 24 pulses of 423,75 kHz (fc/32),</li> <li>3: 27 pulses of 484,28 kHz (fc/28).</li> </ol> |                  |
| M1-Tag: 11c | Bit sync sequence                           | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                  |
| M1-Tag: 12  | Scrambling<br>(for Spread spectrum systems) | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                  |
| M1-Tag: 13  | Bit transmission order                      | Least significant bit first                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                  |
| M1-Tag: 14  | Reserved                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                  |
| M1-Tag: 15  | Polarization                                | N/A (Near Field)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                  |
| M1-Tag: 16  | Minimum tag receiver bandwidth              | see transmitted / received signals 6.1.4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                  |

## 6.2 MODE 2: Physical layer, collision management system and protocols for MODE 2

MODE 2 is not interoperable with any other MODE defined in this part of ISO/IEC 18000.

MODE 2 is non-interfering with any other MODE defined in this part of ISO/IEC 18000.

The performance and conformance measurement aspects for MODE 2 shall be conformant with the relevant clauses of Technical Reports (ISO/IEC TR 18046 and ISO/IEC TR 18047-3, respectively).

**6.2.1 Normative aspects: physical and media access control (MAC) parameters: interrogator to tag link**

See Table 3 — Physical and media access control (MAC) parameters: interrogator to tag link.

**Table 3 — Physical and media access control (MAC) parameters: interrogator to tag link**

| Ref.       | Parameter Name                                                                                                                              | Description                                                                                                                                                                                                                                                        |
|------------|---------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| M2-Int: 1  | Operating frequency range                                                                                                                   | 13,56 MHz $\pm$ 7 kHz                                                                                                                                                                                                                                              |
| M2-Int: 1a | Default operating frequency                                                                                                                 | 13,56 MHz                                                                                                                                                                                                                                                          |
| M2-Int: 1b | Operating channels<br>(for Spread spectrum systems)                                                                                         | N/A                                                                                                                                                                                                                                                                |
| M2-Int: 1c | Operating frequency accuracy                                                                                                                | $\pm$ 100 parts per million<br>Japan: $\pm$ 50 parts per million                                                                                                                                                                                                   |
| M2-Int: 1d | Frequency hop rate<br>(for Frequency Hopping [FHSS] systems)                                                                                | N/A                                                                                                                                                                                                                                                                |
| M2-Int: 1e | Frequency hop sequence<br>(for Frequency Hopping [FHSS] systems)                                                                            | N/A                                                                                                                                                                                                                                                                |
| M2-Int: 2  | Occupied channel bandwidth                                                                                                                  | The modulation sidebands are very low in amplitude but spread wide. They satisfy the ETSI, and FCC regulations.<br>(Occupied channel bandwidth is not regulated in the Japan Radio Law).                                                                           |
| M2-Int: 2a | Minimum receiver bandwidth                                                                                                                  | Suitable to receive tag channel or channels of interest.                                                                                                                                                                                                           |
| M2-Int: 3  | Interrogator transmit maximum Magnetic Field Strength                                                                                       | The interrogator shall not generate a field higher than 12 A/m in any part of the volume where a tuned ISO card sized tag may be present                                                                                                                           |
| M2-Int: 3a | Minimum Operating Field Strength                                                                                                            | Minimum Operating Field Strength: 150 mA/m for tuned ISO card sized tags.<br><br>Application requirements may result in a different minimum operating field strength. In that case the minimum operating field strength shall be declared by the tag manufacturer. |
| M2-Int: 4  | Interrogator transmit spurious Emissions                                                                                                    | See below.                                                                                                                                                                                                                                                         |
| M2-Int: 4a | Interrogator transmit spurious emissions, in-band<br>(for Spread spectrum systems)                                                          | N/A                                                                                                                                                                                                                                                                |
| M2-Int: 4b | Interrogator transmit spurious emissions, out-of-band                                                                                       | Compliant with ETSI, ARIB STD-T82 and FCC maximum out of Band allowed field strength.                                                                                                                                                                              |
| M2-Int: 5  | Interrogator transmitter spectrum mask                                                                                                      | Compliant with ETSI, ARIB STD-T82 and FCC maximum out of Band allowed field strength.                                                                                                                                                                              |
| M2-Int: 6  | Timing                                                                                                                                      | See below.                                                                                                                                                                                                                                                         |
| M2-Int: 6a | Transmit to receive turn around time<br>(the time between the end of a command and when the interrogator is first ready to receive a reply) | 0 - 50 $\mu$ s                                                                                                                                                                                                                                                     |
| M2-Int: 6b | Receive to transmit turn around time<br>“(the time between the end of a reply and when the interrogator can transmit a command)”            | Greater than 0 $\mu$ s                                                                                                                                                                                                                                             |

| Ref.        | Parameter Name                                            | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|-------------|-----------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| M2-Int: 6c  | Dwell time or Interrogator transmit power on ramp         | 0 - 10 $\mu$ s                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| M2-Int: 6d  | Decay time or Interrogator transmit power down ramp       | 0 - 10 $\mu$ s                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| M2-Int: 7   | Modulation                                                | PJM (Phase Jitter Modulation) min. level +/- 3,0 ° max. level +/- 4,0 °                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| M2-Int: 7a  | Spreading sequence (for frequency hopping [FHSS] systems) | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| M2-Int: 7b  | Chip rate (for Spread spectrum systems)                   | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| M2-Int: 7c  | Chip rate accuracy (for Spread spectrum systems)          | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| M2-Int: 7d  | Modulation index                                          | N/A (System is not amplitude modulation)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| M2-Int: 7e  | Duty cycle                                                | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| M2-Int: 7f  | FM Deviation                                              | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| M2-Int: 8   | Data coding                                               | Modified Frequency Modulation (MFM) (see Figure 4 — Command MFM encoding and timing of binary 000100)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| M2-Int: 9   | Bit rate                                                  | 423,75 kbit/s                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| M2-Int: 9a  | Bit rate accuracy                                         | Synchronous to the carrier frequency.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| M2-Int: 10  | Interrogator transmit modulation accuracy                 | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| M2-Int: 11  | Preamble                                                  | Includes an MFM encoding violation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| M2-Int: 11a | Preamble length                                           | 16 bits                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| M2-Int: 11b | Preamble waveform                                         | <p>The command flag defines the start of a command and the bit interval timings. The flag comprises three parts:</p> <ol style="list-style-type: none"> <li>1: a synchronising string of 8 bits of valid MFM data.</li> <li>2: an MFM encoding violation not present in normal MFM data. The violation consists of a sequence of 5 state changes separated by a 1 bit interval, a 2 bit interval, a 1,5 bit interval and a 2 bit interval. The edge of the fifth (last) transition defines the beginning of a bit interval.</li> <li>3: a trailing MFM 0 defining the end of a flag and the beginning of the command.</li> </ol> <p>(See Figure 1 — Two possible command flags)</p> |
| M2-Int: 11c | Bit sync sequence                                         | See M2 Int: 11b                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| M2-Int: 11d | Frame sync sequence                                       | See M2 Int: 11b                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| M2-Int: 12  | Scrambling (for Spread spectrum systems)                  | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| M2-Int: 13  | Bit transmission order                                    | LSB first                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| M2-Int: 14  | Wake-up process                                           | Interrogator Talks First (ITF) System. Tag cannot respond unless it receives valid command from interrogator.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| M2-Int: 15  | Polarization                                              | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

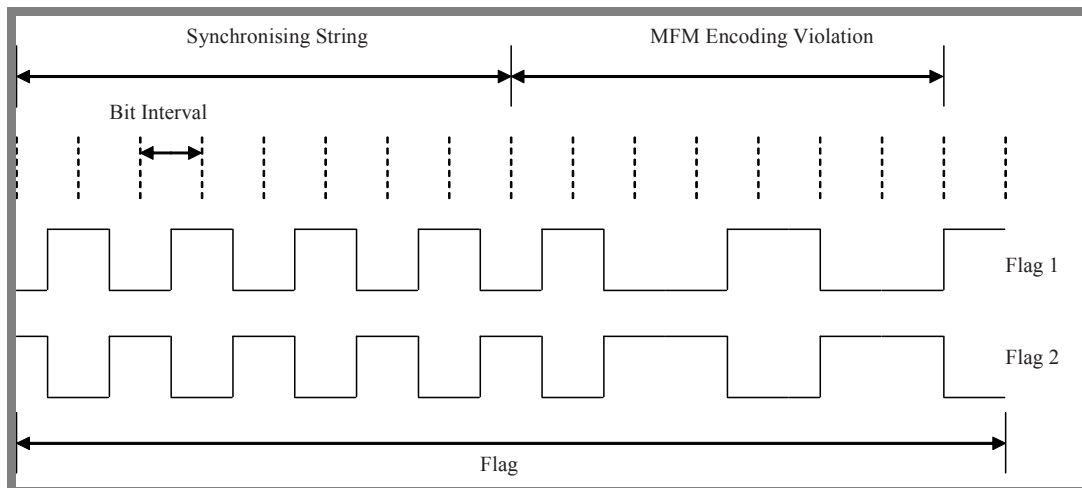


Figure 1 — Two possible command flags

## 6.2.2 Tag to interrogator link

See Table 4 — Tag to interrogator link and Figure 2 — Two possible reply flags.

