

Australian Standard[®]

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

**Part 3: Parameters for air interface
communications at 13.56 MHz**



This Australian Standard® was prepared by Committee IT-034, Automatic Identification and Data Capture Techniques. It was approved on behalf of the Council of Standards Australia on 15 November 2006.

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- Australian Custom Service
 - Australian Data Capture Association
 - Australian Electrical and Electronic Manufacturers Association
 - Australian Retailers Association
 - Australian Veterinary Association
 - Department of Communications, Information Technology and the Arts
 - Department of Defence
 - Department of Primary Industries, Vic
 - GS1 Australia
 - RFID Association of Australia
 - The University of Adelaide
-

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Australian Standard[®]

Information technology—Radio frequency identification for item management

Part 3: Parameters for air interface communications at 13.56 MHz

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PREFACE

This Standard was prepared by the Standards Australia Committee IT-034, Automatic Identification and Data Capture Techniques.

The objective of this Standard is to provide a physical layer, collision management system and protocol values for RFID systems for Item Identification operating at 13.56 MHz.

This Standard is identical with, and has been reproduced from ISO/IEC 18000-3:2004, *Information technology—Radio frequency identification for item management—Part 3: Parameters for air interface communications at 13,56 MHz*.

As this Standard is reproduced from an International Standard, the following applies:

- (a) Its number appears on the cover and title page while the International Standard number appears only on the cover.
- (b) In the source text ‘this part of ISO/IEC 18000’ should read ‘this Australian Standard’.
- (c) A full point substitutes for a comma when referring to a decimal marker.

References to International Standards should be replaced by references to Australian or Australian/New Zealand Standards, as follows:

<i>Reference to International Standard</i>		<i>Australian Standard</i>	
ISO/IEC		AS	
15693	Identification cards—Contactless integrated circuit(s) cards—Vicinity cards	15693	Identification cards—Contactless integrated circuit(s) cards—Vicinity cards
		AS ISO/IEC	
15963	Information technology—Radio frequency identification for item management—Unique identification for RF tags	15963	Information technology—Radio frequency identification for item management—Unique identification for RF tags
18000-1	Information technology—Radio frequency identification for item management—Part 1: Reference architecture and definition of parameters to be standardized	18000.1	Information technology—Radio frequency identification for item management—Part 1: Reference architecture and definition of parameters to be standardized
19762 (all parts)	Information technology—Automatic identification and data capture (AIDC) techniques—Harmonized vocabulary	19762 (all parts)	Information technology—Automatic identification and data capture (AIDC) techniques—Harmonized vocabulary
ISO/IEC TR		AS ISO/IEC	
18047-3	Information technology—Radio frequency identification device conformance test methods—Part 3: Test methods for air interface communications at 13,56 MHz	18047.3	Information technology—Radio frequency identification device conformance test methods—Part 3: Test methods for air interface communications at 13,56 MHz

Only international references that have been adopted as Australian or Australian/New Zealand Standards have been listed.

The terms ‘normative’ and ‘informative’ are used to define the application of the annex to which they apply. A normative annex is an integral part of a standard, whereas an informative annex is only for information and guidance.

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INTRODUCTION

ISO/IEC 18000 has been developed by ISO/IEC JTC 1, SC 31, WG 4, *Radio frequency identification for item management*, 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; to minimise software and implementation costs; and to enable system management and control and information exchange to be common as far as is possible.

This part of ISO/IEC 18000 has been 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 2 MODES of operation, intended to address different applications. Clause 8 of this part of ISO/IEC 18000 summarises the differences between MODE characteristics. 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.

AUSTRALIAN STANDARD

Information technology — Radio frequency identification for item management —**Part 3:
Parameters for air interface communications at 13,56 MHz****1 Scope**

1.1 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

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

1.3 This part of ISO/IEC 18000 defines 2 non interfering MODES.

The MODES are NOT interoperable.

The MODES, whilst not interoperable, are non interfering.

2 Conformance**2.1 Claiming conformance**

In order to claim conformance with this part of ISO/IEC 18000 it is necessary to comply to all of the relevant clauses of this part of ISO/IEC 18000 except those marked 'optional' and 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 7816-6, *Identification cards — Integrated circuit cards — Part 6: Interindustry data elements for interchange*

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

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 — Reference architecture and definition of parameters to be standardized*

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 techniques — Harmonized vocabulary*¹⁾

EN 300 330, *Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical Characteristics and test methods for Radio equipment in the frequency range 9 kHz to 30 MHz*

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

Phase Jitter Modulation

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

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.

≈ MODE 1 -the value is a rounded value (e.g. ≈ 75.52 μs)

PJM Phase Jitter Modulation

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

6.0 General and applicable to both Modes of this part of ISO/IEC 18000

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 two 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 B.

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

NOTE 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.

Informative Comment: 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 to local radio regulations, which may affect performance.

1) To be published.

6.0.3 ISO/IEC 18000-3 reader conformance/compliance

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

6.0.5 Command structure and extensibility

Clauses 6.1 and 6.2, 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 optional command is used, it shall be implemented in the manner specified in the International 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.

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.

6.1 Physical layer, collision management system and protocols for MODE 1 of this part of ISO/IEC 18000

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 "reader talk first" technique.

6.1.2 Normative Aspects

The physical, collision management and transmission protocols determined in this MODE are consistent with the approach taken in ISO/IEC 15693. See annex G. Clauses 6.1.3 – 6.1.8 provide normative parts of MODE 1 by reference.

Clause 6.1.9 determines an optional protocol extension compliant with, but an extension to, ISO/IEC 15693.

6.1.3 Conformance and performance measurement aspects

The performance and conformance measurement aspects for MODE 1 will be given in the relevant clauses of future 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, 2000.

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.

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.

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.

6.1.9 Protocol extension

6.1.9.1 Protocol extension optional

The protocol extension is optional, tags may support it. If supported request and response shall comply with the definition given in Clauses 6.1.9 - 6.1.11.

If the tag does not support the protocol extension it shall not return an error code and shall remain silent.

The request consists of the following fields:

- Flags (see Table 1: Bit 4 set to 1 for protocol extension, Bit 5 - Bit 8 shall be set to 0: RFU)
- Protocol extension byte (Bit 1 and Bit 2 of the Protocol extension byte are reserved for future protocol extensions and have to be set to 0).
- CRC

6.1.9.2 Request flags

The request flags are shown in Table 1.

Table 1 — Request flags 1 to 4 definition

Bit Nb	Flag name	State	Description/limits
Bit 1	Sub-carrier_flag	0	A single sub-carrier frequency shall be used by the RF tag
		1	Two sub-carriers shall be used by the RF tag
Bit 2	Data_rate_flag	0	Low data rate shall be used
		1	High data rate shall be used
Bit 3	Response_flag	0	Optional protocol response as specified in 6.1.10.18 & 6.1.10.19, if the tag does not support this response, it shall remain silent.
		1	Optional protocol response as specified in G.8.4.1 Read single block command, and the response format in Figure G33, using coding dependant upon bits 1 and 2 above. If the tag does not support this response, it shall remain silent.
Bit 4	Protocol_Extension_Flag	1	Protocol format is extended
Bit 5	RFU	0	RFU
Bit 6	RFU	0	RFU
Bit 7	RFU	0	RFU
Bit 8	RFU	0	RFU

6.1.9.3 Request format

Figure 1 only refers to Protocol extension commands if Bit 1 and Bit 2 of the Protocol extension byte are 0.

SOF	Flags	Protocol extension byte	CRC	EOF
	8 bits	8 bits	16 bits	

Figure 1 — Protocol extension request format

6.1.10 Protocol extension- description of collision management method

6.1.10.1 Collision management in protocol extension

This protocol extension contains two major branches: the non-slotted non-terminating multiple tag reading branch, described in 6.1.10.2 and the slotted terminating adaptive round multiple tag reading branch described in 6.1.10.3.

6.1.10.2 Non-slotted non-terminating multiple tag reading protocol

In the non-slotted non-terminating aloha protocol, a Wake-up command shall cause the RF tags to reply at random, with self-determined intervals, as long as they continue to be in the energising field. In this protocol, interrogators will receive, detect and report all replies which arrive without collisions, but will not try to influence the interrogation process other than through the issuing of additional wake-up signals to introduce newly arriving tags into the reply process. Programming is performed with 1 RF tag in the field.

This implementation:

- only requires a Wake-up command
- uses a default reply length (length may be programmed by user)
- performs well when one or only a small number of tags are in the interrogation field at one time.

After a Wake-up command the interrogator listens for RF tags. The type of tag forms part of the preamble of the main reply and is thus signalled to the interrogator which will not try to signal any other commands to a non-slotted non-terminating tag. It is recommended that the default-reply-time to non-reply-time approximately forms the ratio 1 to 10.

Figure 2 shows 3 tags working in the non-slotted non-terminating tag protocol.

- The interrogator issued a Wake-up command and all 3 tags responded resulting in a collision.
- Next RF tag 1 and RF tag 3 responded after a varying hold off time resulting in a collision.
- Next RF tag 2 responded alone and was decoded.
- Next RF tag 1 responded alone and was decoded.
- Next RF tag 2 and RF tag 3 responded resulting in a collision.
- Next RF tag 1 and RF tag 2 responded resulting in a collision.
- Finally RF tag 3 responded and was decoded.

