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Information technology — Radio frequency identification for item management

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

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National foreword

This British Standard is the UK implementation of ISO/IEC 18000-4:2008. It supersedes BS ISO/IEC 18000-4:2004, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee IST/34, Automatic identification and data capture techniques.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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INTERNATIONAL STANDARD

ISO/IEC 18000-4

Second edition
2008-09-01

Information technology — Radio frequency identification for item management —

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

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

Partie 4: Paramètres de communications d'une interface d'air à 2,45 GHz

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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 18000-4 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology* Subcommittee SC 31, *Automatic identification and data capture techniques*.

This second edition cancels and replaces the first edition (ISO/IEC 18000-4:2004), 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*

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Introduction

This part of ISO/IEC 18000 is one of a series of International Standards and Technical Reports developed by ISO/IEC JTC 1/SC 31, WG 4 for the identification of items (Item Management) using radio frequency identification (RFID) technology.

This part of ISO/IEC 18000 defines the 2,45 GHz protocols that support ISO/IEC 18000-1. Each of the specific physical/data link configurations is defined in a separate sub-clause. The configuration descriptions include a Physical Layer and a Data Link Layer.

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 concerning radio-frequency identification technology given in all parts of the document and especially in 5.2 and 5.3.

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

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INTERNATIONAL STANDARD **ISO/IEC 18000-4:2008(E)**

Information technology — Radio frequency identification for item management —

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

1 Scope

This part of ISO/IEC 18000 defines the air interface for radio frequency identification (RFID) devices operating in the 2,45 GHz Industrial, Scientific, and Medical (ISM) band used in item management applications. This part of ISO/IEC 18000 provides a common technical specification for RFID devices that can be used by ISO committees developing RFID application standards. This part of ISO/IEC 18000 is intended to allow for compatibility and to encourage inter-operability of products for the growing RFID market in the international marketplace. This part of ISO/IEC 18000 defines the forward and return link parameters for technical attributes including, but not limited to, operating frequency, operating channel accuracy, occupied channel bandwidth, maximum equivalent isotropically radiated power (EIRP), spurious emissions, modulation, duty cycle, data coding, bit rate, bit rate accuracy, bit transmission order, and where appropriate operating channels, frequency hop rate, hop sequence, spreading sequence, and chip rate. This part of ISO/IEC 18000 further defines the communications protocol used in the air interface.

This part of ISO/IEC 18000 contains two modes. The first is a passive tag operating as an interrogator talks first and the second is a battery-assisted tag operating as a tag talks first. The detailed technical differences between the modes are shown in the parameter tables.

2 Normative references

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

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

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 18047-4, *Information technology — Radio frequency identification device conformance test methods — Part 4: Test methods for air interface communications at 2,45 GHz*

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

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3 Terms and definitions

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

4 Symbols and abbreviated terms

Cht	Carrier high level tolerance
Clt	Carrier low level tolerance
$f_{bitrate}$	base frequency of the bit rate of Manchester code without bit changes
f_c	frequency of operating field (carrier frequency)
FHSS	Frequency Hopping Spread Spectrum
M	Modulation
Ma	Modulation overshoot
Mb	Modulation undershoot
Mlt	Modulation lower tolerance
Mut	Modulation upper tolerance
Tbmf	Manchester fall time
Tbmr	Manchester rise time
Tcf	carrier fall time
Tcr	carrier rise time
Tcs	carrier steady time
Tf	fall time
Tfhf	carrier FHSS fall time
Tfhr	carrier FHSS rise time
Tfhs	carrier FHSS steady time
Tflb	forward link bit time
Tr	rise time
Trlb	return link bit time

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5 2,45 GHz RFID protocols that support this part of ISO/IEC 18000

5.1 General

5.1.1 Protocols

Clause 5 defines the ISO/IEC 18000-4 2,45 GHz RFID command/data level communication protocols. These protocols facilitate communication between compliant tag and compliant interrogator. The timing parameters and signal characteristics for the protocols are defined in the physical link specifications in each mode.

5.1.2 Frequency

This part of ISO/IEC 18000 is intended to address RFID devices operating in the 2 450 MHz Industrial, Scientific and Medical (ISM) frequency band.

5.1.2.1 Interface definitions

This part of ISO/IEC 18000 supports standard parameters as described in ISO/IEC 18000-1 and standard air interface implementations for wireless, non-contact information system equipment for Item Management applications. Typical applications operate at ranges greater than one meter.

5.1.2.1.1 RFID system definition

The radio-frequency identification (RFID) system shall include a host system and RFID equipment (interrogator and tags). The host system runs an application program, which controls interfaces with the RFID. The RFID equipment shall be composed of two principal components: tags and interrogators. The tag is intended for attachment to an item, which a user wishes to manage. It is capable of storing a tag ID number and other data regarding the tag or item and of communicating this information to the interrogator. The interrogator is a device, which communicates to tags in its field of view. Additionally, the interrogator can use its transmitted RF carrier to power the tag. Systems, which rely on the transmitted interrogator carrier for powering the tag, are typically referred to as passive tag systems. The interrogator controls the protocol, reads information from the tag, directs the tag to store data in some cases, and ensures message delivery and validity.