Table 4 — Tag to interrogator link

| Ref.       | Parameter Name                                                      | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
|------------|---------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------------|-------------------|---|-----|----|---|------|----|---|------|---|---|------|-----|---|------|-----|---|------|-----|---|------|---|---|------|-----|
| M2-Tag:1   | Operating frequency range                                           | 13,56 MHz $\pm$ 3,013 MHz                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| M2-Tag: 1a | Default operating frequency                                         | N/A (System does not rely on a default operating frequency)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| M2-Tag: 1b | Operating channels<br>(for Spread spectrum systems)                 | <p>Multi-frequency operating system where tags can select from 8 reply channels. Tags transmit the whole of their reply using a selected channel.<br/>The tag may use one of eight subcarriers. The subcarriers are derived by division of the powering field's frequency.</p> <table border="1"> <thead> <tr> <th>Channel</th><th>Frequency<br/>kHz</th><th>Division<br/>Ratio</th></tr> </thead> <tbody> <tr> <td>A</td><td>969</td><td>14</td></tr> <tr> <td>B</td><td>1233</td><td>11</td></tr> <tr> <td>C</td><td>1507</td><td>9</td></tr> <tr> <td>D</td><td>1808</td><td>7,5</td></tr> <tr> <td>E</td><td>2086</td><td>6,5</td></tr> <tr> <td>F</td><td>2465</td><td>5,5</td></tr> <tr> <td>G</td><td>2712</td><td>5</td></tr> <tr> <td>H</td><td>3013</td><td>4,5</td></tr> </tbody> </table> | Channel | Frequency<br>kHz | Division<br>Ratio | A | 969 | 14 | B | 1233 | 11 | C | 1507 | 9 | D | 1808 | 7,5 | E | 2086 | 6,5 | F | 2465 | 5,5 | G | 2712 | 5 | H | 3013 | 4,5 |
| Channel    | Frequency<br>kHz                                                    | Division<br>Ratio                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| A          | 969                                                                 | 14                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| B          | 1233                                                                | 11                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| C          | 1507                                                                | 9                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| D          | 1808                                                                | 7,5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| E          | 2086                                                                | 6,5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| F          | 2465                                                                | 5,5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| G          | 2712                                                                | 5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| H          | 3013                                                                | 4,5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| M2-Tag: 1c | Operating frequency accuracy                                        | Synchronous to the carrier frequency.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| M2-Tag: 1d | Frequency hop rate<br>(for Frequency hopping [FHSS]<br>systems)     | Tags transmit the whole of a reply on a selected channel                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| M2-Tag: 1e | Frequency hop sequence<br>(for Frequency hopping [FHSS]<br>systems) | Reply channel is randomly selected by the tag.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |

| Ref.       | Parameter Name                                                                                                                                 | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
|------------|------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------------|-------------------|---|-----|----|---|------|----|---|------|---|---|------|-----|---|------|-----|---|------|-----|---|------|---|---|------|-----|
| M2-Tag: 2  | Occupied channel bandwidth                                                                                                                     | 106 kHz for each of 8 reply channels                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| M2-Tag: 3  | Transmit Maximum Magnetic Field Strength                                                                                                       | In accordance with local regulations                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| M2-Tag: 4  | Transmit spurious emissions                                                                                                                    | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| M2-Tag: 4a | Transmit spurious emissions, In-band (for Spread spectrum systems)                                                                             | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| M2-Tag: 4b | Transmit spurious emissions, Out-of-band                                                                                                       | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| M2-Tag: 5  | Transmit spectrum mask                                                                                                                         | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| M2-Tag: 6  | Timing                                                                                                                                         | See below.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| M2-Tag: 6a | Transmit to receive turn around time (the time between the end of a reply and when a the tag is first ready to receive a command)              | 0 – 200 $\mu$ s                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| M2-Tag: 6b | Receive to transmit turn around time (time between the end of the last bit of a read command and a tag beginning the first bit of a tag reply) | 77 to 88 $\mu$ s                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| M2-Tag: 6c | Dwell time or transmit power on ramp                                                                                                           | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| M2-Tag: 6d | Decay time or Transmit power down ramp                                                                                                         | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| M2-Tag: 7  | Modulation                                                                                                                                     | Loadmodulation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| M2-Tag: 7a | Spreading sequence (for Frequency hopping [FHSS] systems)                                                                                      | Tags transmit the whole of a reply in a randomly selected or an interrogator selected channel.                                                                                                                                                                                                                                                                                                                                                                                                                                                             |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| M2-Tag: 7b | Chip rate (for Spread spectrum systems)                                                                                                        | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| M2-Tag: 7c | Chip rate accuracy (for Spread spectrum systems)                                                                                               | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| M2-Tag: 7d | On-Off ratio                                                                                                                                   | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| M2-Tag: 7e | Subcarrier frequency                                                                                                                           | 8 subcarrier frequencies available: <table border="1"> <thead> <tr> <th>Channel</th><th>Frequency<br/>kHz</th><th>Division<br/>Ratio</th></tr> </thead> <tbody> <tr> <td>A</td><td>969</td><td>14</td></tr> <tr> <td>B</td><td>1233</td><td>11</td></tr> <tr> <td>C</td><td>1507</td><td>9</td></tr> <tr> <td>D</td><td>1808</td><td>7,5</td></tr> <tr> <td>E</td><td>2086</td><td>6,5</td></tr> <tr> <td>F</td><td>2465</td><td>5,5</td></tr> <tr> <td>G</td><td>2712</td><td>5</td></tr> <tr> <td>H</td><td>3013</td><td>4,5</td></tr> </tbody> </table> | Channel | Frequency<br>kHz | Division<br>Ratio | A | 969 | 14 | B | 1233 | 11 | C | 1507 | 9 | D | 1808 | 7,5 | E | 2086 | 6,5 | F | 2465 | 5,5 | G | 2712 | 5 | H | 3013 | 4,5 |
| Channel    | Frequency<br>kHz                                                                                                                               | Division<br>Ratio                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| A          | 969                                                                                                                                            | 14                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| B          | 1233                                                                                                                                           | 11                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| C          | 1507                                                                                                                                           | 9                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| D          | 1808                                                                                                                                           | 7,5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| E          | 2086                                                                                                                                           | 6,5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| F          | 2465                                                                                                                                           | 5,5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| G          | 2712                                                                                                                                           | 5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| H          | 3013                                                                                                                                           | 4,5                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| M2-Tag: 7f | Subcarrier frequency accuracy                                                                                                                  | Synchronous to the carrier frequency.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| M2-Tag: 7g | Subcarrier modulation                                                                                                                          | BPSK (Binary phase shift keying)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| M2-Tag: 7h | Duty cycle                                                                                                                                     | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| M2-Tag: 7i | FM Deviation                                                                                                                                   | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |
| M2-Tag: 8  | Data coding                                                                                                                                    | MFM (Modified frequency modulation)(see Figure 7 — Reply MFM encoding and timing of binary 000100)                                                                                                                                                                                                                                                                                                                                                                                                                                                         |         |                  |                   |   |     |    |   |      |    |   |      |   |   |      |     |   |      |     |   |      |     |   |      |   |   |      |     |

| Ref.        | Parameter Name                                                          | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|-------------|-------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| M2-Tag: 9   | Bit rate                                                                | 105,9375 kbit/s                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| M2-Tag: 9a  | Bit rate accuracy                                                       | Synchronous to the carrier frequency.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| M2-Tag: 10  | Tag transmit modulation accuracy (for Frequency hopping [FHSS] systems) | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| M2-Tag: 11  | Preamble                                                                | Includes an MFM encoding violation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| M2-Tag: 11a | Preamble length                                                         | 16 bits                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| M2-Tag: 11b | Preamble waveform                                                       | The reply flag defines the start of a reply and the bit interval timings. The flag comprises three parts:<br>1: a synchronising string of 9 bits of valid MFM data.<br>2: a MFM encoding violation not present in normal data. The violation consists of a sequence of 4 state changes separated by a 2 bit interval, a 1,5 bit interval and a 2 bit interval. The edge of the fourth transition defines the beginning of a bit interval<br>3: a trailing zero defining the end of the flag.<br>(See Figure 2 — Two possible reply flags) |
| M2-Tag: 11c | Bit sync sequence                                                       | See M2-Tag:11b                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| M2-Tag: 11d | Frame sync sequence                                                     | See M2-Tag:11b                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| M2-Tag: 12  | Scrambling (for Spread spectrum systems)                                | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| M2-Tag: 13  | Bit transmission order                                                  | LSB first                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| M2-Tag: 14  | Reserved                                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| M2-Tag: 15  | Polarization                                                            | N/A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| M2-Tag: 16  | Minimum tag receiver bandwidth                                          | See Figure 3 — Command modulation scheme                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |

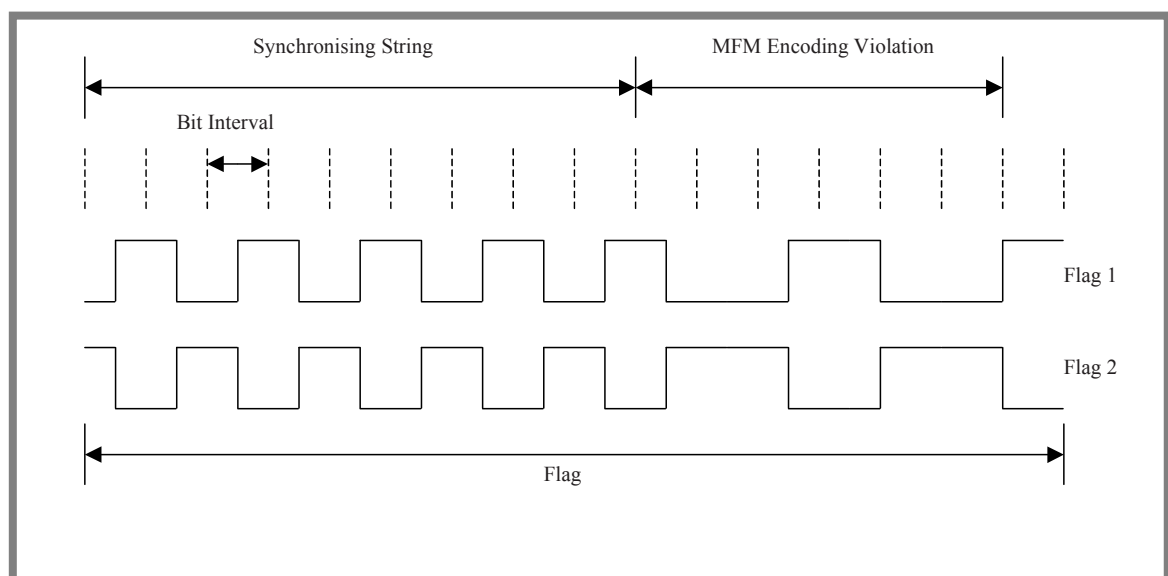


Figure 2 — Two possible reply flags

## 6.2.3 Description of operating method

### 6.2.3.1 General

This clause defines the characteristics of the air interface between the interrogator and the tag. It details the transfer of power and the bi-directional communications between the interrogator and the tag.

Tags may be passive. In which case, power is transferred from the interrogator to the tag by a high frequency magnetic field using coupled antennae in the interrogator and the tag. The powering field frequency  $f_c$  is  $13,56 \text{ MHz} \pm 7 \text{ kHz}$ . The interrogator shall be capable of powering a tag at all positions inside the interrogator operating volume.

Commands are transmitted from the interrogator to the tag by Phase Jitter Modulation (PJM) of the powering field. PJM transmits data as very small phase changes in the powering field. These phase changes are between  $\pm 3,0^\circ$  and  $\pm 4,0^\circ$ . There is no reduction in the transfer of power to the tag during PJM. The bandwidth of PJM is no wider than the original double-sided spectrum of the data. The sideband levels and data rates are decoupled. This allows the sideband levels be set at any arbitrary level without affecting the data rate. Phase Jitter Modulation is described in Annex B.

The command data rate is 423,75 kbit/s encoded using Modified Frequency Modulation (MFM).

An interrogator can be full or half duplex. If an interrogator is full duplex then it can transmit commands whilst simultaneously receiving multiple tag replies. Tags are half duplex.

Tags reply to the interrogator by inductive coupling whereby the voltage across the tag antenna coil is modulated by a subcarrier. The subcarrier is derived from division of the powering field's frequency.

Tags can select from one of eight subcarrier frequencies between 969 kHz and 3013 kHz. The reply data rate is 105,9375 kbit/s encoded using Modified Frequency Modulation (MFM) and modulated onto the subcarrier as Binary Phase Shift Keying (BPSK).

To ensure that tags replying on different channels are simultaneously received tag replies are band limited to reduce data and subcarrier harmonic levels.

### 6.2.3.2 Communications signal interface interrogator to tag

Commands are transmitted from the interrogator to the tag by PJM of the powering field. The command data rate is 423,75 kbit/s and all commands are MFM encoded prior to the PJM modulator.

#### 6.2.3.2.1 Modulation

Commands are transmitted from the interrogator to the tag by PJM of the powering field. In PJM data is transmitted as very small phase reversals in the powering field. This allows the sideband levels be set at any arbitrary level without affecting the data rate.

The tags operate as intended with minimum PJM sideband levels that comply with the appropriate FCC and ETSI regulations.

The PJM phase shift waveform of the interrogator magnetic field is described in Figure 3 — Command modulation scheme and Table 5 — Command Modulation Parameters.

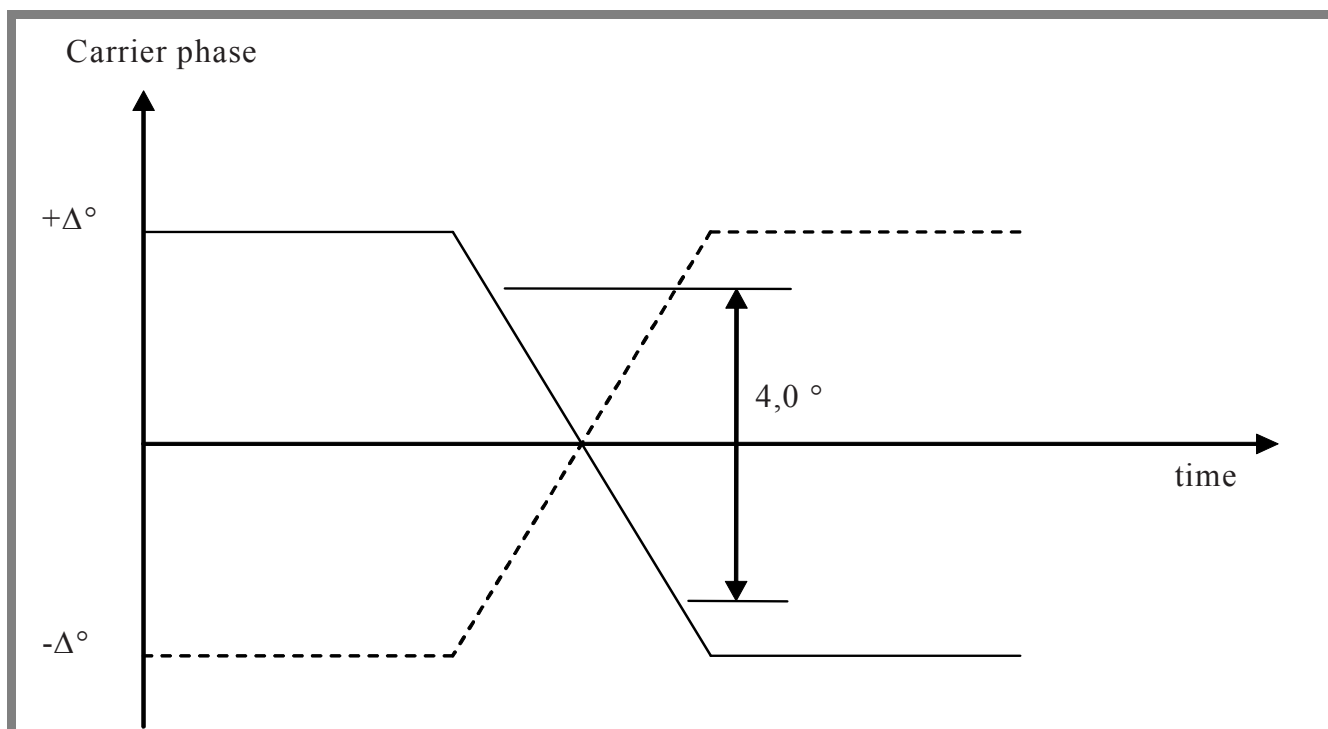


Figure 3 — Command modulation scheme

Table 5 — Command Modulation Parameters

| Parameter                                                         | Minimum | Maximum | Units         |
|-------------------------------------------------------------------|---------|---------|---------------|
| phase shift $+\Delta^\circ, -\Delta^\circ$                        | 3,0     | 4,0     | deg.          |
| time after which the phase shift shall remain above the 95% point | 0       | 1,0     | $\mu\text{s}$ |

NOTE:  $4,0^\circ$  of the total phase shift must be completed in 500 ns or less. The phase shift cannot exceed the final value by 5% at any time. The rise and fall phase shifts shall not have a difference greater than 40 ns at any position between the 10% to 90% points. The phase shift magnitude shall remain constant during the whole command.

#### 6.2.3.2.2 Data rate and data coding

The encoded command data rate is 423,75 kbit/s ( $f_c / 32$ ). The period of a bit interval used for encoding command data is 2,3599  $\mu\text{s}$ .