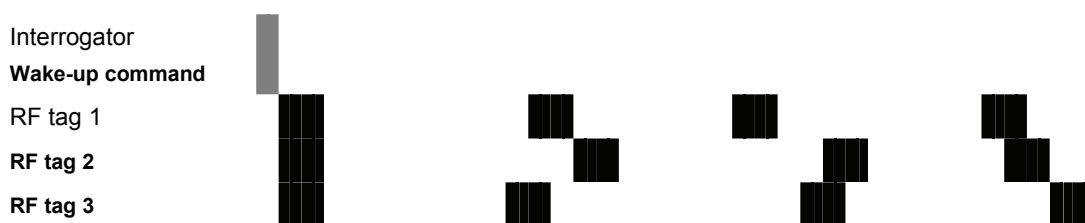


Figure 2 — Example of RF tag response in non-slotted non-terminating multiple tag reading protocol

6.1.10.3 RF tag states in non-slotted, non-terminating adaptive round protocol

The Power-off and Ready states are the same as in the normal protocol.

The transition from the Ready state to the active state occurs as the result of a protocol extension non-terminating/non-slotted Wake-up command (Protocol Extension_flag is set).

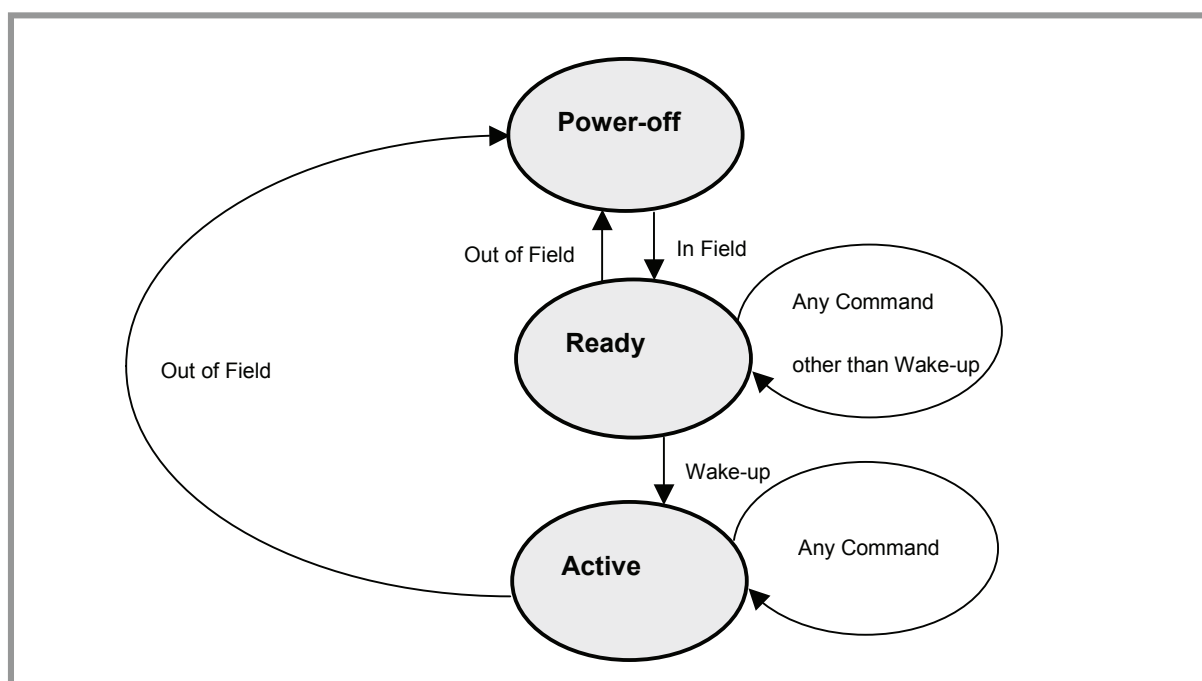


Figure 3 — Tag states in non-slotted non-terminating multiple tag reading protocol

6.1.10.4 Slotted terminating adaptive round multiple tag reading protocol

In the slotted terminating adaptive round protocol, after Wake-up and during the interrogation cycle, there is a continuing dialogue between tags and the interrogator/reader, and a tag shall not continue to reply indefinitely.

The Reader Talks First (RTF) Wake-up can be given frequently for highly dynamic populations. Within a large population of tags, there will be a diminishing number of tags replying, until all have been read.

In this protocol tags will select a random slot number, from a maximum slot number, in which to offer a reply. The maximum slot number is set in the tag as a default value, which may be temporarily over-ridden by an interrogator command. The interrogator signals the start of each slot. The tag keeps track of the number of the current slot timed from the Wake-up command responsible for it waking and subsequent transition to the active state. After responding the RF tag will automatically transition from the active state to the quiet state. If the tag is in the active state when the current slot number equals the maximum slot number, an increment in the current slot number shall cause the tag to reset its current slot value back to one and recalculate the

random slot number in which to re-offer its reply. This case arises if the response of a tag collided with another in its chosen reply slot, or the response contained an error. This cycling of current slot numbers continues until the tag response is decoded without error and it remains in the quiet state, or the tag leaves the energising field.

The maximum slot number is referred to as the number of slots in a round. The number of slots in a round may be expanded and contracted as the tag populations grow and shrink.

6.1.10.5 Example of interrogator to tag dialogue

Upon receiving a Wake-up command, tags do not necessarily reply immediately, but begin self-selecting within a default round length a randomly chosen reply slot within this first round. The time duration of a tag reply slot is dependent upon the chosen response format and the number of pages in the default reply. The number of slots which a tag expects within a reply round is dependent upon initial tag programming, but can be modified by interrogator commands. The start of each reply slot is signalled by the interrogator.

An example dialogue is shown in Figure 4.

- The interrogator issued a Wake-up command, which moved RF tags in the ready state to the active state.
- RF tags read their default round size from memory and randomly select a slot in which to respond.
- Slot 0 contained a response from RF tag 1 which after the reply transitions to the quiet state.
- The interrogator issued a Next-slot command, which contained the TEL of RF tag 1 which remains quiet.
- Slot 1 contained no response, and the interrogator issued a Close-slot (EOF) command.
- Slot 2 contained two responses, the precursors of which vary in their contents, so a collision is detected and the slot is closed before the main reply. The two RF tags will offer a response again next round (after the maximum number of slots in the current round have elapsed).
- Slot 3 contained two responses, the collision was not detected during the precursor but was detected in the CRC check of the main reply, so a collision was detected and the interrogator issued an Ultimate-error command. The two RF tags will offer a response again next round.
- Slot 4 contained two responses, but one is significantly stronger than the other so it appeared to the interrogator that only 1 RF tag was in the slot. The interrogator issued a Next-slot command which contained the TEL of RF tag 6. RF tag 7 will offer a response again after the maximum number of slots in the current round.
- Slot 5 contained a response of a particular RF tag which, for one of a variety of reasons, needed to be isolated. The interrogator issued a Selective-stand-by command, which moved RF tag 8 to the active state. RF tags 1 and 6 stay in the quiet state, while all other tags in the active state moved to the Stand-by state.
- At this time there is only one RF tag in the active state and there is an opportunity to request more data or program that tag. The interrogator issued a reply-with-range command, which causes RF tag 8 to respond with an addressed range (Slot 6).
- The interrogator then issued a Next-slot command, which left RF tag 8 in the quiet state.
- The interrogator then issued a Re-enter-round command, which moved the RF tags in the Stand-by state back to the active state.
- Slot 7 contained a response from RF tag 9.

Table 2 — Timing for the slotted terminating adaptive round

	Minimum	Typical	Maximum
t1	$4064/f_c$ (300 μ s)	$4096/f_c$ (302 μ s)	$4128/f_c$ (304 μ s)
t2		44 bits	
t3	$992/f_c$ (73 μ s)	$1024/f_c$ (76 μ s)	$1056/f_c$ (78 μ s)

Where:

t1 = interrogator/reader to tag & tag to interrogator/reader turn around time

t2 = gap between optional precursor and main reply

t3 = period before close slot command is issued

Note: The time t2 is 44 bits where the duration of 1 bit is 4 pulses of $32/f_c$. The RF tag only listens for the close slot command after the nominal 302 μ s turn around time has elapsed from the end of the precursor modulation.