5.1.2.1.2 Minimum features

RFID systems defined by this part of ISO/IEC 18000 provide the following minimum features:

- identify tag in range,
- read data,
- write data or handle read only systems gracefully,
- selection by group or address,
- graceful handling of multiple tags in the field of view,
- error detection.

5.1.2.1.3 Conformance

To claim conformance with this part of ISO/IEC 18000, an RFID system shall comply with one of the physical/data link implementations described in 5.2 and 5.3.

The rules for RFID device conformity evaluation are given in ISO/IEC TR 18047-4.

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5.1.3 Tag identification number

A tag identification number shall be included in commands directed to a specific tag unless the protocol provides other means like TTF (Tag Talks First) protocols. This part of ISO/IEC 18000 mandates that each tag shall include a manufacturer's tag identification number as defined in Annex A for mode 1 and in Annex C for mode 2.

A separate User Tag Identification is not mandatory, but is an option. When a UserTagID is used, it shall consist of the number of bytes required by the user application. This number and other application data shall be accessed as user data fields on the tag. These fields can be accessed via the API using the driver's field name resolution mechanism. The UserTagID is a user-defined tag identifier and is not necessarily unique.

5.1.4 Potential interference

Standards developers have a duty to ensure that no "significant interference" exists between Standardized modes. "Significant Interference" exists if a system of one Standardized mode (working within the most widespread regulated power emissions) is likely to impede the successful operation of a system of another Standardized mode (working within the most widespread regulated power emissions), *in likely expected operating situations.*

Marginal measurable interference that does not impede operation *in likely expected operating situations*, or that could be avoided by simple and inexpensive design improvement, shall not be considered cause to reject a mode.

- Therefore, TTF modes are clearly identified as such in this part of ISO/IEC 18000.

- Therefore, installers of RFID systems are advised that they should make best efforts to be a good neighbour in installing any systems, bearing in mind that there may be other systems sharing the same bandwidth and are advised to take precautions to minimise interference to other systems. Installers are equally advised to be prepared to handle interference within the bandwidth from other users up to transmission powers permitted by local regulations.

5.2 MODE 1: Passive backscatter RFID system

The FHSS backscatter option or the narrow band operation RFID system shall include an interrogator that runs the FHSS backscatter option 1 RFID protocol or in narrow band operation, as well as one or more tags within the interrogation zone.

When placed in the RF field of an interrogator, the tag shall begin to power up. If the field is adequate, the tag shall execute a power-on reset and shall be ready to receive commands. Each command shall begin with a preamble and start delimiters that, taken together, enable the tag to perform clock and data recovery on the incoming signal. Data to and from the tag is checked for errors using a Cyclic Redundancy Code (CRC). Therefore, CRC fields are present in all interrogator interrogations and in all tag responses. Additional data protection is provided by Manchester encoding on the forward (interrogator to tag link) and FM0 encoding on the return (tag to interrogator) link.

By using the FHSS backscatter option 1 RFID command set or in narrow band operation, the interrogator can execute a number of functions on tags in its field. For example, the interrogator can send a command sequence, which allows it to identify multiple tags simultaneously in its RF field. Alternately, it can select a subset of the tags in the field based on tag memory contents. It can also read data stored on a tag in its field, as well as write or lock data to such a tag.

The description of the RFID tag command set in the following clause shall provide detail regarding the command field and return data/acknowledgement fields, if any. In addition, it shall cover additional high-level elements of the FHSS backscatter option RFID protocol, including how the multiple item identification algorithm works and byte ordering requirements. The more general aspects of the protocol (preambles, CRC-16, etc.) are covered in detail in 5.2.2.7.

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This portion of the International Standard describes a passive backscatter RFID system that supports the following system capabilities:

System protocol

- Identify and communicate with multiple tags in the field
- Select a subgroup of tags to identify or communicate with based on information that the user has stored in the tag
- Read from and write or rewrite data many times to individual tags
- User controlled permanent lock memory

Data integrity protection

- Manchester bit-wise encoding and CRC-16 packet-level protection is applied to the forward link (interrogator-to-tag) data.
- FM0 bit-wise encoding and CRC-16 packet-level protection is applied to the return link (tag-to-interrogator) data.

In this RFID system, interrogators both power and communicate with the tags that are within their range. Tags receive data as on-off key amplitude modulation of the power/data signal from the interrogator. During the time that the tag communicates back to the interrogator, the interrogator broadcasts a steady radio frequency power level, and the tag modulates the impedance of its radio frequency load attached to the tag antenna terminals. The interrogator then receives the data back from the tag as a variation in reflection of its transmitted power.