All commands are MFM encoded prior to the PJM modulator. Bits are encoded using MFM encoding rules. MFM has the lowest bandwidth occupancy of the binary encoding methods. The bit value is defined by a change in state. These encoding rules are defined as follows:

- A bit 1 is defined by a state change at the middle of a bit interval.
- A bit 0 is defined by a state change at the beginning of a bit interval.
- Where a bit 0 immediately follows a bit 1 there is no state change.

An example of command MFM encoding of the binary string 000100 is shown in Figure 4 — Command MFM encoding and timing of binary 000100.

Typically the edges shown in Figure 4 — Command MFM encoding and timing of binary 000100 and Figure 5 — MFM Encoding and timing for two possible command flags shall be synchronised to the powering field. If not synchronised then these edges shall be generated at the interrogator within  $\pm 0,04 \mu\text{s}$  of the times shown.



Figure 4 — Command MFM encoding and timing of binary 000100

#### 6.2.3.2.3 Interrogator to tag frames

The command flag defines the start of a command and the bit interval timings. The flag comprises three parts:

- A synchronising string of 8 bits of valid MFM data.
- An MFM encoding violation not present in normal MFM data. The violation consists of a sequence of 5 state changes separated by a 1 bit interval, a 2 bit interval, a 1,5 bit interval and a 2 bit interval.
- A trailing MFM 0 defining the end of a flag and the beginning of the command.

The synchronising string, encoding violation and a trailing zero for two possible command flags are illustrated in Figure 5 — MFM Encoding and timing for two possible command flags.

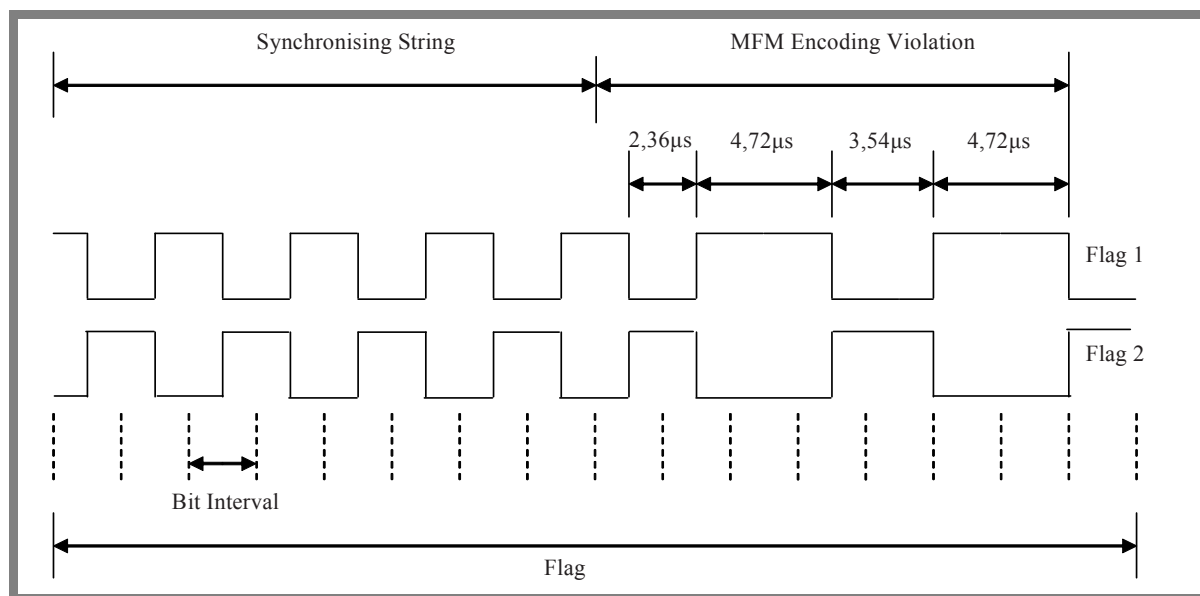


Figure 5 — MFM Encoding and timing for two possible command flags

#### 6.2.3.3 Communications signal interface tag to interrogator

Replies are MFM encoded prior to the BPSK modulator. Tags reply using one of eight selectable modulated subcarriers.

##### 6.2.3.3.1 Subcarriers

The tag may use one of eight subcarriers. The subcarriers are derived by division of the powering field's frequency. The channel frequencies and division ratios are tabulated in Table 6 — Channel frequencies and division ratios.

**Table 6 — Channel frequencies and division ratios**

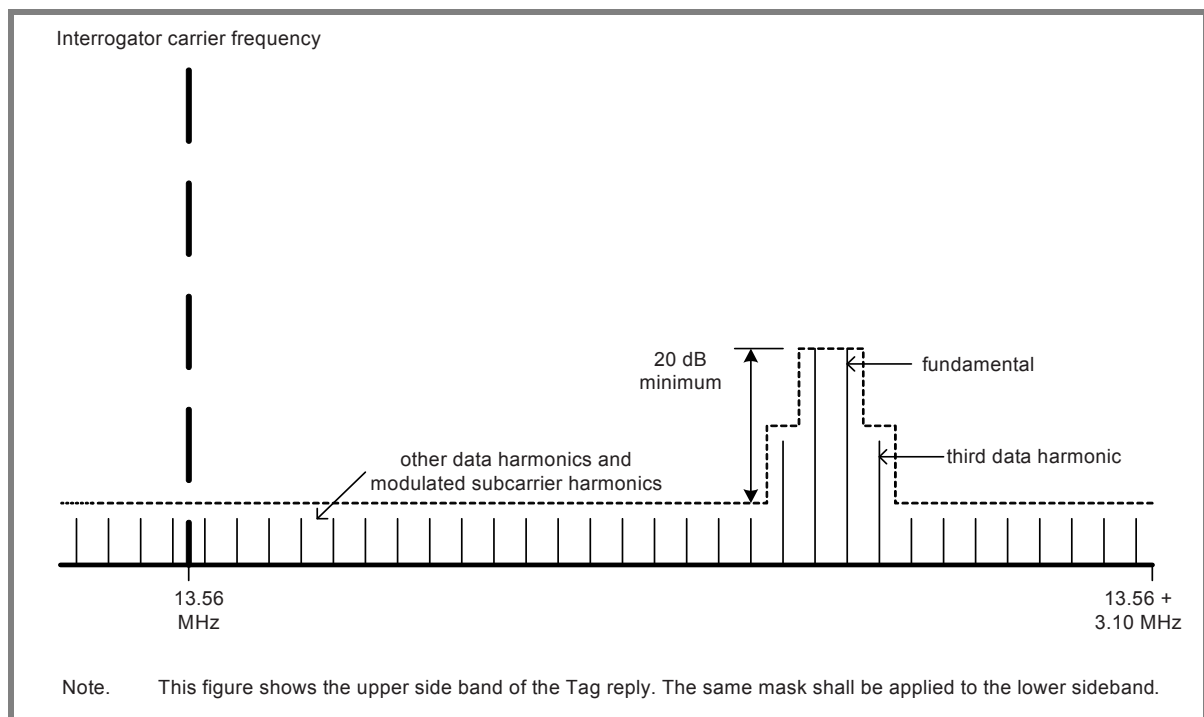
| Channel | Frequency kHz | Division Ratio |
|---------|---------------|----------------|
| A       | 969           | 14             |
| B       | 1233          | 11             |
| C       | 1507          | 9              |
| D       | 1808          | 7,5            |
| E       | 2086          | 6,5            |
| F       | 2465          | 5,5            |
| G       | 2712          | 5              |
| H       | 3013          | 4.5            |

**6.2.3.3.2 Modulation**

The tag replies to the interrogator by inductive coupling whereby the voltage across the tag antenna coil is modulated by a subcarrier. Modulation is based on impedance modulation. Encoded data is modulated on to the subcarrier as BPSK modulation.

Systems shall respect local regulations. In order to ensure that tags replying on different channels are simultaneously received, all tag replies shall be band limited to reduce data and subcarrier harmonic levels.

**NOTE** For example, the tag reply spectrum for 105,9375 kbit/s MFM encoded all zeros data stream, may be defined to be within the tag reply mask provided in Figure 6 — Tag reply mask below. Such mask limitation would be appropriate for ITU region 1, 2 and meets Japanese regulations.

**Figure 6 — Tag reply mask**

### 6.2.3.3.3 Data rate and data encoding

The encoded reply data rate is 105,9375 kbit/s ( $f_c / 128$ ). The period of a bit interval used for encoding command data is 9,4395  $\mu$ s. The modulation used is BPSK.

Tags reply using one of eight selectable modulated subcarriers. The subcarriers are derived by division of the powering field's frequency. Replies are encoded using MFM and modulated onto the subcarrier as Binary Phase Shift Keying (BPSK).

MFM encoding rules are shown in 6.2.3.2.2. An example of reply MFM encoding of the binary string 000100 is shown in Figure 7 — Reply MFM encoding and timing of binary 000100. Typically the edges shown in Figure 7 — Reply MFM encoding and timing of binary 000100 and Figure 8 — MFM Encoding and timing for two possible reply flags shall be synchronised to the powering field. If not synchronised then these edges shall be generated at the tag within  $\pm 0.15 \mu$ s of the times shown.