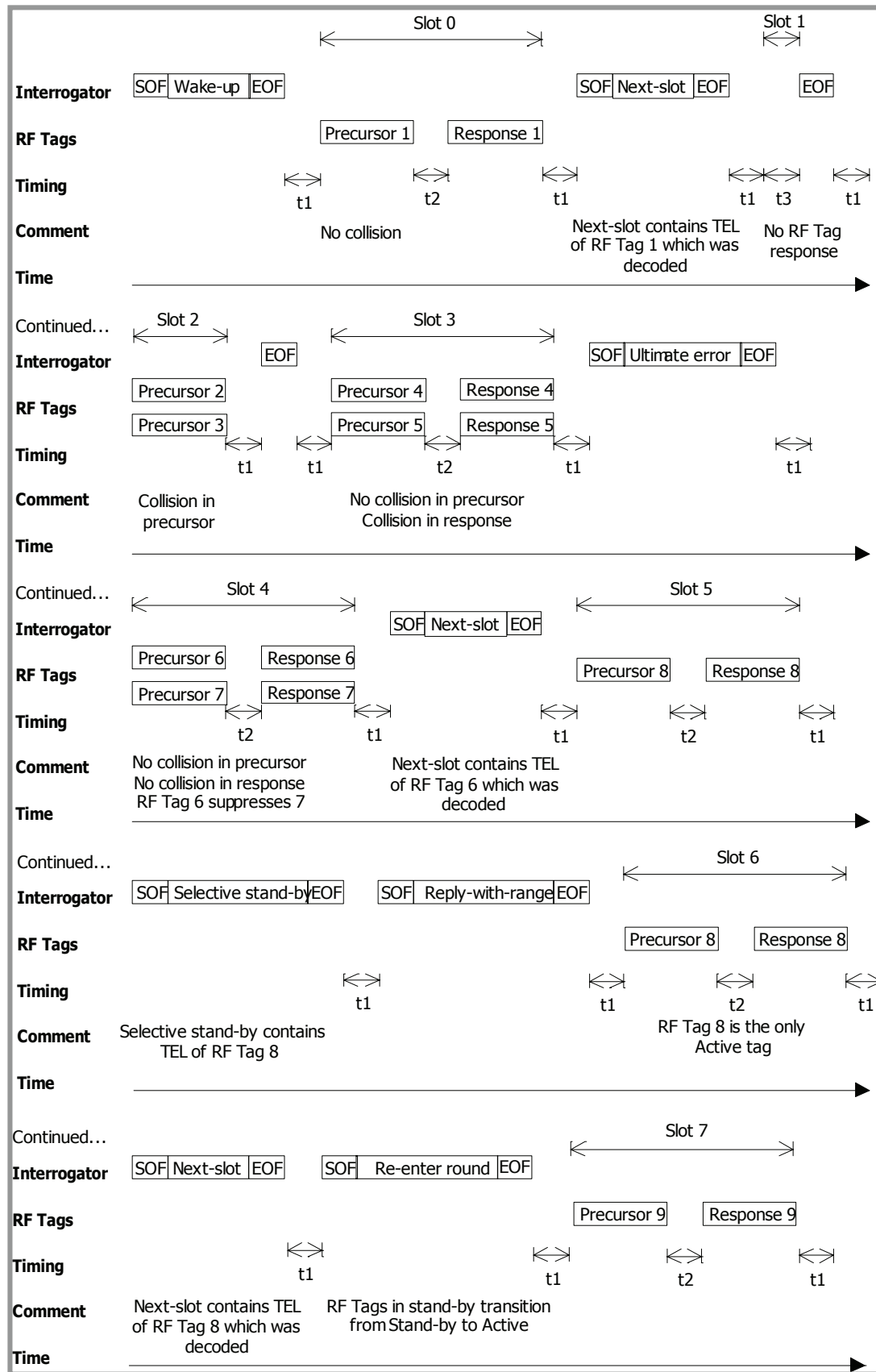
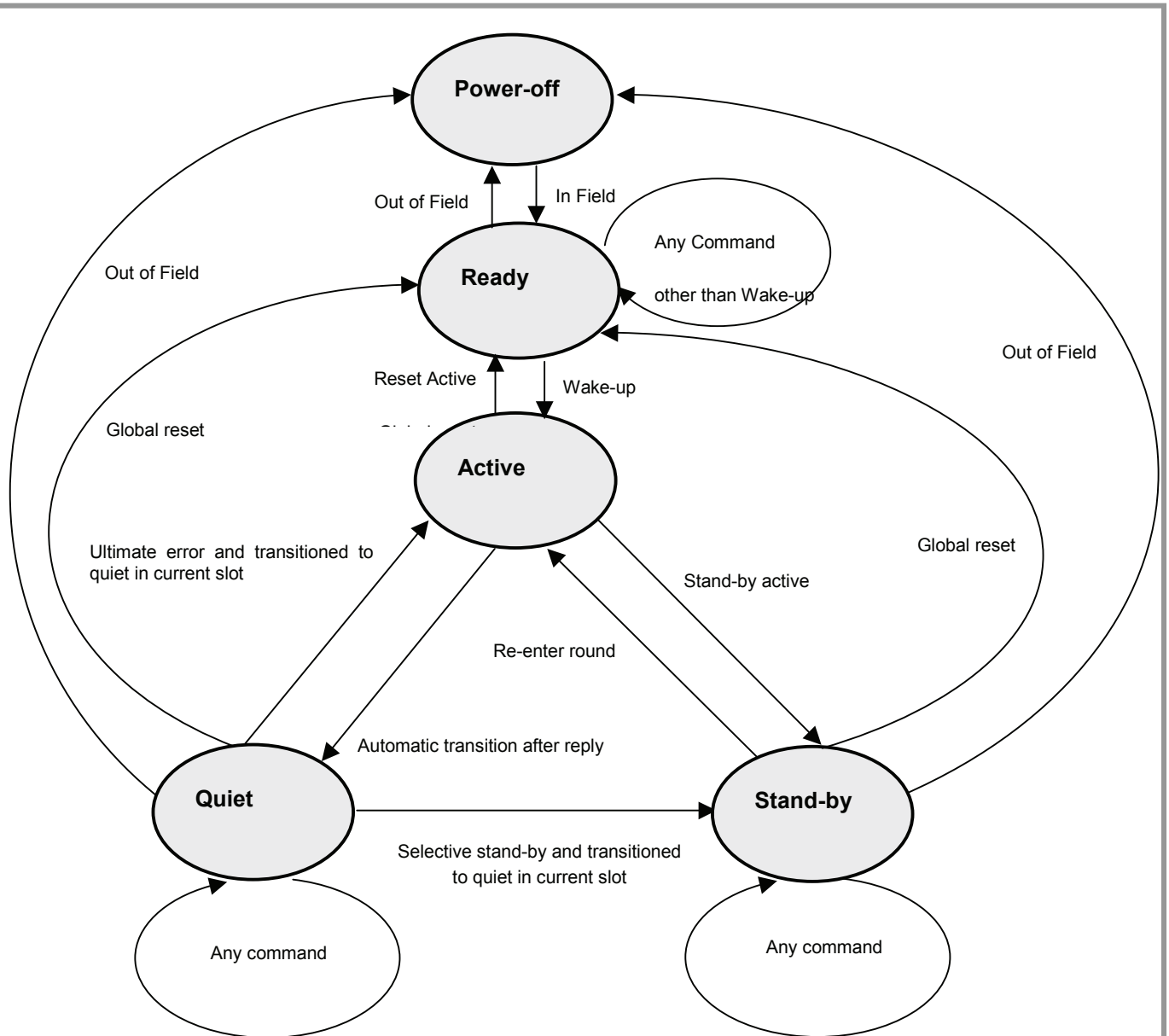


Figure 4 — Slotted terminating adaptive round

6.1.10.6 RF tag states in slotted terminating adaptive round protocol

The Power-off, ready, and quiet states are the same as in the normal protocol. The Selected state of the base protocol can be accessed via the base protocol commands.

The transition from the ready state to the active state occurs as the result of a protocol extension Wake-up command (Protocol Extension_flag is set).



NOTE 1 The transition to the Power-off state from another state occurs after 300ms when state storage bit is set. If power is removed for >10s the tag does not remember any previous state. If power is removed between 300ms and 10s the storage action is uncertain.

NOTE 2 The RF tag state transition diagram shows only valid transitions. In all other cases the current RF tag state remains unchanged. When the RF tag cannot process an interrogator request (e.g. CRC error etc.), it shall stay in its current state except if it has just transitioned to the quiet state where the tag will return to the active state.

Figure 5 — RF tag state transition diagram

6.1.10.7 The active state

An RF tag in the active state will respond with its default reply when the current slot number equals a randomly selected reply number (chosen from the maximum number of slots within the current round of slots). If the current slot number increments past the current maximum number of slots within the round, the current slot number is set back to 1 and a new random reply number is chosen.

The RF tag continues the above process until:

- after having replied, is left in the automatically transitioned to quiet state;
- it receives a command to transition to another state; or
- it leaves the energising field

6.1.10.8 The stand-by state

An RF tag in the Stand-by state shall respond to only a Global reset or a Re-enter round command. The tag holds the value of the current slot number, to be incremented further only after having returned to the active state by the receipt of a Re-enter round command.

In the case of a Global reset command, the RF tag transitions to the ready state and all counters are reset to initial values as would happen if the RF tag had just entered the energising field.

6.1.10.9 MODE 1: Protocol extension - tag response formats

Two response formats are allowed: a main reply with a precursor; and a main reply without a precursor.

The bit ordering for the main reply RF tag response is LSB first and LSByte first.

The bit ordering for the 12 bit precursor, if present, is LSB first.

The precursor allows the early detection of a collision within a slot which may be closed by the interrogator by a close slot (EOF) in the gap between the precursor and the main reply. If the precursor is implemented it shall have a fixed duration of $3456/f_c$, followed by a gap of t_2 (see Table 2) before the main reply.

The hardware implementation of the RF tag, together with the wake up command, determines whether or not a precursor is present. The RF tag may be configured, in hardware, to issue the precursor when the time to transmit the default reply data, or the requested reply data, without a precursor would be large with respect to the duration of the precursor and associated gap. Not issuing a precursor only means that the protocol will not be able to perform the early closure of colliding slot, (the collision would be dealt with after the main replies have been transmitted).

By examining the start of the tag response the interrogator determines whether or not a precursor is present. In the case of mixed RF tags, the interrogator would not observe a period of no tag modulation after a period of time equal to the fixed precursor duration, and thus the interrogator would not attempt to close the slot.