5.2.1 MODE 1: Physical and media access control (MAC) parameters

5.2.1.1 MODE 1: Interrogator to tag link

Table 1 — Physical link specifications - forward link

Ref.	Parameter name	Description
M1-Int:1:	Operating Frequency Range	As permitted by local radio regulations in the band from 2 400 to 2 483,5 MHz.
M1-Int: 1a	Default Operating Frequency	2 450 MHz
M1-Int: 1b	Operating Channels	As required by local radio regulations. *As an example in the US 79 channels from 2 422,5 to 2 461,5 in 0,5 MHz increments may be used.*
M1-Int: 1c	Operating Frequency Accuracy	Maximum tolerance is ±50 ppm, however local tolerance may apply in case required by local regulations.
M1-Int: 1d	Frequency Hop Rate	The hop rate, if applicable, is determined by each country's regulatory authority in which the system is being operated. *As an example, within the US the maximum time at any frequency as set by FCC, clause 15,247 of FCC part 15 is 0,4 s.*
M1-Int: 1e	Frequency Hop Sequences	Pseudo-random hopping patterns uniformly utilising the designated frequency band.
M1-Int: 2	Occupied Channel Bandwidth	Maximum 0,5 MHz. Bandwidth specification according definition of local radio regulations. *As an example, within the US the 20 dB bandwidth is regulated by reference document 1.2.2, clause 15.247 of FCC part 15.*

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Table 1 *(continued)*

Ref.	Parameter name	Description
M1-Int: 3	Interrogator Transmit Maximum EIRP	The maximum output power is regulated by each country's regulatory authority in which the system is being operated. *As an example, within the US reference document, clause 15.247 of FCC part 15 at the time of drafting of this part of ISO/IEC 18000, has as a maximum 30 dBm output from the interrogator, and 4W (36 dBm) EIRP from the interrogator transmit antenna.* *As an example, within the Japan reference document, for a fixed frequency (i.e. narrowband) mode of operation in the ISM band the system may operate as "licensed" providing 300 mW of conductive power into a directional antenna of gain below 20 dBi. Channel definition under FHSS "unlicensed" operation may be used for this mode of operation.*
M1-Int: 4	Interrogator Spurious Emissions	Covered in M1-Int: 4a and M1-Int 4b
M1-Int: 4a	Interrogator Transmit Spurious Emissions, In Band (for Spread Spectrum systems)	not applicable
M1-Int: 4b	Interrogator Transmit Spurious Emissions, Out of Band	The interrogator shall transmit in conformance with spurious emissions requirements defined by the country's regulatory authority within which the system is operated. *As an example, within the US reference, clause 15.205 and 15.209 of FCC part 15 sets the limit at the time of drafting of this document at 500 μV/m @ 3 m*
M1-Int: 5	Interrogator Transmitter Spectrum Mask	Communication carrier: ASK
M1-Int: 6	Timing	Covered in M1-Int: 6a to M1-Int 6d
M1-Int: 6a	Transmit to Receive Turn Around Time	See 5.2.2.9.2
M1-Int: 6b	Receive to Transmit Turn Around Time	As determined by the communication protocol – refer to tag 6a.
M1-Int: 6c	Dwell time or Interrogator Transmit Power-On Ramp	< 5 % of bit period
M1-Int: 6d	Decay time or Interrogator Transmit Power-Down Ramp	< 5 % of bit period
M1-Int: 7	Modulation	ASK. Details are described in 5.2.2.4
M1-Int: 7a	Spreading sequence (for Direct Sequence Spread Spectrum [DSSS] systems)	Not applicable
M1-Int 7b	Chip Rate (for Spread Spectrum systems)	Not applicable
M1-Int 7c	Chip Rate Accuracy (for Spread Spectrum systems)	Not applicable
M1-Int 7d	Modulation Index	99 %. For details see 5.2.2.4.1
M1-Int 7e	Duty Cycle	50 % ±5 %
M1-Int:7f	FM Deviation	Not applicable

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Table 1 *(continued)*

Ref.	Parameter name	Description
M1-Int: 8	Data Coding	Manchester
M1-Int: 9	Bit Rate	30 – 40 kbit/s
M1-Int: 9a	Bit Rate Accuracy	100 ppm
M1-Int: 10	Interrogator Transmit Modulation Accuracy	See 5.2.2.4.1
M1-Int: 11	Preamble	Yes, see 5.2.2.8.3
M1-Int: 11a	Preamble length	9 bits, see 5.2.2.8.3
M1-Int: 11b	Preamble Waveform	See 5.2.2.8.3
M1-Int: 11c	Bit Sync Sequence	Yes, see 5.2.2.8.4
M1-Int: 11d	Frame Sync Sequence	Yes, see 5.2.2.8.4
M1-Int: 12	Scrambling (for Spread Spectrum Systems)	Not applicable
M1-Int: 13	Bit transmission order	MSB first
M1-Int: 14	Wake-up process	Presence of an appropriate RF signal at the tag followed by a wake-up command as required by the tag type.
M1-Int: 15	Polarisation	Interrogator dependent. Not defined in this part of ISO/IEC 18000.

5.2.1.2 MODE 1: Tag to interrogator link

Table 2 — Physical link specifications — backscatter return link

Ref.	Parameter name	Description
M1-Tag: 1	Operating Frequency Range	As permitted by local radio regulations in the band from 2 400 to 2 483,5 MHz.
M1-Tag: 1a	Default Operating Frequency	2 450 MHz
M1-Tag: 1b	Operating Channels (for Spread Spectrum systems)	As required by local radio regulations. See M1-Int: 1b.
M1-Tag: 1c	Operating Frequency Accuracy	Maximum tolerance is ± 50 ppm, however local tolerance may apply in case required by local regulations.
M1-Tag: 1d	Frequency Hop Rate (for Frequency Hopping [FHSS] systems)	The hop rate is set the regulatory authority within the country in which the system is operated.
M1-Tag: 1e	Frequency Hop Sequence (for Frequency Hopping [FHSS] systems)	Driven by Interrogator. See M1-Int: 1e
M1-Tag: 2	Occupied Channel Bandwidth	See M1-Int: 2
M1-Tag: 3	Transmit Maximum EIRP	The maximum output power transmitted by the interrogator during backscatter operation is regulated by the country's regulatory authority in which the system is operated. Examples are mentioned under M1-Int: 3