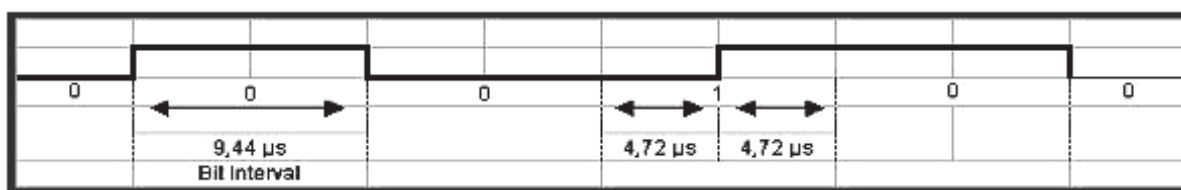


Figure 7 — Reply MFM encoding and timing of binary 000100

### 6.2.3.3.4 Tag to interrogator frames

The reply flag defines the start of a reply and the bit interval timings. The reply flag comprises three parts:

- A synchronising string of 9 bits of valid MFM data.
- A MFM encoding violation not present in normal data. The violation consists of a sequence of 4 state changes separated by a 2 bit interval, a 1,5 bit interval and 2 bit interval. The edge of the fourth transition defines the beginning of a bit interval.
- A trailing 0.

A synchronising string, encoding violation and a trailing zero for two possible reply flags are illustrated in Figure 8 — MFM Encoding and timing for two possible reply flags.

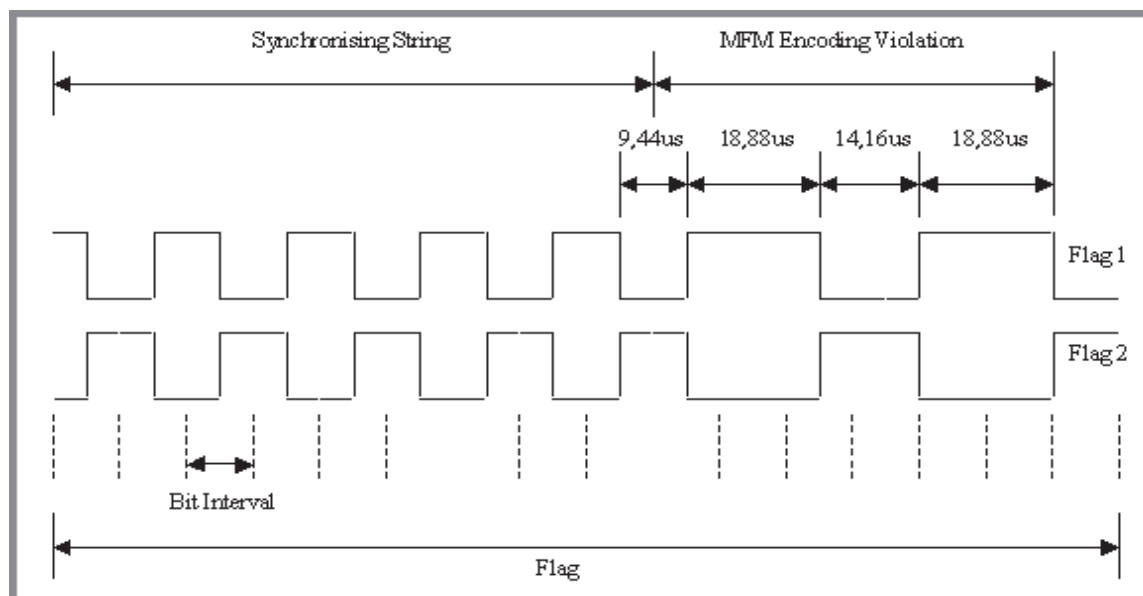


Figure 8 — MFM Encoding and timing for two possible reply flags

## 6.2.4 Protocol parameters

See Table 7 — Protocol parameters.

**Table 7 — Protocol parameters**

| Ref.     | Parameter Name                      | Description                                                                                                                                     |
|----------|-------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| M2-P: 1  | Who talks first                     | Interrogator Talks First (ITF) System. Tag cannot respond unless it receives valid command from interrogator.                                   |
| M2-P: 2  | Tag addressing capability           | Yes, tags can be addressed individually or as groups.                                                                                           |
| M2-P: 3  | Tag ID                              |                                                                                                                                                 |
| M2-P: 3a | Tag ID length                       | 64 bits (32 bit specific identifier, 16 bit application group identifier and 16 bit manufacturing identifier).                                  |
| M2-P: 3b | Tag ID format                       | See clauses 6.2.5.6 to 6.2.5.9                                                                                                                  |
| M2-P: 4  | Read size                           | Two bytes (16 bits) to maximum memory size.                                                                                                     |
| M2-P: 5  | Write size                          | Minimum and Maximum Write size is dependent upon memory technology, according to instruction defined in 6.2.5.14.                               |
| M2-P: 6  | Read transaction time               | 1,282ms + 150 $\mu$ s per 16 bits (2 bytes).                                                                                                    |
| M2-P: 7  | Write transaction time              | 1,282ms + 75,5 $\mu$ s per 16 bits (2 bytes), not including memory erase and write time.                                                        |
| M2-P: 8  | Error detection                     | 16 bit CRC interrogator to tag, 32 bit tag to interrogator.                                                                                     |
| M2-P: 9  | Error correction                    | None.                                                                                                                                           |
| M2-P: 10 | Memory size                         | Product Dependant. No technical limitation.                                                                                                     |
| M2-P: 11 | Command structure and extensibility | Command field is 16 bits long, extendable without limit in 16 bit blocks.<br>8 command types, each with 16 extension types presently available. |

## 6.2.5 Description of protocol operating method

### 6.2.5.1 Overview

Tags may be passive; in which case power is transferred from the interrogator to the tag by a High Frequency (HF) magnetic field using coupled antennas in the interrogator and the tag.

Dialogue between the interrogator and the tag is conducted on an Interrogator-Talks-First (ITF) basis. Following activation of the tag by a powering field the tag waits silently for a valid command. After receiving a valid command the tag transmits a reply to the command.

Phase Jitter Modulation (PJM) is used (described in 6.2.3 above).

The tag memory is expandable beyond 1 Megabit so that the system is inherently upgradeable, subject to product definition/design.

Multiple tag identification is performed using a combination of Frequency and Time Division Multiple Access (FTDMA). There are eight reply channels available for tags to use. In response to a valid command each tag randomly selects a channel on which to transmit its reply. The reply is transmitted once using the selected channel. Upon receiving the next valid command each tag randomly selects a new channel and transmits the

reply using the new selected channel. This method of reply frequency hopping using random channel selection is repeated for each subsequent valid command. In addition to random channel selection the tag can randomly mute individual replies. When a reply is muted the tag will not transmit that reply. Random muting is necessary when identifying very large populations of tags. All FTDMA frequency and time parameters are defined by the command.

All commands are time stamped and tags store the first time stamp received after entering an interrogator. The stored time stamp defines precisely when the tag first entered the interrogator and provides a high resolution method of determining tag order which is decoupled from the speed of identification.

Tag temporary settings shall be stored in tag memory (for example using a technique such as Temporary Random Access Memory TRAM) that retains data contents during power outages caused by switching of the powering field in orientation insensitive interrogators.

#### 6.2.5.2 Definition of data elements

Read data is the data read from chip memory by a valid command.

Write data is the data written to chip memory by a valid command.

Stored data is the data stored in chip memory.

Hardcode data is the data in virtual chip ROM.

#### 6.2.5.3 RF tag memory organization

This part of ISO/IEC 18000 describes the tag memory in virtual terms only and does not intend to restrict the physical implementation of any tag's memory.

The tag memory is split into the three areas shown in Table 8 — Tag memory areas.

**Table 8 — Tag memory areas**

| Memory Area                      | Comment                                                                                        |
|----------------------------------|------------------------------------------------------------------------------------------------|
| manufacturing system memory area | contains all fields that are set and locked during chip/tag manufacture and manufacturing test |
| user system memory area          | set and locked as required by the user                                                         |
| user memory area                 | set and locked as required by the user                                                         |

Tags with 4 kbit or less of virtual memory will use 8 bit address and 8 bit length fields. Tags with greater than 4 kbit of virtual memory shall allow for both 8 and 16 bit address and length fields.

The tag memory includes tag identifiers, configuration and user defined fields. The virtual memory map, see Table 9 — Virtual memory map, includes the defined fields. The bit order of any defined fields is such that the least significant field bit is stored at the lower virtual memory bit address.

The virtual memory is organised and addressed as 16 bit words. MODE 2 makes provision for tag types with varying memory block sizes, where a block is one or more 16 bit words. Read commands read zero or more words. Write commands write whole words, where the number of words that can be written is determined by the memory construction.

Memory may be locked. Once locked, memory cannot be overwritten.

#### 6.2.5.4 Virtual tag memory

Table 9 — Virtual memory map shows the virtual memory layout of the tag.