6.1.10.10 Response format with precursor

The response with precursor consists of the following fields:

- Precursor
- Gap (t2 as defined in Table 2).
- Main reply

Precursor	Gap	Main reply
------------------	------------	-------------------

Figure 6 — Protocol extension response format with precursor

6.1.10.11 Response format without precursor

The response without precursor consists of the following fields:

Main reply

Main reply

Figure 7 — Protocol extension response format without precursor

6.1.10.12 Precursor format

The precursor consists of the following fields:

Leader as defined in Figure 12.

Collision detection (12 bits using coding in Figure 13 and Figure 14).

Leader	Collision detection
---------------	----------------------------

Figure 8 — Precursor format

6.1.10.13 Tag excitation level (optional)

If TEL is unsupported by the tag TEL bits shall be transmitted as 0000.

If TEL is supported by the tag, the tag is able to provide a 4 bit measure of its excitation level. The level 0000 is unused as this value means that TEL is unsupported. This results in 15 valid TEL levels. If less levels are desired then the levels are reduced by resetting TEL bits to 0 starting from the LSB (e.g. 4 levels would have the 2 LSBs fixed at 00). TEL can be turned off by wakeup command parameters, and if implemented will be set to 0000, when turned off.

The TEL level is used in both the precursor as part of the collision detection bits and in the preamble of the tag reply. The TEL value is later echoed by the interrogator/reader and its use protects against the small signal suppression effect.

Variation in coupling between the tag and the interrogator, which occurs over the desired range of operating distances, is such that the power dissipated on chip approximately covers a 30 dB dynamic range of induced current.

The first level starts at the POR (Power on Reset) level of the RF Chip and increments approximately every 2 dB from that level. The final level covers excitation above 28 dB from POR.

Note : RF tags using chips implemented on different processes and using different antenna coils may exhibit different levels when they are exposed to the same magnetic field strength.

6.1.10.14 Collision detection format - TEL implemented, and requested.

Tag excitation level implemented (valid TEL values 0x01-0x0F)

The collision detection consists of the following fields:

4 TEL bits (less resolution can be obtained by fixing LSB(s) to 0)

8 Random bits (less resolution can be obtained by fixing LSB(s) to 0).

TEL bits	Random bits
4 bits	8 bits

Figure 9 — Collision detection field format with TEL implemented

6.1.10.15 Collision detection format - TEL not implemented

Tag excitation level not implemented (main reply will have fixed TEL = 0000)

The collision detection consists of the following fields:

12 Random bits (less resolution can be obtained by fixing LSB(s) to 0)

Random bits
12 bits

Figure 10 — Collision detection field format with TEL not implemented

6.1.10.16 Main reply format

The main reply consists of the following fields:

Preamble (32 bits using coding as defined in 6.1.10.17).

reply data (multiples of 32 bits using coding as defined in 6.1.10.19).

CRC (16 bits using coding as defined in 6.1.10.19)

End of signalling terminator (as defined in Figure 18).

Preamble	Reply data	CRC	End of Signalling Terminator
32 bits	n*32 bits	16 bits	2 bits

Figure 11 — Main reply format

6.1.10.17 Main reply preamble format

The preamble consists of the fields described in Table 3.

Table 3 — Preamble format

Bit Nb	Preamble name	Description/limits
1-4	Start of signalling	1110 (Bit1-4) - Start of main reply. Mandatory.
5	Protocol	0 – non-slotted non-terminating 1 – Tag slotted terminating adaptive round Set by chip manufacturer.
6	UID	0 – main reply does not include UID 1 – first 64 bits of main reply is UID Programmable.
7	Selection	0 - Selection function is not implemented 1 - Selection function is implemented Set by chip manufacturer.
8	State storage	0 - State does not survive an energising field gap. State survives a 300ms energising field gap. Set by chip manufacturer.
9-12	Tag excitation level	0000 (Bit9-12) - If TEL is not implemented. TTTT (Bit9-12) - Dynamic level (excluding 0000) if TEL is implemented.
13	Special bit	0 - Special bit function is off. 1 – Special bit function is on. Programmable.
14-16	Round size	(Bit14-16) 000 – RFU 001 – 8 010 – 16 011 – 32 100 – 64 101 – 128 110 – 256 111 - RFU Programmable. Can be over-ridden by interrogator command.
17-32	Page range	8 Bit Start (Bit17-24) and 8 Bit Finish page (Bit25-32) numbers of reply. Programmable. Can be over-ridden by interrogator command.

6.1.10.18 Bit representation and coding

6.1.10.18.1 Precursor coding

The sub clauses below define the Precursor coding.

6.1.10.18.2 Precursor leader coding

A leader starts with 8 pulses of $f_c/32$ ($\approx 423,75$ kHz) followed by 4 pulses of $f_c/32$ ($\approx 423,75$ kHz) of the opposite phase, see Figure 12.

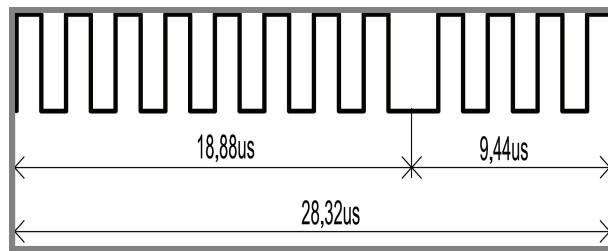


Figure 12 — Leader coding

6.1.10.18.3 Precursor collision detection binary 0 coding

A logic 0 starts with 4 pulses of $f_c/32$ ($\approx 423,75$ kHz) followed by an unmodulated time of $128/f_c$ ($\approx 9,44$ μ s), see Figure 13.

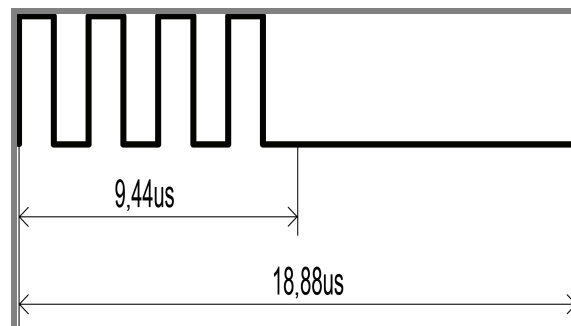


Figure 13 — Collision detection coding - binary 0

6.1.10.18.4 Precursor collision detection binary 1 coding

A logic 1 starts with an unmodulated time of $128/f_c$ ($\approx 9,44$ μ s) followed by 4 pulses of $f_c/32$ ($\approx 423,75$ kHz), see Figure 14.

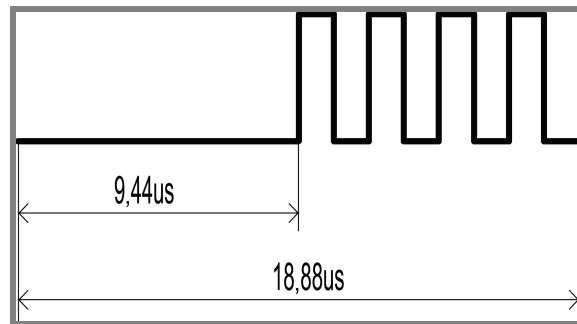


Figure 14 — Collision detection coding - Binary 1

6.1.10.19 Main reply coding

Main reply (including the preamble and CRC) coding uses DBPSK with 4 pulses of $f_c/32$ ($\approx 423,75$ kHz) for each bit.

6.1.10.19.1 Binary 0 coding

4 pulses of $f_c/32$ ($\approx 423,75$ kHz) which have the opposite phase from the previous 4 pulses represents a binary 0, see Figure 15.

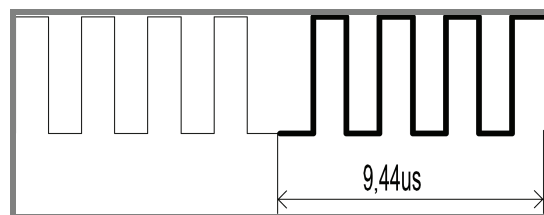


Figure 15 — Reply Coding - Binary 0

6.1.10.19.2 Binary 1 coding

4 pulses of $f_c/32$ ($\approx 423,75$ kHz) which have the same phase from the previous 4 pulses represents a binary 1, see Figure 16.

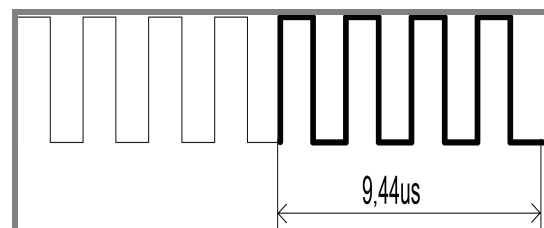


Figure 16 — Reply coding - binary 1

6.1.10.19.3 Example of binary coding.

See Figure 17 for an example of a “10”.

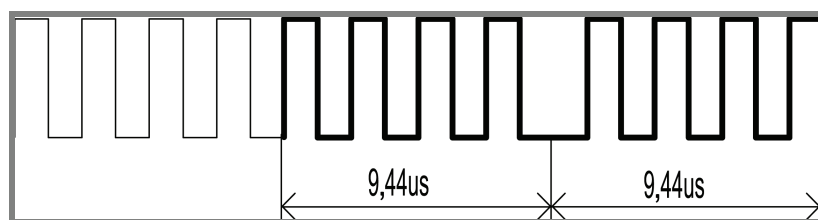


Figure 17 — Reply coding - “10”

6.1.10.19.4 End of signalling terminator coding.

The end of signalling terminator (see Figure 18) comprises:

6 pulses of $f_c/32$ ($\approx 423,75$ kHz) which have the opposite phase from the previous 4 pulses;

6 pulses of $f_c/32$ ($\approx 423,75$ kHz) which have the opposite phase from the previous 6 pulses.