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Table 2 *(continued)*

Ref.	Parameter name	Description
M1-Tag: 4	Transmit Spurious Emissions	Covered in M1-Int: 4a and M1-Int 4b
M1-Tag: 4a	Transmit Spurious Emissions, In-Band (for Spread Spectrum systems)	As permitted by local radio regulations.
M1-Tag: 4b	Transmit Spurious Emissions, Out of Band	During backscatter return link operation, the interrogator shall transmit in conformance with spurious emissions requirements set by the country's regulatory authority. *As an example, within the US reference, 15.205 and 15.209 of FCC part 15 limits the at the time of drafting this document the level to 500 µV/m @ 3 m*
M1-Tag: 5	Transmit Spectrum Mask	As permitted by local radio regulations.
M1-Tag: 6a	Transmit to Receive Turn Around Time	< 1 ms. For details see 5.2.2.8.2
M1-Tag: 6b	Receive to Transmit Turn Around Time	As determined by the communication protocol – refer to interrogator 6a.
M1-Tag: 6c	Dwell Time or Transmit Power On Ramp	Not applicable
M1-Tag: 6d	Decay Time or Transmit Power Down Ramp	Not applicable
M1-Tag: 7	Modulation	Backscatter. Details are defined in 5.2.2.5.2
M1-Tag: 7a	Spreading Sequence (for Direct Sequence Spread Spectrum [DSSS] systems)	Not applicable
M1-Tag: 7b	Chip Rate (for Spread Spectrum systems)	Not applicable
M1-Tag: 7c	Chip Rate Accuracy (for Spread Spectrum systems)	Not applicable
M1-Tag: 7d	On-Off Ratio	Not applicable
M1-Tag: 7e	Sub-carrier Frequency	Not applicable
M1-Tag: 7f	Sub-carrier Frequency Accuracy	Not applicable
M1-Tag: 7g	Sub-Carrier Modulation	Not applicable
M1-Tag: 7h	Duty Cycle	50 % ± 5 %
M1-Tag: 7i	FM Deviation	Not applicable
M1-Tag: 8	Data Coding	FM0
M1-Tag: 9	Bit Rate	30 – 40 kbit/s
M1-Tag: 9a	Bit Rate Accuracy	± 15 %
M1-Tag: 10	Tag Transmit Modulation Accuracy (for Frequency Hopping [FHSS] systems)	Not applicable

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Table 2 *(continued)*

Ref.	Parameter name	Description
M1-Tag: 11	Preamble	See 5.2.2.5.6
M1-Tag: 11a	Preamble Length	16 bit made up of a quiet period, followed by sync. followed by a code violation followed by an orthogonal code
M1-Tag: 11b	Preamble Waveform	Bi-phase encoded data '1'
M1-Tag: 11c	Bit Sync Sequence	Yes, included in the preamble
M1-Tag: 11d	Frame Sync Sequence	Yes, included in the preamble
M1-Tag: 12	Scrambling (for Spread Spectrum systems)	Not applicable
M1-Tag: 13	Bit Transmission Order	MSB first
M1-Tag: 14	Reserved	Reserved
M1-Tag: 15	Polarisation	Product design feature. Not defined in this part of ISO/IEC 18000.
M1-Tag: 16	Minimum Tag Receiver Bandwidth	2 400 – 2 483,5 MHz

5.2.1.3 MODE 1: Protocol parameters

Table 3 — Protocol parameters

Ref.	Parameter name	Description
M1-P: 1	Who talks first	Interrogator talks first
M1-P: 2	Tag addressing capability	Yes
M1-P: 3	Tag UID	Contained in tag memory and accessible by means of commands
M1-P: 3a	UID Length	64 bit
M1-P: 3b	UID Format	See Annex A
M1-P: 4	Read size	Addressable in byte blocks
M1-P: 5	Write Size	Addressable in byte blocks. Writing in blocks of 1, 2, 3 or 4 bytes. (See details in 5.2.3.6.2.5)
M1-P: 6	Read Transaction Time	Once a tag has been identified and selected, a 64 bit data block can typically be read in less than 10 ms. This time may vary depending on data rate used as constrained by the local radio regulations.
M1-P: 7	Write Transaction Time	Once a tag has been identified and selected, an 8 to 32 bit data block can typically be written in less than 20 ms. This time may vary depending on data rate used as constrained by the local radio regulations.
M1-P: 8	Error detection	CRC-16
M1-P: 9	Error correction	No forward error correction code used. Errors are handled by signalling an error to the interrogator that then repeats its last transmission.
M1-P: 10	Memory size	Minimum memory size of 64 bits. Recommended minimum memory size of 18 bytes.
M1-P: 11	Command structure and extensibility	Several command codes are reserved for future use.