Table 9 — Virtual memory map

| Word no      | memory type                 | comment                               | register | bit number                   |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |
|--------------|-----------------------------|---------------------------------------|----------|------------------------------|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|
|              |                             |                                       |          | 15                           | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 0            | manufacturing system memory | defined fields                        | RFM      | reserved for manufacturer    |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |
| 1            |                             |                                       | MC       | manufacturing code           |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |
| 2            |                             |                                       | SID0     | specific identifier 0        |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |
| 3            |                             |                                       | SID1     | specific identifier 1        |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |
| 4            | user system memory          | defined fields                        | GID      | application group identifier |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |
| 5            |                             |                                       | CID      | conditional identifier       |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |
| 6            |                             |                                       | CW       | configuration word           |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |
| 7            | user memory                 | undefined if password is not required | PW0      | Password 0                   |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |
| 8            |                             |                                       | PW1      | Password 1                   |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |
| 9            |                             |                                       | PW2      | Password 2                   |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |
| 10 and above |                             | undefined fields                      |          |                              |    |    |    |    |    |   |   |   |   |   |   |   |   |   |   |

Word 10 and above shall be user memory followed by any remaining system memory.

Specific identifier 0 and password 0 are the least significant words of these multi word fields.

#### 6.2.5.5 Lock pointer

The lock pointer is a 16 bit virtual system memory field, used to prevent tag memory from being over written. The field points to a word in memory. All complete sub-blocks of memory at addresses less than the number stored in the lock pointer cannot be over written. Interrogator commands cannot decrement the lock pointer.

#### 6.2.5.6 Unique identification (Tag ID)

The unique identification for MODE 2 may be set permanently at manufacturing.

It shall comprise a logical 64 bit block, consistent with ISO/IEC 15963.

The physical implementation on the tag is left to the manufacturer.

The 64 logical bits are organized into three parts. See Figure 9 — Logical organization of tag ID.

| MODE 2 TAG Tag ID MASK    |                                     |                              |
|---------------------------|-------------------------------------|------------------------------|
| <b>MASK 1</b>             | <b>MASK 2</b>                       | <b>Mask 3</b>                |
| <b>Manufacturing code</b> | <b>Application Group Identifier</b> | <b>Specific Identifier</b>   |
| 16 Bits                   | 16 Bits                             | 32 Bits                      |
|                           | AFI Not Determined                  | Serially issued binary value |

Figure 9 — Logical organization of tag ID

#### 6.2.5.7 Manufacturing code

The manufacturing code is a mask of 16 bits.

The physical operation of the system requires only that this mask is populated with a binary value.

However, in order to uniquely identify manufacturers, registration shall be in accordance with ISO/IEC 15963.

Transmission from the tag for this Mode shall be LSB first, and the data available shall conform to the disposition in Table 10 — Manufacturing code field.

Example implementation according to ISO/IEC 15963.

The manufacturing code is a 16 bit field set at manufacturing test. The encoding for the manufacturing code is shown in Table 10 — Manufacturing code field

**Table 10 — Manufacturing code field**

| MSB  |   | LSB                                           |   |
|------|---|-----------------------------------------------|---|
| 16   | 9 | 8                                             | 1 |
| 'E0' |   | manufacturer code according to ISO/IEC 7816-6 |   |

#### 6.2.5.8 Application group identifier (AFI)

The second mask is of 16 bits.

The physical operation of the system requires only that this mask is populated with a binary value.

The purpose of this mask is to identify applications or families of tags.

It is recommended that the first octet of this mask is used to encode an AFI as defined in ISO/IEC 15961-3; if so the value of the AFI shall be as registered with the RA as defined in ISO/IEC 15961-2.

The second octet of this mask is not specified.

#### 6.2.5.9 Specific identifier

The third mask is of 32 bits.

It shall be allocated at manufacture, and shall provide a unique binary value which shall be sequentially issued by the manufacturer and shall not be reused by that manufacturer. It shall provide a unique tag ID for that manufacturer.

The combination of this Specific Identifier value, Application Group Identifier and the Manufacturing code, shall provide a permanent and unambiguous unique tag identification.

This identifier allows a tag to be specifically identified and specifically communicated to. The manufacturing test software shall ensure that the specific identifier is incremented once each time a tag is loaded with this identifier.

#### 6.2.5.10 Conditional identifier

In addition to the tag Tag ID the tag memory shall carry an additional mask, known as the Conditional Identifier (CID). The mask shall be 2 octets (16 bits).

The physical operation of the system requires only that this mask is populated with a binary value.

The CID may be provided at manufacture (as for example a date of manufacture) or may be provided later.

This part of ISO/IEC 18000 is not prescriptive as to whether the CID is programmed at manufacture or later, but manufacturers shall decide which of these options and shall use the CID consistently thereafter.

Example: The CID may provide a date-code to enable conditional access/disbarment according to the data condition, thus, for example tags manufactured before the CID, or after the CID could be eliminated or selected.

#### 6.2.5.11 Configuration word

The configuration word is a 16 bit field set by the user. The tag configuration is usually set to suit the application. The encoding for the configuration word is shown in Table 11 — Configuration word field.

**Table 11 — Configuration word field**

| Bit number  | Field           | State | Description           |
|-------------|-----------------|-------|-----------------------|
| Bit 0 to 6  | RFU             |       | Shall be set to '0'   |
| Bit 7 to 14 | Custom Settings |       |                       |
| Bit 15      | Password        | 0     | password not required |
| Bit 15      | Password        | 1     | password required     |

#### 6.2.5.12 Password

The password field is a 48 bit identifier set by the user. It is used to provide a level of security for memory access. If the tag is configured to 'password not required' the password memory space is free for user memory. If the tag is configured to 'password required' the password cannot be read.

#### 6.2.5.13 User memory

The user sets the user memory.

#### 6.2.5.14 Hardcode

Hardcode is formatted as 16 bit words and is included in some tag types. This part of ISO/IEC 18000 describes the hardcode in virtual terms only and does not intend to restrict the physical implementation of hardcode. The hardcode defines the tag parameters, including memory size and memory block size.

In a normal reply all hardcode words are transmitted first, followed by the time stamp and then the rest of the reply. The MSB of all hardcode words shall be set to '1'. The encoding for the hardcode is shown in Table 12 — Hardcode field.

**Table 12 — Hardcode field**

| Bit number  | Field                  | State                              | Description                                            |
|-------------|------------------------|------------------------------------|--------------------------------------------------------|
| Bit 0 to 6  | parameter/<br>function | 00 <sub>h</sub>                    | memory size in 4 word units (LSB)                      |
|             |                        | 01 <sub>h</sub>                    | memory size in 4 word units (MSB)                      |
|             |                        | 02 <sub>h</sub>                    | memory block size in words                             |
|             |                        | 03 <sub>h</sub>                    | memory sub-block size in words                         |
|             |                        | 04 <sub>h</sub>                    | memory erase + write time in 100 $\mu$ s units         |
|             |                        | 05 <sub>h</sub> to 07 <sub>h</sub> | reserved for custom hardcodes                          |
| Bit 7 to 14 | code/value             | 00 <sub>h</sub> to FF <sub>h</sub> | hexvalue or code associated with parameter or function |
| Bit 15      | MSB                    |                                    | shall be set to '1'                                    |

For the purposes of this document 'memory erase + write time' shall be the time between the end of the last bit of a write command and the beginning of the first bit of a tag reply. Also 'memory size' shall be from word 0 to the top of user memory.

For example a tag with:

- 8192 bits of memory (512 words, 128 \* 4 word units)
- 4 word memory block size
- 1 word memory sub-block size
- 4 ms memory erase + write time (40 \* 100  $\mu$ s units)

would have the following hardcode:

- memory size C000<sub>h</sub>
- block size 8202<sub>h</sub>
- sub-block size 8083<sub>h</sub>
- erase + write time 9404<sub>h</sub>

In the above example:

- The memory size MSB is not used, as all the value bits are '0'.
- A sub-block size of 1 word and a block size of 4 words indicates that 1, 2, 3, and 4 memory word writes are allowed where all writes shall be within a block, (no writes across block boundaries).

The block size origin is word 0.

Memory can be locked at sub-block intervals, if the sub-block interval is not given then the memory can only be locked at block intervals.

#### 6.2.5.14.1 Default tag parameters

If the memory size is not defined in hardcode then the memory size is 64 words.

If the memory block size is not defined in hardcode then the memory block size is 4 words.

If the memory sub-block size is not defined in hardcode then the memory sub-block size is 1 word.

If the memory erase + write time is not defined in hardcode then the memory erase + write time is 5.0 ms or less.

#### 6.2.5.15 Block security status

Refer to Clauses 6.2.5.5 Lock Pointer and 6.2.5.12 Password.

#### 6.2.5.16 Description of operating methodology

Tag and interrogator communications is based on the Interrogator-Talks-First system. The tag will only respond to a command if the command received is valid. Commands are generally used to identify tags and to read, write and lock memory. Commands also determine the reply type (short or normal) and the reply mode (fixed channel or random channel etc.). A short reply is used to speed up communications, whereas a normal reply includes all hardcode and some system memory.