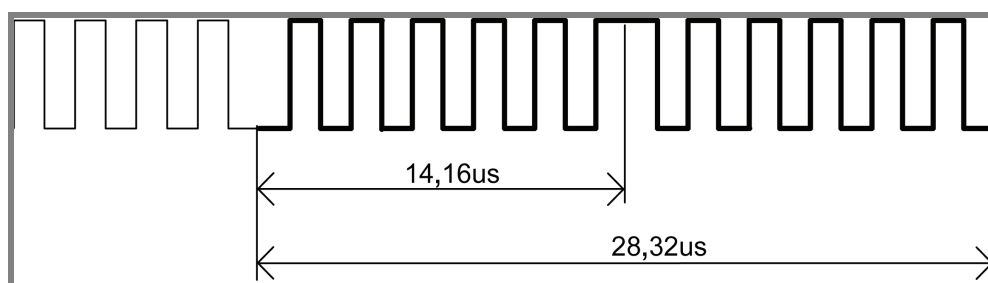


Figure 18 — End of signalling terminator coding

6.1.11 Protocol extension commands

6.1.11.1 Protocol extension command codes

If the Protocol Extension_flag is set the protocol extension byte has Bit 1 and Bit 2 set to 0 and Bits 3-8 are used for protocol extension commands described in Table 4.

For non-slotted/non-terminating tags there is only one mandatory command (0xC4) and two optional commands (0x64 and 0x74). The other commands, together with (0x64 and 0x74) are used by slotted/terminating tags.

Table 4 — Protocol extension command codes

Command code	Command name	Description/limits
0x(0-F)0 TTTT0000	Next slot	Signals the end of the current slot to all tags participating in a round. Contains TEL value TTTT in Most Significant Nibble (MSN).
0x02 00000010	Stay quiet	The Stay quiet command of the normal protocol (command code 02) may be used to signal next slot to RF tags which contain the UID in the default reply (UID Bit set to 1 in preamble), and the protocol extension bit set
0x04 00000100	Reply now	Signals to all tags in the active state to respond with their default reply in the current slot.

0x14 00010100	Reply with full data	Signals to all tags in the active state to update their reply start and stop page addresses with the first and last page addresses of tag memory respectively.
0x24 00100100	Reply with range	Signals to all tags in the active state to update their reply start and stop page addresses with the first and last page addresses contained in the command respectively. The stop address shall be greater than the start address for the default values to be updated.
0x34 00110100	Ultimate error	Signals to tags that have just replied in the current slot to reply again next round.
0x44 01000100	Re-enter round	Signals to tags in the Stand-by state to move to the active state.
0x54 01010100	Reset active tags	Signals to tags in the Active state to move to the ready state.
0x64 01100100	Clear special bit	Clears the special bit to 0.
0x74 01110100	Set special bit	Sets the special bit to 1.
0x(8-B)4 10WW0100	Wake up terminating/slotted tags only	This transfers a tag from the ready state to the active state. WW selects between wake up parameters (see Table 5).
0xC4 11000100	Wake up non-terminating/non- slotted tags only	Wake up non-slotted, non-terminating tags only
0xD4 11010100	Global reset	Signals to all tags to move to the ready state.
0xE4 11100100	Set Protocol Default Parameters	All tags to store in non-volatile memory new protocol default parameters, for round size, start and stop reply pages.
0x(0-F)8 TTTT1000	Selective stand-by	Signals to all tags in the active state to move to the Stand-by state. Signals to tags in the quiet state which have just replied in the current slot and which have TEL bits matching (TTTT in MSN) with those in the command to move to the active state - those tags with non-matching TEL bits move to the Stand-by state.
0x25 00100101	Select	The Select command of the normal protocol (command code 25) may be used to signal next slot to RF tags which contain the UID in the default reply (UID Bit set to 1 in preamble), and the protocol extension bit set. Signals to all tags in the active state to move to the Stand-by state. Signals to tags in the quiet state which have just replied in the current slot and which have a matching UID with the UID specified in the command to move to the active state and those tags with non-matching UID bits move to the Stand-by state.
0x(0-7)C 0RRR1100	New round size	Signals to tags in the active state to reset their slot count registers, set their slot count register to the value represented by RRR and begin a new round (see Table 6).
0x(8-F)C 1CCC1100	Comparison	A comparison command enables tags in the active state to remain in that state by matching any combination of bytes in a particular tag page with bytes sent as further data in the command. tags which do not fit the comparison criteria are sent to the Stand by state.

6.1.11.2 Protocol extension commands

6.1.11.2.1 Next-slot (mandatory)

The Next-slot command is mandatory by implementing one or both of the forms in 6.1.11.2.2 or 6.1.11.2.3.

6.1.11.2.2 Next-slot with TEL

Command code (Protocol extension byte) = 0x(0-F)0

The command carries a 4 bit TEL level TTTT (0-F) in the MSN of the command.

When receiving the Next-slot command:

- - a tag in the active state shall increment its slot counter;
- - a tag which has transitioned to the quiet state in the current slot which does not have matching TEL bits shall transition to the active state and increment its slot counter;
- - a tag which has transitioned to the quiet state in the current slot which has matching TEL bits shall remain in the quiet state.

If TEL is not implemented it is recommended that the UID be present in the tag response (Bit6 of the reply preamble as defined in Table 3 be set to 1), and the Next slot without TEL command be used.

SOF	Flags	Protocol extension byte	CRC16	EOF
	8 bits	8 bits	16 bits	

Figure 19 — Next-Slot With TEL Format

RF tag response

An RF tag in the active state shall respond with its default reply when the current slot number equals its random slot number.

6.1.11.2.3 Next slot without TEL

Command code = 0x02

The stay quiet command of the normal protocol may be used to signal next slot to RF tags which contain the UID in the default reply (UID Bit set to 1 in preamble).

- - when receiving this form of Next-slot (Stay quiet):
- - a tag in the active state shall increment its slot counter;

a tag which has transitioned to the quiet state in the current slot which does not have matching UID bits shall transition to the active state and increment its slot counter;

a tag which has transitioned to the quiet state in the current slot which has matching UID bits shall remain in the quiet state.

SOF	Flags	Stay quiet	UID	CRC16	EOF
	8 bits	8 bits	64 bits	16 bits	

Figure 20 — Next-slot without TEL format (stay quiet)

RF tag response

An RF tag in the active state shall respond with its default reply when the current slot number equals its random slot number.

An RF tag in the quiet state shall offer no response.

6.1.11.2.4 Reply now (optional)

Command code (Protocol extension byte) = 0x04

When receiving the reply now command all tags in the active state shall reply in the current slot with their default reply.

SOF	Flags	Protocol extension byte	CRC16	EOF
	8 bits	8 bits	16 bits	

Figure 21 — Reply-now format

RF tag response

An RF tag in the active state shall respond with its default reply in the current slot (over-rides the requirement for random slot number to equal current slot number).

6.1.11.2.5 Reply with full data (optional)

Command code (Protocol extension byte) = 0x14

When receiving the reply with full data command all tags in the active state shall update their default reply start and stop addresses with the first and last page addresses of their memory.

SOF	Flags	Protocol extension byte	CRC16	EOF
	8 bits	8 bits	16 bits	

Figure 22 — Reply-with-full-data format

RF tag response

An RF tag in the active state will respond with its default reply (which has been updated to cover the full memory) when the current slot number equals its random slot number.

6.1.11.2.6 Reply with range (optional)

Command code (Protocol extension byte) = 0x24

When receiving the reply with range command all tags in the active state shall update their default reply start and stop addresses with the start and stop addresses contained in the command. The stop address shall be greater than the start address for the default values to be updated.

SOF	Flags	Protocol extension byte	Start address	Stop address	CRC16	EOF
	8 bits	8 bits	8 bits	8 bits	16 bits	

Figure 23 — Reply-with-range Format

RF tag response

An RF tag in the active state will respond with its default reply (which has been updated with new start and stop pages) when the current slot number equals its random slot number.

6.1.11.2.7 Ultimate error (mandatory)

Command code (Protocol extension byte) = 0x34

When receiving the Ultimate error command:

a tag in the active state shall increment its slot counter;

a tag which has transitioned to the quiet state in the current slot shall transit to the active state and increment its slot counter.

SOF	Flags	Protocol extension byte	CRC16	EOF
	8 bits	8 bits	16 bits	

Figure 24 — Ultimate-error format

RF tag response

An RF tag in the active state will respond with its default reply when the current slot number equals its random slot number.

6.1.11.2.8 Re-enter round (mandatory if selective-standby is implemented)

Command code (Protocol extension byte) = 0x44

When receiving the Re-enter round command tags in the stand by state shall transit to the active state.

SOF	Flags	Protocol extension byte	CRC16	EOF
	8 bits	8 bits	16 bits	

Figure 25 — Re-Enter-round format

RF tag response

An RF tag in the active state will respond with its default reply when the current slot number equals its random slot number.

6.1.11.2.9 Reset active (mandatory if comparison is implemented)

Command code (Protocol extension byte) = 0x54

When receiving the reset active command tags in the active state shall transition to the ready state.

SOF	Flags	Protocol extension byte	CRC16	EOF
	8 bits	8 bits	16 bits	

Figure 26 — Reset-active format

RF tag response

There is no tag response.