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5.2.1.4 MODE 1: Anticollision parameters

Table 4 — Anticollision parameters

Ref.	Parameter name	Description
M1-A: 1	Type (Probabilistic or Deterministic)	Probabilistic
M1-A: 2	Linearity	Essential linear up to 2^256 tags depending on size of data content
M1-A: 3	Tag inventory capacity	The algorithm permits the reading of not less than 250 tags in the reading zone of the interrogator.

5.2.2 Physical layer and data coding

5.2.2.1 Interrogator power-up waveform

The interrogator power-up waveform shall comply with the mask specified in Figure 1 and Table 5.

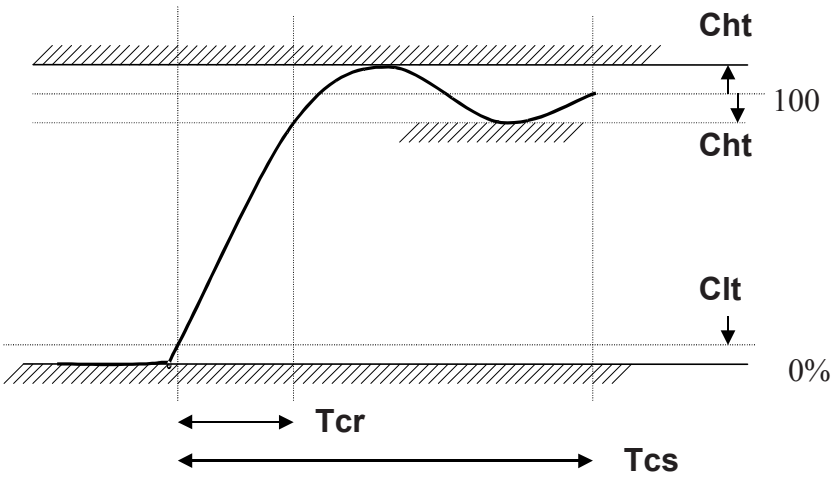

Figure 1 — Interrogator power-up waveform

Table 5 — Interrogator power-up waveform parameter values

Parameter	Min	Max
Tcs		400 µs
Tcr	0 µs	30 µs
Cht		3 %
Clt		1 %

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5.2.2.2 Interrogator power-down

Once the carrier level has dropped below the ripple limit Cht, power down shall be monotonic and of duration Tcf, as specified in Figure 2 and Table 6.

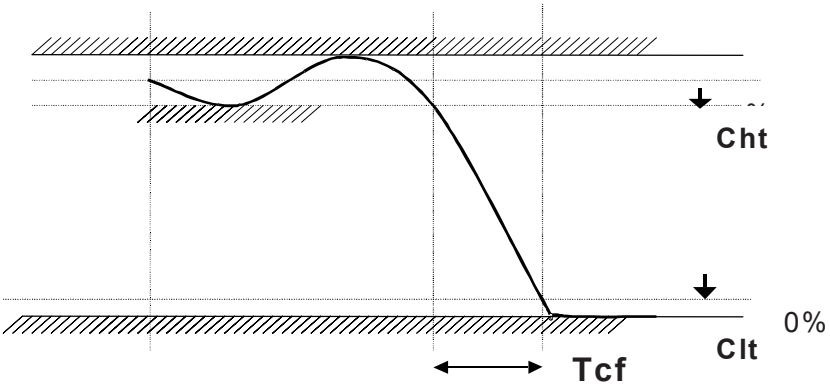

Figure 2 — Interrogator power-down waveform

Table 6 — Interrogator power-down timings

Parameter	Min	Max
Tcf	1 µs	500 µs
Cht		3%
Clt		1%

5.2.2.3 Frequency hopping carrier rise and fall times

When the interrogator operates in the frequency hopping spread spectrum mode (FHSS), the carrier rise and fall times shall conform to the characteristics specified in Figure 3 and Table 7.

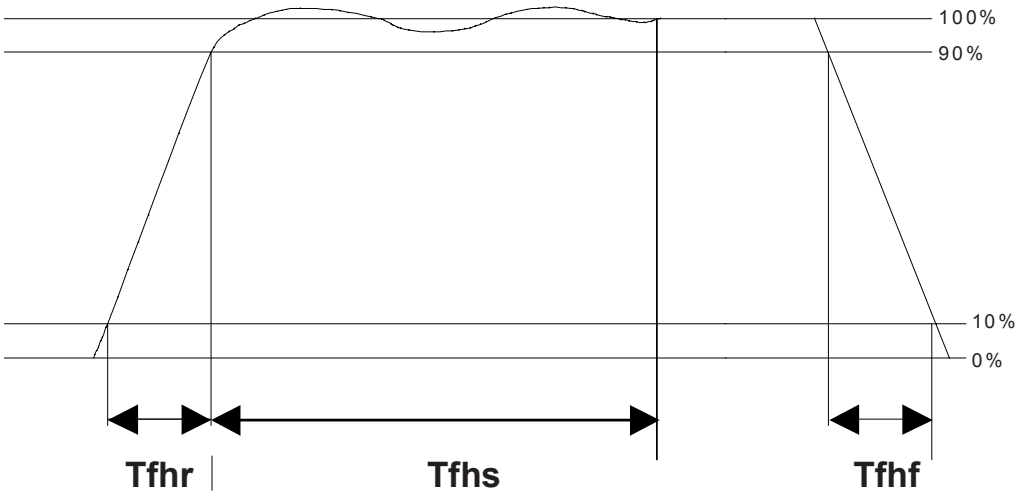

Figure 3 — FHSS carrier rise and fall characteristics

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Table 7 — FHSS carrier rise and fall parameters

Parameter	Min	Max
Tfhr		15 µs
Tfhs	400 µs	
Tfhf		15 µs

NOTE The numbers in Table 7 are an example for current FCC regulations only.