All tags, irrespective of their types can be identified using a universal group command. The universal group command can set the tags to transmit a normal reply. The hardcode and system memory included in a normal reply provides sufficient information so that a user can send other valid commands to the tags.

The various reply modes are selected to suit the interrogator types (single or multi channel) and to speed up communication depending upon tag population within the interrogator operating volume.

**6.2.5.16.1 Methods**

See 6.2.5.1 and 6.2.5.2

**6.2.5.16.2 Command format**

The format of command fields is shown in Table 13 — Command fields. All fields are transmitted least significant bit first. For multi word fields the least significant bit of the least significant word defines the least significant bit of the field. All commands defined in this subsection are Mandatory as classified in 6.0 above.

**Table 13 — Command fields**

| Code | Field                        | Bit | Comment                                                |
|------|------------------------------|-----|--------------------------------------------------------|
| F    | Flag                         | 16  | MFM violation sequence                                 |
| Cd   | command                      | 16  | command field                                          |
| Cn   | command number               | 16  | command number field                                   |
| SS   | Specific identifier          | 32  | identifier field                                       |
| G    | application group identifier | 16  | identifier field                                       |
| Ci   | conditional identifier       | 16  | identifier field                                       |
| PPP  | password                     | 48  | identifier field                                       |
| R    | read address and length      | 16  | 8 bit address and 8 bit length fields for memory read  |
| W    | write address and length     | 16  | 8 bit address and 8 bit length fields for memory write |
| Ra   | read address                 | 16  | 16 bit address field for memory read                   |
| RI   | read length                  | 16  | 16 bit length field for memory read                    |
| Wa   | write address                | 16  | 16 bit address field for memory write                  |
| WI   | write length                 | 16  | 16 bit length field for memory write                   |
| D    | write data                   | 16  | data to be written                                     |
| C    | CRC                          | 16  | validation CRC                                         |

The format for valid commands is shown in ,Table 14 — Valid command format where:

The password field shall only be provided if required by the tag.

The read/write commands shown include a single word write.

**Table 14 — Valid command format**

| Command type        | Start fields | Identifier fields | Address and length fields | Data | CRC |
|---------------------|--------------|-------------------|---------------------------|------|-----|
| group read          | F [Cd] Cn    | G Ci              | [R] or [Ra RI]            |      | C   |
| specific read       | F [Cd] Cn    | SS                | [R] or [Ra RI]            |      | C   |
| group read/write    | F [Cd]Cn     | G Ci [PPP]        | [R W] or [Ra RI Wa WI]    | D    | C   |
| Specific read/write | F [Cd]Cn     | SS [PPP]          | [R W] or [Ra RI Wa WI]    | D    | C   |

The minimum length command is 7 words (112 bits).

For a zero length write no data will be provided. For a multi-word length writes each word to be written is followed by a CRC. The command format for a two word write is shown in Table 15 — Valid multi-word read/write command format.

**Table 15 — Valid multi-word read/write command format**

| Command Type        | Start Fields | Identifier Fields | Address and Length Fields | Data | CRC | Data | CRC |
|---------------------|--------------|-------------------|---------------------------|------|-----|------|-----|
| group read/write    | F [Cd] Cn    | G Ci  PPP         | [R W] or [Ra Ri Wa Wl]    | D    | C   | D    | C   |
| Specific read/write | F [Cd] Cn    | SS  PPP           | [R W] or [Ra Ri Wa Wl]    | D    | C   | D    | C   |

For all write commands if the start, identifier or address and length fields are invalid no data will be written to tag memory.

If any CRC is invalid the tag will not reply.

### 6.2.5.16.3 Command fields

#### 6.2.5.16.3.1 Flag field

The flag field contains a MFM violation that is not present during normal data. The field indicates the beginning of a command.

#### 6.2.5.16.3.2 Command field

The encoding of the command field is shown in Table 16 — Command field bit encoding.

**Table 16 — Command field bit encoding**

| Bit number  | Field              | State | Description                                                   |
|-------------|--------------------|-------|---------------------------------------------------------------|
| bit 0       | command type       | 0     | read command                                                  |
|             |                    | 1     | read/write command                                            |
| bit 1       | identifier type    | 0     | specific command                                              |
|             |                    | 1     | application group conditional (group) command                 |
| bit 2       | reply type         | 0     | short reply                                                   |
|             |                    | 1     | normal reply                                                  |
| bit 3       | fixed/random       | 0     | fixed channel reply                                           |
|             |                    | 1     | random channel reply                                          |
| bits 4 to 6 | channel/mute ratio | 000   | [fixed channel A] or [random channel unmuted]                 |
|             |                    | 001   | [fixed channel B] or [random channel ½ muted]                 |
|             |                    | 010   | [fixed channel C] or [random channel ¾ muted]                 |
|             |                    | 011   | [fixed channel D] or [random channel $\frac{7}{8}$ muted]     |
|             |                    | 100   | [fixed channel E] or [random channel $\frac{31}{32}$ muted]   |
|             |                    | 101   | [fixed channel F] or [random channel $\frac{127}{128}$ muted] |
|             |                    | 110   | [fixed channel G] or [random channel $\frac{511}{512}$ muted] |
|             |                    | 111   | [fixed channel H] or [random channel fully muted]             |

| Bit number   | Field               | State | Description                                                               |
|--------------|---------------------|-------|---------------------------------------------------------------------------|
| bit 7        | address and length  | 0     | 8 bit address and 8 bit length fields                                     |
|              |                     | 1     | 16 bit address and 16 bit length fields                                   |
| bit 8        | test command enable | 0     | normal command                                                            |
|              |                     | 1     | proprietary test command                                                  |
| bits 9 to 13 | RFU                 |       | shall be set to '0' for mandatory commands                                |
| bit 14       | command class       | 0     | mandatory command                                                         |
|              |                     | 1     | custom command                                                            |
| bit 15       | command extension   | 0     | indicates to the tag that this word is the last command field             |
|              |                     | 1     | indicates to the tag that the following word is a command field extension |

For a command to be valid the command field shall be set equal to one of the combinations shown in Table 16 — Command field bit encoding. In addition the address and length field (bit 7) shall be set to '0' for tags with 4 kbit or less of virtual memory. The function provided by bit 8 is only intended for use during wafer/chip testing and must be disabled by the manufacturer so that only normal commands are available to a user.

The following describes the fields within the command field.

#### 6.2.5.16.3.3 Command type

The command type field determines if the command is a read or a read/write.

A read command is used to read tag memory. For fast tag identification the read length field can be set to zero.

A read/write command is used to read and write to tag memory. For write only operation the read length is set to zero. To lock tag memory the write length is set to zero and the write address is set to the lowest unlocked memory address.

#### 6.2.5.16.3.4 Identifier type

The identifier type field determines if the command is a specific or an application group conditional command.

Specific commands are used to identify and communicate to individual tags.

Application group conditional (group) commands are used to identify and communicate to a group of tags that meet a conditional test or all groups of tags that meet a conditional test.

#### 6.2.5.16.3.5 Reply type

The reply type field determines if the tag reply is short or normal.

A short reply is used to minimise communication time.

A normal reply is used when the interrogator requires the hardcode and system memory data to be included in a reply.

#### 6.2.5.16.3.6 Fixed/random

The fixed/random field determines if the tag reply is on a fixed selected channel or a random selected channel.

#### 6.2.5.16.3.7 Channel/mute ratio

The channel/mute ratio field determines either the channel selected or the mute ratio selected.

This field is linked to the fixed/random field described above. If fixed channel is selected then the channel/mute ratio field determines the actual channel to be used in the reply. If random channel is selected then the channel/mute ratio field determines the mute ratio.

For valid random channel commands:

- If unmuted is selected the tag will transmit replies repetitively on randomly selected channels.
- If  $\frac{1}{2}$  to  $\frac{511}{512}$  muted is selected the tag will randomly choose to transmit (unmuted) or not transmit (muted) individual replies. The muted ratio supplied in the command ( $\frac{1}{2}$  muted,  $\frac{3}{4}$  muted etc.) determines the probability of the reply being muted.
- If fully muted is selected the tag will not reply and the tag will be set to the temporary mute state. While the tag is in the temporary mute it will only respond to interrogator command with a new interrogator identifier, see 6.2.5.16.3.9.

#### 6.2.5.16.3.8 Address and length

The address and length field defines whether a command includes 8 bit address and 8 bit length fields or 16 bit address and 16 bit length fields.

#### 6.2.5.16.3.9 Command number

The command number is used to set a local time stamp and identify interrogators.

The encoding for the command number is shown in Table 17 — Command number fields.

**Table 17 — Command number fields**

| Bit number   | Field                   | State | Description                         |
|--------------|-------------------------|-------|-------------------------------------|
| Bit 0 to 7   | local time stamp        |       | set as required by the interrogator |
| bits 8 to 14 | Interrogator identifier |       | set as required by the interrogator |
| Bit 15       | MSB                     |       | shall be set to '0'                 |

The most significant byte of the command number shall be other than 00<sub>h</sub>.