6.1.11.2.10 Clear special bit (optional)**Command code (Protocol extension byte) = 0x64**

When receiving the Clear special bit command all tags in the active state shall clear their special bit to 0.

SOF	Flags	Protocol extension byte	CRC16	EOF
	8 bits	8 bits	16 bits	

Figure 27 — Clear special bit format

RF tag response

There is no tag response.

6.1.11.2.11 Set special bit (optional)**Command code (Protocol extension byte) = 0x74**

When receiving the Set special bit command all tags in the active state shall set their special bit to 1.

SOF	Flags	Protocol extension byte	CRC16	EOF
	8 bits	8 bits	16 bits	

Figure 28 — Set special bit format

RF tag response

There is no tag response.

6.1.11.2.12 Wake-up (mandatory, for terminating/slotted tags)**Command code (Protocol extension byte) = 0x(8-B)4**

The command carries a 2 bit wake up parameter, 10WW (8-B) - see Table 5

When receiving any one of the 4 wake-up commands only terminating/slotted tags in the ready state shall transition to the active state. The use of the 4 wake up commands allows the interrogator/reader to disable TEL and/or the precursor in tag replies. If the interrogator/reader requests TEL and/or the precursor and the tag does not implement TEL and/or the precursor, then TEL and/or the precursor are not provided in the tag reply.

Table 5 — Wake up parameters

Command code 10WW0100	Wake Up request
10000100	TEL and precursor
10010100	TEL, no precursor
10100100	Precursor, no TEL
10110100	No precursor, no TEL

SOF	Flags	Protocol extension byte	CRC16	EOF
	8 bits	8 bits	16 bits	

Figure 29 — Wake-up format

RF tag response

An RF tag in the active state shall respond with its default reply when the current slot number equals its random slot number.

6.1.11.2.13 Wake-up (mandatory, for non-terminating/non-slotted tags)**Command code (Protocol extension byte) = 0xC4**

When receiving this wake-up command only non-terminating/non-slotted tags shall begin their reply sequence.

SOF	Flags	Protocol extension byte	CRC16	EOF
	8 bits	8 bits	16 bits	

Figure 30 — Wake-up format

RF tag response

A non-terminating/non-slotted RF tag, shall respond with its reply.

6.1.11.2.14 Global reset (optional)**Command code (Protocol extension byte) = 0xD4**

When receiving the Global reset command all tags shall transit to the ready state.

SOF	Flags	Protocol extension byte	CRC16	EOF
	8 bits	8 bits	16 bits	

Figure 31 — Global-reset format

RF tag response

There is no tag response.

6.1.11.2.15 Selective stand-by (optional)**6.1.11.2.15.1 Selective stand-by with TEL****Command code (Protocol extension byte) = 0x(0-F)8**

The command carries a 4 bit TEL level TTTT (0-F).

When receiving the Selective stand-by command:

all tags in the active state shall transition to the stand-by state;

Tags which have just replied in the current slot and which have TEL bits matching (TTTT in MSN) with those in the command shall move to the active state;

Tags which have just replied in the current slot and which have non-matching TEL bits move to the Stand-by state.

SOF	Flags	Protocol extension byte	CRC16	EOF
	8 bits	8 bits	16 bits	

Figure 32 — Selective-stand-by with TEL format

RF tag response

An RF tag in the active state shall respond with its default reply when the current slot number equals its random slot number.

6.1.11.2.15.2 Selective stand-by without TEL

Command code = 0x25

The Select command of the normal protocol may be used to signal selective stand-by to RF tags which contain the UID in the default reply (UID Bit set to 1 in preamble).

When receiving this form of Selective stand-by (Select):

all tags in the active state shall transition to the stand-by state;

Tags which have just replied in the current slot and which have UID bits matching with those in the command shall move to the active state;

Tags which have just replied in the current slot and which have non-matching UID bits move to the stand-by state.

SOF	Flags	Select	MFG tag ID	CRC16	EOF
	8 bits	8 bits	64 bits	16 bits	

Figure 33 — Selective-stand-by without TEL format (select)

RF tag response

An RF tag in the active state shall respond with its default reply when the current slot number equals its random slot number.

6.1.11.2.16 New round size (mandatory)

Command code (Protocol extension byte) = 0x(0-7)C

The command carries a 3 bit round size RRR (0-7) - see Table 6.

When receiving the New round size command, tags in the active state shall update their round size to the value contained in the command and recalculate their random reply slot number from the new maximum value (0RRR). These tags will then assume the current slot number is one.

Table 6 — New-round-size values

Command code 0RRR1100	Round size
00001100	RFU
00011100	8
00101100	16
00111100	32
01001100	64
01011100	128
01101100	256
01111100	RFU

SOF	Flags	Protocol extension byte	CRC16	EOF
	8 bits	8 bits	16 bits	

Figure 34 — New-round-size format

RF tag response

An RF tag in the active state shall respond with its default reply when the current slot number equals its random slot number.

6.1.11.2.17 Comparison (optional)

Command code (Protocol extension byte) = 0x(8-F)C

The comparison command enables tags in the active state to remain in that state by matching any combination of bytes in a particular tag page with bytes sent as further data in the command. Tags which do not fit the selection criteria are sent to the stand by state.

To compare tags using inverse logic, tags in the active state are first compared with normal logic and then moved to the ready state by a Reset active tags command. Then tags in the stand-by state are moved to the active state by a Re-enter round command.

Refinement of comparison is performed by progressively comparing (and at the same time eliminating) tags with comparison criteria.

The comparison is performed on the Comparison_page of memory. The comparison bits (CCC) in the command represent comparison functions and are listed in Table 7.

B0, B1, B2, B3 each represent 8 bits in the Comparison_page or Comparison_data with B0 representing the least significant byte.

Table 7 — Comparison functions

Command code 1CCC1100	Comparison function
10001100	contents of the Comparison_page in tag memory = Comparison_data in the command
10011100	B0-B1 of the Comparison_page in tag memory with B0-B1 of the Comparison_data in the command using B2-B3 of the Comparison_data in the command as a mask
10101100	B2-B3 of the Comparison_page in tag memory with B0-B1 of the Comparison_data in the command using B2-B3 of the Comparison_data in the command as a mask
10111100	B0 of the Comparison_page in tag memory $\leq$ B0 of the Comparison_data in the command
11001100	B0-B1 of the Comparison_page in tag memory $\leq$ B0-B1 of the Comparison_data in the command
11011100	contents of Comparison_page in tag memory $\leq$ Comparison_data in the command
11101100	RFU
11111100	RFU

Comparison with a mask is carried out on a bit-wise comparison between 16 bits of data in the Comparison_page in memory and the Comparison_data_B2_B3 (the most significant 16 bits) contained in the comparison command (see Figure 35). When using a 16 bit mask for the comparison, the mask bit shall be 1 to indicate that the corresponding bit position in memory is to be considered, and the mask bit shall be 0 to indicate that the corresponding bit position in memory is to be ignored.

In the “less than or equal to” comparisons, 32 bits are sent as part of the Comparison_data but only the relevant bytes are compared.

A “greater than” function can be performed by eliminating tags which are less than or equal to”. A “less than” *number* function can be performed by choosing *number* to be one smaller than the number required to be less than.

SOF	Flags	Protocol extension byte	Comparison_page	Comparison_data	CRC16	EOF
	8 bits	8 bits	8 bits	32 bits	16 bits	

Figure 35 — Comparison format

Mask	Data
Comparison_data_B2_B3	Comparison_data_B0_B1
16 bits	16 bits

Figure 36 — Comparison_data with comparison mask

RF tag response

An RF tag in the active state will respond with its default reply when the current slot number equals its random slot number.

6.1.11.2.18 Set protocol default parameters (optional)

Command code (Protocol extension byte) = 0xE4

When receiving the Set protocol default parameters command all tags in the active state shall program new values for the default round size, start and stop addresses, in the non-volatile memory, with the values contained in the command. The stop address shall be greater than the start address for the default values to be stored. The RFU bits shall be set to 0, and the round size to be defined according to table 6. If this command is not implemented, the default round size will be 8, and the default start and stop page will be page 1.

SOF	Flags	Protocol extension byte	RFU	Default Round Size	Default Start address	Default Stop address	CRC16	EOF
	8 bits	8 bits	5 bits	3 bits	8 bits	8 bits	16 bits	

Figure 37 — Set protocol default parameters - format

RF tag response

There is no tag response.

6.1.12 Air interface application layer

6.1.12.1 Structure

The application layer shall be determined and controlled solely within the interrogator and shall not be carried across the air interface.