5.2.2.4 Forward link

5.2.2.4.1 Carrier modulation

The data transmission from the interrogator to the tag is achieved by modulation of the carrier (ASK). The data coding is performed by generating pulses that create a Manchester coding.

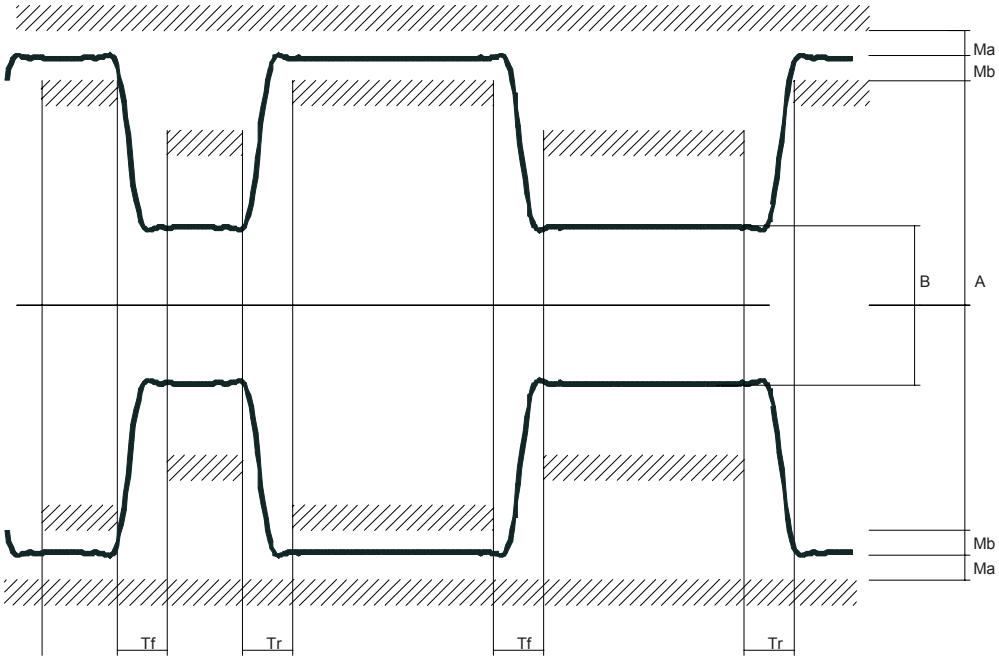

Figure 4 — Example of 40 kbit/s signal

Table 8 — Parameter for 99 % Modulation

Parameter	Minimum	Nominal	Maximum
M = (A-B)/(A + B)	90	99	100
Ma	0		0,03 (A-B)
Mb	0		0,03 (A-B)
Tr	0 µs	1,8 µs	0,1 / $f_{bitrate}$
Tf	0 µs	1,8 µs	0,1 / $f_{bitrate}$

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5.2.2.4.2 Bit coding of forward link fields

Data is Manchester encoded as per Figure 5.

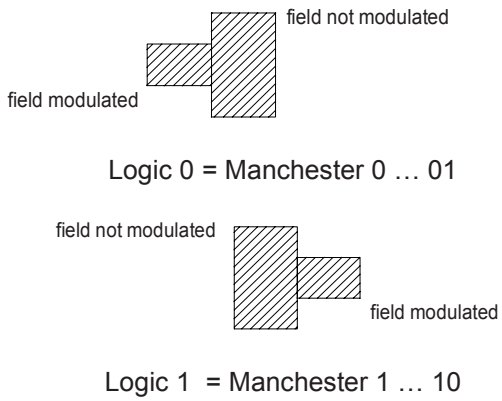

Figure 5 — Forward link bit coding

5.2.2.5 FM0 return link

5.2.2.5.1 General

The tag transmits information to the interrogator by modulating the incident energy and reflecting it back to the interrogator (backscatter).

5.2.2.5.2 Modulation

The tag switches its reflectivity between two states. The “space” state is the normal condition in which the tag is powered by the interrogator and able to receive and decode the forward link. The “mark” state” is the alternative condition created by changing the antenna configuration or termination.

5.2.2.5.3 Data rate

The return link data rate is derived from the forward link data rate and is typically 40 kbit/s. For details see Table 9.

5.2.2.5.4 Data coding

Data is coded using the FM0 technique, also known as Bi-Phase Space.

One symbol period Trlb is allocated to each bit to be sent. In FM0 encoding, data transitions occur at all bit boundaries. In addition, data transitions occur at the mid-bit of logic 0 being sent.

Table 9 — Return link parameters

Data rate	Trlb	Tolerance
30 – 40 kbit/s	25 µs – 33 µs	± 15 %

Coding of data is MSB first. Figure 6 illustrates the coding for the 8 bits of 'B1'.