When a tag enters a new interrogator the tag will store the command number from the first valid command received. The tag shall store this number during brief powered down periods. All tag replies include this stored number, which is called the time stamp. The least significant byte of the command number is periodically incremented by the interrogator and used in subsequent commands. The tag does not update the time stamp. The time stamp therefore indicates when a tag first received a valid command.

A tag determines that it has entered a new interrogator when the most significant byte of the command number (included in all valid commands) and the time stamp are different, or if the tag detects that it has been powered down for longer than a defined period.

In a multi tag scenario if two or more tags reply at the same time on the same channel no reply will be received. If the population is large it is possible that a tag may have to transmit a few times before it selects a unique channel and is therefore received. There is also a chance that the tag will select a unique channel for its first transmission. Thus the order in which tags are received cannot be used to determine the order in which they entered the interrogator. However the time stamp included in the reply will give the correct tag order.

#### 6.2.5.16.3.10 Tag identifiers

#### 6.2.5.16.3.11 Specific identifier field

The specific identifier is used to communicate to an individual tag. For a command to be valid the specific identifier in the command shall be set equal to the specific identifier stored in tag to be communicated to.

#### 6.2.5.16.3.12 Application group identifier field

The application group identifier is used to communicate with tags from the same application group or from all application groups. For a command to be valid the application group identifier in the command shall be set equal to either  $FFFF_h$  or to the application group identifier stored in the tags to be communicated to.

If the command identifier is set  $FFFF_h$  and the rest of the command is valid then all application groups will be communicated to.

#### 6.2.5.16.3.13 Conditional identifier field

The conditional identifier is used to communicate to tags that meet a conditional test. For a command to be valid the conditional identifier in the command shall be less than or equal to the conditional identifier stored in the tag.

#### 6.2.5.16.3.14 Password field

The password is used to restrict writes to tag memory. For a command to be valid the password shall only be provided if the tag is configured to password required, and then only for read/write commands. For a read/write command to a password protected tag to be valid the password in the command shall be set equal to the password stored in the tag.

#### 6.2.5.16.3.15 Address and length fields

The command field determines if the command includes 8 bit address and 8 bit length fields or 16 bit address and 16 bit length fields.

The address and length fields define the start address and length in words for memory reads and writes. For a command to be valid, the address and length field shall only select from valid memory addresses. Valid memory addresses are as follows:

- For a memory read of tags configured to password not required: word 0 to the maximum user memory word is available.
- For a memory read of tags configured to password required word: 10 to the maximum user memory word is available.
- For a memory write: the address stored in the lock pointer to the maximum user memory word.
- When locking tag memory: the address stored in the lock pointer and above.
- To lock tag memory the write length is set to zero and the write address is set to the lowest unlocked memory address, if the command is valid the tag will set the lock pointer equal to the write address.
- In addition, for a command to be valid the address and length fields shall be set as required by different tag types to allow for any block addressing restrictions.

If clearly defined in the manufacturers chip data book:

- valid memory addresses for memory reads can include system memory that is above the user memory area
- valid memory addresses for memory reads can include words 0 to 6 for tags configured to password required.

#### 6.2.5.16.3.16 8 bit address and 8 bit length fields

Where the command field selects 8 bit address and 8 bit length fields the address and length field shall be encoded as shown in Table 18 — 8 bit address and 8 bit length fields memory reads and Table 19 — 8 bit address and 8 bit length fields for memory writes.

**Table 18 — 8 bit address and 8 bit length fields memory reads**

| Bit number   | Field               | State | Description                 |
|--------------|---------------------|-------|-----------------------------|
| Bits 0 to 7  | 8 bit address field |       | set as required by the user |
| Bits 7 to 15 | 8 bit length field  |       | set as required by the user |

**Table 19 — 8 bit address and 8 bit length fields for memory writes**

| Bit number   | Field               | State | Description                 |
|--------------|---------------------|-------|-----------------------------|
| Bits 0 to 7  | 8 bit address field |       | set as required by the user |
| Bits 7 to 15 | 8 bit length field  |       | set as required by the user |

#### 6.2.5.16.3.17 16 Bit address and 16 bit length fields

Where the command field selects 16 bit address and 16 bit length fields the address and length field shall be 16 bits each.

#### 6.2.5.17 Write data

The write data is the data to be written to the tag.

#### 6.2.5.18 CRC

All command CRCs are calculated from the end of the flag field.

The 16 bit command CRC algorithm used is the IBM “Synchronous Data-Link Control” (SDLC) polynomial, standardised by CCITT for use in the X.25 packet-switching protocol, and is implemented in most serial communications tags and is embodied in ISO/IEC 13239. The CRC shall be calculated as per the definition in ISO/IEC 13239.

The algorithm used is as follows:

$$g(X) = X^{16} + X^{12} + X^5 + 1$$

The generation algorithm departs slightly from the basic CRC16 technique, in that the generator is pre-loaded with ‘1’ bits rather than ‘0’ bits. Additionally the checkbits are inverted before transmission. Consequently, a valid message is not recognised by a remainder of zero (as is the case with CRC16), but by a specific constant.

An example interrogator command and CRC is given below:

**flag field**  
 command field 0000  
 command number 1234  
 specific identifier 0 1234  
 specific identifier 1 5678  
 read address and length 1001  
 CRC 8C16

The method and an example of this 16 bit CRC is given in Annex M.

#### 6.2.5.19 Reply format

Reply fields are shown in Table 20 — Reply fields. All fields are transmitted least significant bit first. For multi byte fields the least significant bit of the least significant byte defines the least significant bit of the field.

**Table 20 — Reply fields**

| Code | Field                        | Bits | Comment                |
|------|------------------------------|------|------------------------|
| F    | Flag                         | 16   | MFM violation sequence |
| H    | Hardcode                     | 16   | hardcode field         |
| T    | time stamp                   | 16   | identifier field       |
| L    | lock pointer                 | 16   | identifier field       |
| M    | manufacturing code           | 16   | identifier field       |
| SS   | specific identifier          | 32   | identifier field       |
| G    | application group identifier | 16   | identifier field       |
| Ci   | conditional identifier       | 16   | identifier field       |
| Co   | configuration word           | 16   | identifier field       |
| D    | read data                    | 16   | read data              |
| CC   | CRC                          | 32   | validation CRC         |

Table 21 — Valid reply format shows the format for valid replies.

**Table 21 — Valid reply format**

| Reply Type | Start Fields | System Memory Fields | Data | CRC |
|------------|--------------|----------------------|------|-----|
| Normal     | F [H] T      | L M SS G Ci Co       | [D]  | CC  |
| Short      | F T          | SS                   | [D]  | CC  |

The minimum length reply is 96 bits.

The reply type is determined by the interrogator command.

#### 6.2.5.20 Reply fields

##### 6.2.5.20.1 Flag field

The flag field contains a MFM violation that is not present during normal data. The field indicates the beginning of a reply.

#### 6.2.5.20.2 Hardcode fields identifier fields

If the tag design includes hardcode then all hardcode data is sent in normal replies. The MSB of the hardcode is set to '1' and the MSB of the following timestamp is set to '0'. The interrogator can detect the end of hardcode data by examining the MSB of received words.

#### 6.2.5.20.3 Time stamp field

The time stamp is used to provide superior tag order identification. The time stamp is set equal to the command number included in the first valid command received after the tag entered a new interrogator.

#### 6.2.5.20.4 System memory fields

The reply system memory fields are as per the system memory stored in tag virtual memory.

#### 6.2.5.21 Read data

The read data is the data requested by a valid command.

#### 6.2.5.22 CRC field

The reply CRC is calculated from the end of the start flag field.

The reply CRC is the 32 bit Ethernet CRC. Its properties are similar to the 16 bit IBM CRC used in the command path, in that the register is loaded with ones, the output word is inverted and the final computation results in a specific constant rather than zero.

The algorithm used is as follows:

$$g(X) = X^{32} + X^{26} + X^{23} + X^{22} + X^{16} + X^{12} + X^{11} + X^{10} + X^8 + X^7 + X^5 + X^4 + X^2 + X^1 + 1$$

An example tag reply and CRC is given below.

|                       |           |
|-----------------------|-----------|
| <b>flag field</b>     |           |
| time stamp            | 1234      |
| specific identifier 0 | 1234      |
| specific identifier 1 | 5678      |
| read data             | ABCD      |
| CRC                   | E8C5 8742 |

The method and an example of this 32 bit CRC is given in Annex N.

#### 6.2.5.23 RF tag states

##### 6.2.5.23.1 State diagram

A tag can be in one of four following states:

- Power Off  
The tag is in the Power Off state when it cannot be activated by the interrogator. Power off is also achieved as a result of an LPB detection.
- Active  
The tag is in the active state when it is activated by the interrogator. In this state it shall process any interrogator command.
- Tag Reply  
The tag is in the tag Reply state when it has received a valid command. If the tag remains powered then it will stay in this state until it has completed the reply, after which it will return to the active state.