6.2 MODE 2: Physical layer, collision management system and protocols for MODE 2 of this part of ISO/IEC 18000

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 future 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

Table 8 — 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 (for Spread spectrum systems)	N/A
M2-Int: 1c	Operating frequency accuracy	$\pm$ 100 parts per million Japan: $\pm$ 50 parts per million
M2-Int: 1d	Frequency hop rate (for Frequency Hopping [FHSS] systems)	N/A
M2-Int: 1e	Frequency hop sequence (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. (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 EIRP	Not relevant parameter in 13,56 MHz systems Maximum EIRP depends on installation Compliant with ETSI and FCC maximum in Band allowed field strength. (Interrogator Transmit Maximum EIRP is not regulated in the Japan Radio Law).
M2-Int: 4	Interrogator transmit spurious Emissions	
M2-Int: 4a	Interrogator transmit spurious emissions, in-band (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	
M2-Int: 6a	Transmit to receive turn around time	0 - 50 μ s
M2-Int: 6b	Receive to transmit turn around time	Class 1 : 0 - 100 μ s Class 2 : Dependent on application
M2-Int: 6c	Dwell time or Interrogator transmit power on ramp	0 - 10 μ s

Ref.	Parameter Name	Description
M2-Int: 6d	Decay time or Interrogator transmit power down ramp	0 - 10 μ s
M2-Int: 7	Modulation	PJM (Phase Jitter Modulation) min. level +/- 1,0 ° max. level +/- 2,0 °
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 41)
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	The command flag defines the start of a command and the bit interval timings. The 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 zero defining the end of a flag. (See Figure 38 below)
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	Reader Talks First (RTF) System. Tag cannot respond unless it receives valid command from interrogator.
M2-Int: 15	Polarization	N/A

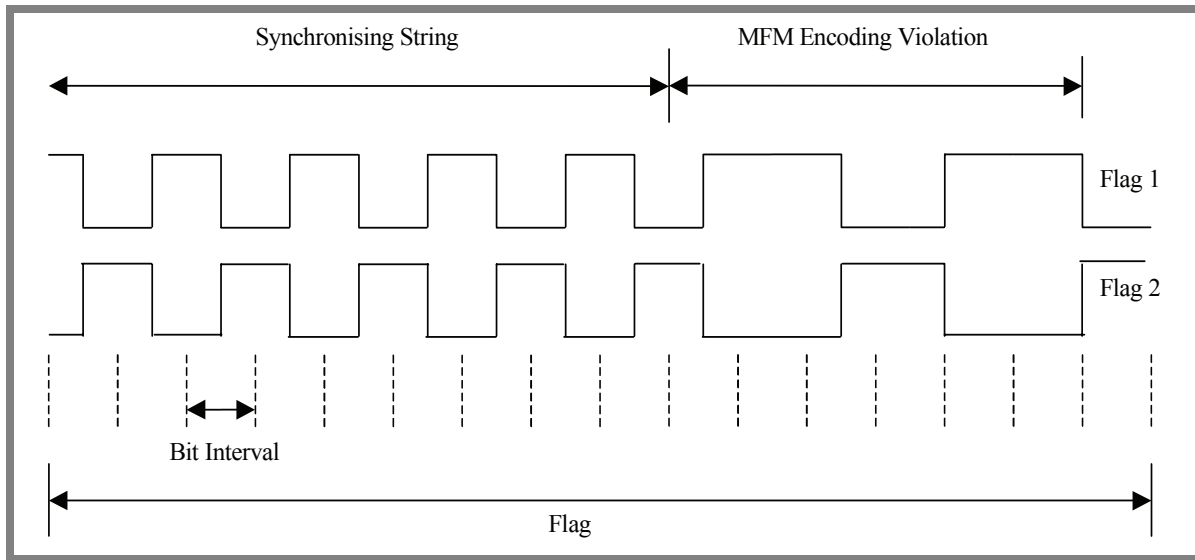


Figure 38 — Two possible command flags

6.2.2 Tag to interrogator link

Table 9 — 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 (for Spread spectrum systems)	Multi-frequency operating system where tags can select from 8 reply channels. Tags transmit the whole of their reply using a selected channel. The tag may use one of eight subcarriers. The subcarriers are derived by division of the powering field's frequency. <table border="1"> <thead> <tr> <th>Channel</th><th>Frequency kHz</th><th>Division 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 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
Channel	Frequency kHz	Division Ratio																											
A	969	14																											
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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 (for Frequency hopping [FHSS] systems)	Tags transmit the whole of a reply on a selected channel																											
M2-Tag: 1e	Frequency hop sequence (for Frequency hopping [FHSS] systems)	Reply channel is randomly selected by the tag.																											
M2-Tag: 2	Occupied channel bandwidth	106 kHz for each of 8 reply channels																											
M2-Tag: 3	Transmit maximum EIRP	N/A																											

Ref.	Parameter Name	Description																											
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																													
M2-Tag: 6a	Transmit to receive turn around time	0 - 200µs																											
M2-Tag: 6b	Receive to transmit turn around time	50 to 100µs.																											
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	Load Modulation																											
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	Sub-carrier frequency	8 sub-carrier frequencies available: <table border="1"> <thead> <tr> <th>Channel</th><th>Frequency kHz</th><th>Division 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 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
Channel	Frequency kHz	Division Ratio																											
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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	Sub-carrier frequency accuracy	Synchronous to the carrier frequency.																											
M2-Tag: 7g	Sub-carrier 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 44)																											
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																											

Ref.	Parameter Name	Description
M2-Tag: 11b	Preamble waveform	The reply flag defines the start of a reply and the bit interval timings. The 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 zero defining the end of a flag. (See Figure 39 below)
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 40

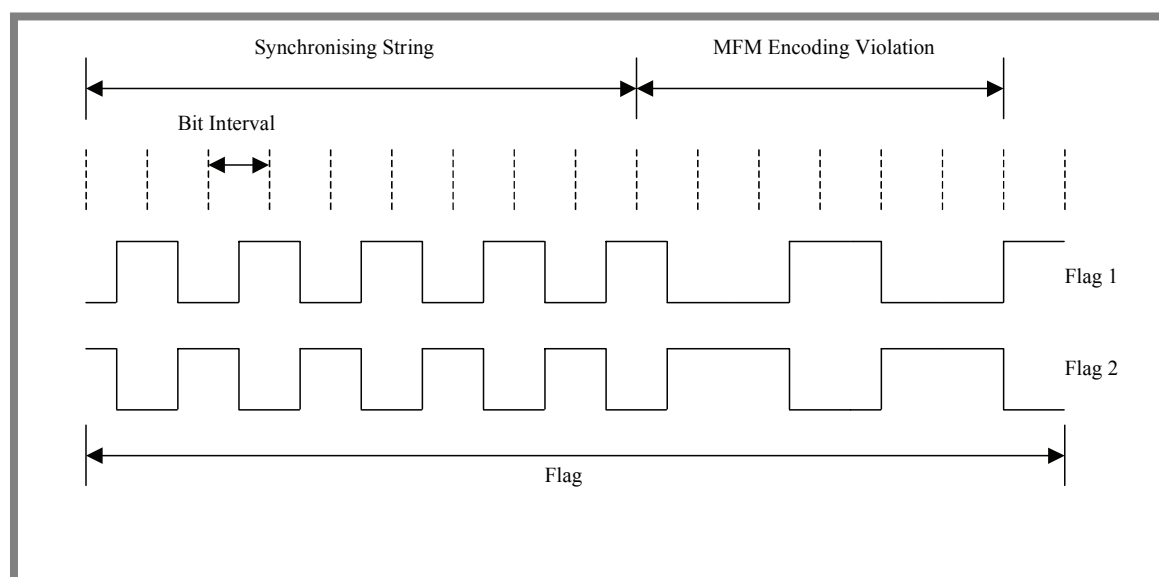


Figure 39 — Two possible reply flags

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 are passive. 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 $\pm 1,0^\circ$ and $\pm 2,0^\circ$. 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 A.

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

The air interface operates as a full duplex communication link. The interrogator operates with full duplex transmissions being able to transmit PJM commands whilst simultaneously receiving multiple tag replies. Tags operate with half duplex transmissions.

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.

The interrogator 'Receive to Transmit Turn Around Time' defines two Classes. Performance dependant implementations will normally select Class 1 Receive to transmit turn around time. Low cost implementations where high speed performance is not critical may select Class 2 Receive to transmit turn around time where the needs of the application determine the Receive to transmit turn around time. Either option is compliant.

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 changes 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 a 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 40.

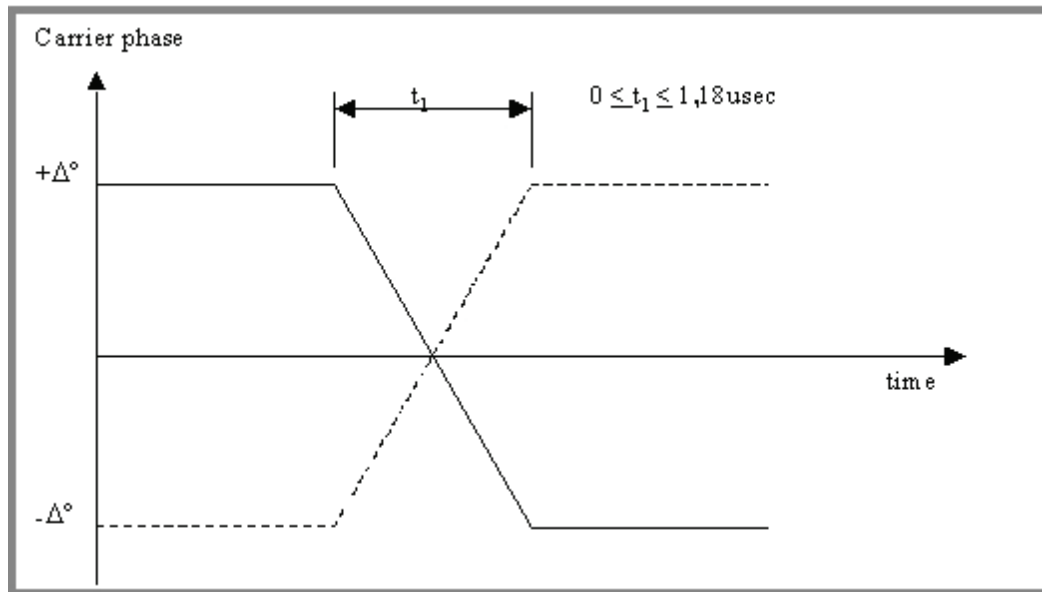


Figure 40 — Command modulation scheme

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 μs .