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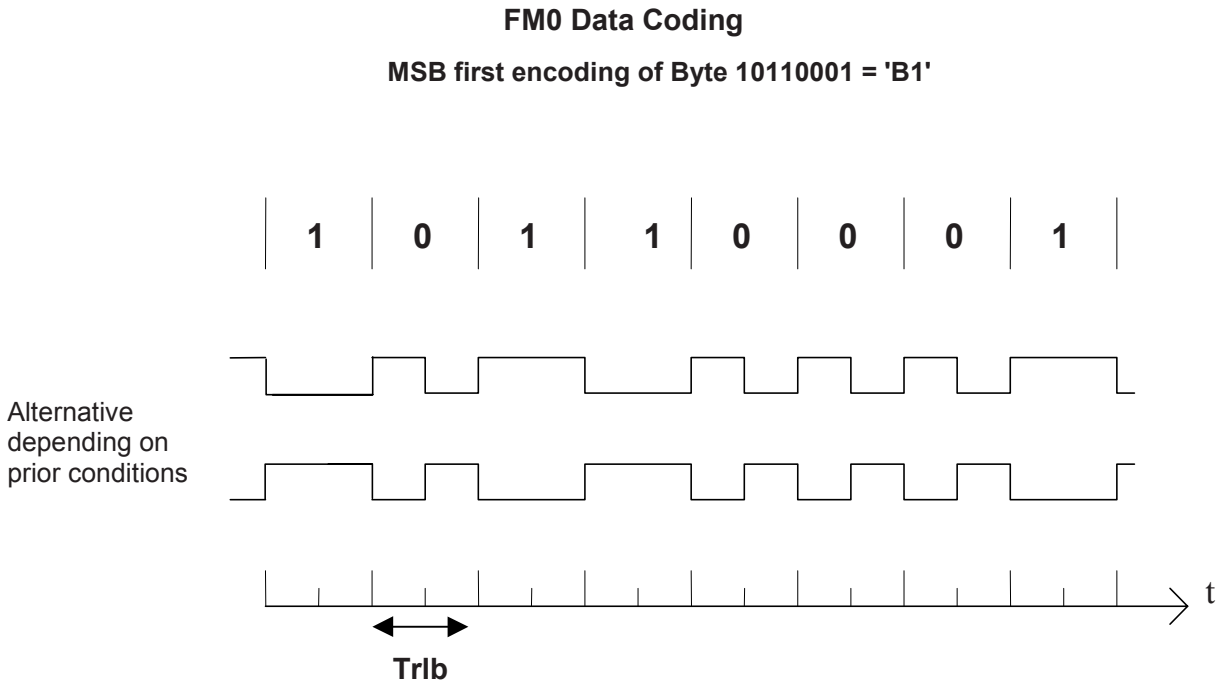

Figure 6 — Tag to interrogator data coding

5.2.2.5.5 Message format

A Return Link Message consists of n data bits preceded by the Preamble and followed by the tag data. The data bits are sent MSB first.

The Preamble enables the interrogator to lock to the tag data clock and begin decoding of the message. It consists of 16 bits as shown in Table 10. There are multiple code violations (sequence not conforming to FM0 rules) that act as a frame marker for the transition from Preamble to Data.

5.2.2.5.6 Return preamble

The return preamble is a sequence of backscatter modulation specified in Table 10.

Table 10 — Return preamble

00 00 01 01 01 01 01 01 01 01 00 01 10 11 00 01

Data ‘0’ is represented by the tag’s modulator being in the high impedance state, Data ‘1’ is represented by the tag’s modulator switching to the low impedance state, thereby causing a change in the incident energy to be back-scattered.

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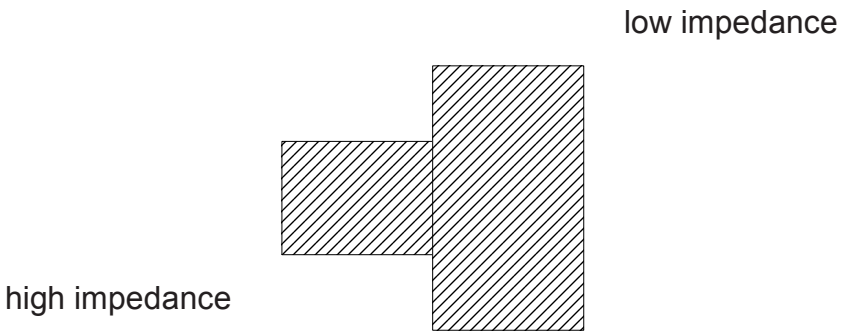
The tag shall execute backscatter, a half-bit 1 and half-bit 0 sent by the tag defined as follows in Figure 7.



NOTE 1 = low impedance (backscatter), 0 = high impedance (no backscatter).

Figure 7 — Return link preamble

5.2.2.6 Cyclic redundancy check (CRC)

When sending a command to the tag, the interrogator shall attach an inverted CRC to the message packet. On receiving a command from the interrogator, the tag shall verify that the checksum or the CRC value is valid. If it is invalid, it shall discard the frame, shall not respond and shall not take any other action.

The 16 bits CRC applies for both communication directions: From interrogator to tag and from tag to interrogator.