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 41.

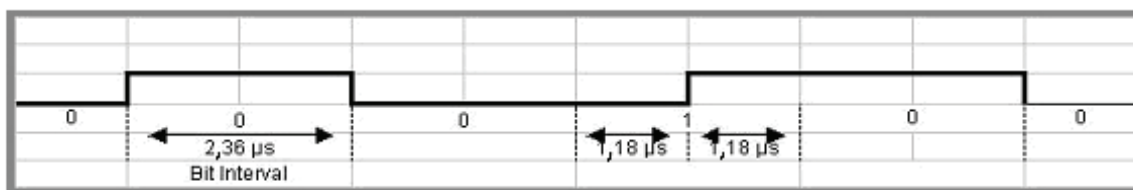


Figure 41 — Command MFM encoding and timing of binary 000100

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 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 defining the end of a flag.

The synchronising string, encoding violation and a trailing zero for two possible command flags are illustrated in Figure 42.

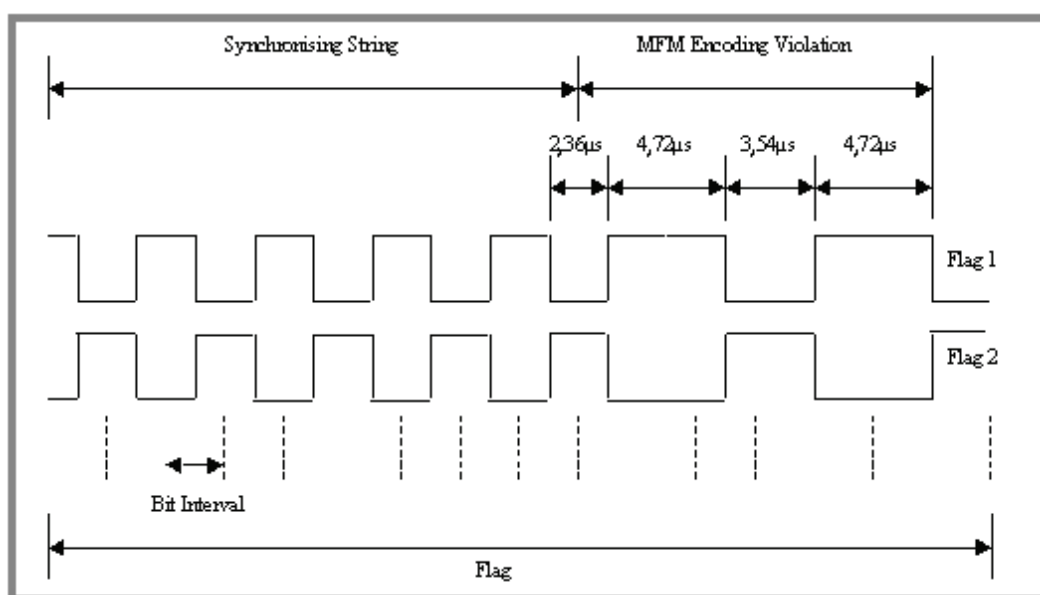


Figure 42 — MFM Encoding and timing for two possible command flags

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 10.

Table 10 — 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 43 below. Such mask limitation would be appropriate for ITU region 1, 2 and meets Japanese regulations.

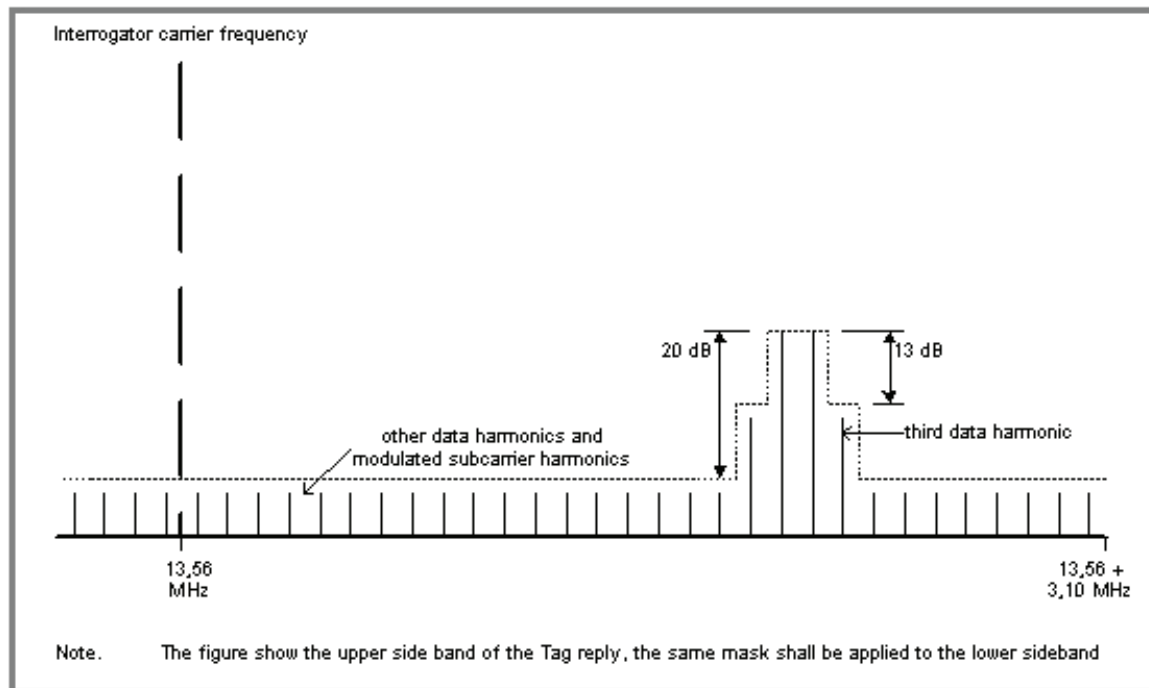


Figure 43 — Tag reply mask

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 μ 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 Clause 6.2.3.2.2. An example of reply MFM encoding of the binary string 000100 is shown in Figure 44.

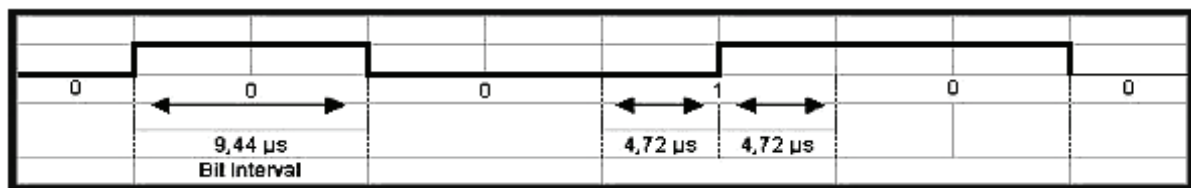


Figure 44 — Reply MFM encoding and timing of binary 000100

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 45.

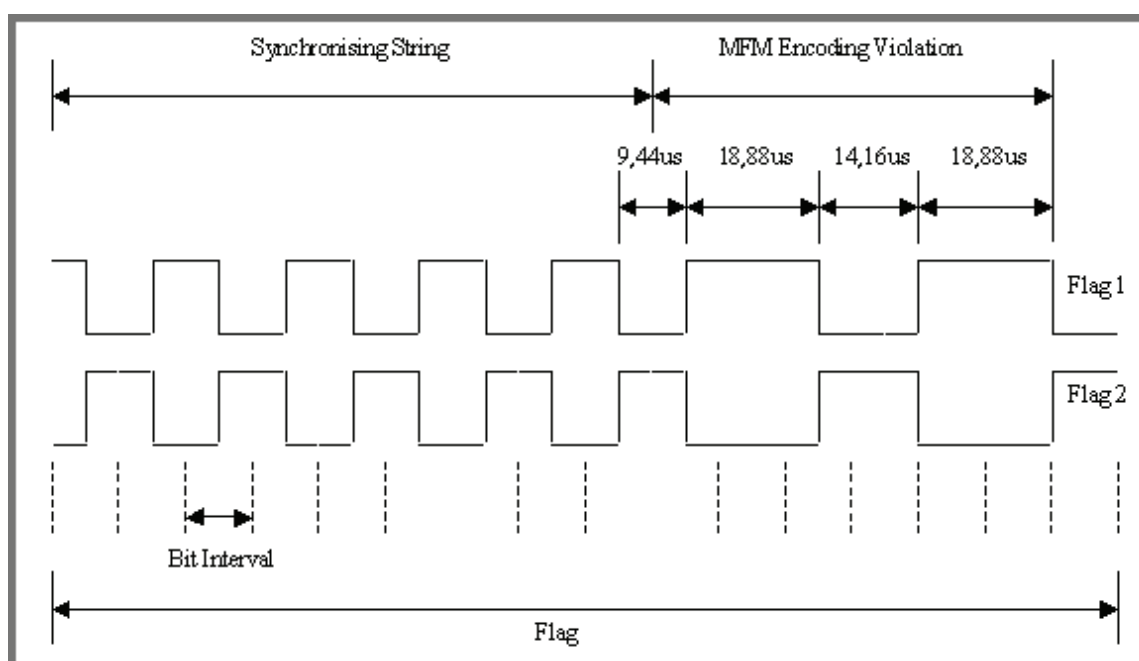


Figure 45 — MFM Encoding and timing for two possible reply flags