The polynomial used to calculate the CRC is $X^{16} + X^{12} + X^{5} + 1$. The 16-bit register shall be preloaded with 'FFFF'. The resulting CRC value shall be inverted, attached to the end of the packet and transmitted.

The most significant byte shall be transmitted first. The most significant bit of each byte shall be transmitted first.

At the tag, the incoming CRC bits are inverted and then clocked into the register. After the LSB bit is clocked into the tag, the 16 bit CRC register should contain all zeros.

The 16 bit CRC shall be calculated on all data bits up to, but not including, the first CRC bit.

On receiving of a response from the tag, it is recommended that the interrogator verifies that the CRC value is valid. If it is invalid, appropriate remedial action is the responsibility of the interrogator designer.

Table 11 — CRC 16 bits and bytes transmission rules

MSByte	LSByte
MSB LSB	MSB LSB
CRC 16 (8 bits)	CRC 16 (8 bits)

↑ first transmitted bit of the inverted CRC

5.2.2.7 Protocol concept

Data is encoded and presented in slightly different ways in the constituent fields. For interrogator-to-tag communication (forward link), data is sent using an on-off key format. The radio frequency field being on corresponds to 1, while the radio frequency field being off corresponds to 0. The on-off ratio specification is defined in clause 5.2.2.4. In the case of Manchester coding a Manchester 1 is a 1 to 0 transition, while a Manchester 0 is a 0 to 1 transition.

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For tag-to-interrogator communication (return link), data is sent using backscatter techniques. This requires that the interrogator provide steady power to the tag during the return link. While the interrogator powers the tag, the tag shall change alternately the effective impedance of the tag front end and thus changing the overall radio frequency reflectivity of the tag as seen by the interrogator. During this time, the interrogator shall not modulate the carrier. During the WAIT field (when tags write data into their memory), the interrogator shall also provide steady power to the tag, and shall not modulate the carrier. The transmission protocol defines the mechanism to exchange instructions and data between the interrogator and the tag, in both directions.

It is based on the concept of "interrogator talks first".

This means that any tag shall not start transmitting (modulating) unless it has received and properly decoded an instruction sent by the interrogator.

The protocol is based on an exchange of a command from the interrogator to the tag and a response from the tag(s) to the interrogator.

The conditions under which the tag sends a response are defined in clause 5.2.3.6.

Each command and each response are contained in a frame. The frame is specified in clause 5.2.2.7.

Each command consists of the following fields:

Preamble

Delimiter

Command code

Parameter fields, depending on the command

Application data fields, depending on the command

CRC

Each response consists of the following fields:

Return Preamble

Application data fields

CRC

The protocol is bit-oriented. The number of bits transmitted in a frame is a multiple of eight (8), i.e. an integer number of bytes. However, the frame itself is not based on an integer number of bytes.

In all byte fields, the MSB shall be transmitted first, proceeding to the LSB. In all word (8-byte) data fields, the MSB shall be transmitted first.

The MSB shall be the byte at the specified address. The LSB shall be the byte at the specified address plus 7 (i.e., bytes are transmitted in incrementing address order).

The byte significance is relevant to data transmission and to the GROUP_SELECT and GROUP_UNSELECT greater than and less than comparisons.

The MSB of the byte mask shall correspond to the most significant data byte, the byte at the specified address.

Word (8-byte) addresses are not required to be on an 8-word boundary and may be on any byte boundary.

RFU bits and bytes shall be set to zero (0).

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5.2.2.8 Command format

5.2.2.8.1 General

The command consist of the following fields:

Preamble

Delimiter

Command

Parameter and data files

CRC

Table 12 — General command format

Preamble Detect	Preamble	Delimiter	Command	Parameter	Data	CRC

5.2.2.8.2 Preamble detect field

The preamble detect field consist of a steady carrier (no modulation) during a time of at least 400 µs. This corresponds to 16 bits for a communication rate of 40 kbit/s.

5.2.2.8.3 Preamble

The preamble is equivalent to 9 bits of Manchester 0.

010101010101010101

5.2.2.8.4 Delimiter

5.2.2.8.4.1 Start delimiter 1

In NRZ format; includes Manchester errors; spaces ignored

11 00 11 10 10 – Delimiter 1

5.2.2.8.5 CRC

See clauses 5.2.2.6 and Annex B.

5.2.2.9 Response format

5.2.2.9.1 General

The response consists of the following fields:

Quiet

Return Preamble

Data fields

CRC

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Table 13 — General response format

Quiet	Return Preamble	Data	CRC

The tag shall use a backscatter technique to communicate data to the interrogator. The interrogator shall be steadily powering the tag as well as listening to the tag response throughout the tag-to-interrogator (backscatter) communication. This applies to all fields in the return link.

5.2.2.9.2 QUIET

The tag shall not backscatter for 16 * T_{rlb} – 0,75 * T_{flb}. The duration of the quiet time is determined by the communication speed of the forward and return link.

5.2.2.9.3 CRC

See clauses 5.2.2.6 and Annex B.

5.2.2.10 WAIT

During the WAIT field, the interrogator provides steady power to the tag for duration of at least 15 ms. No on-off key data may be sent during the write operation.

When a tag receives a write command, it shall execute a write operation. (The details of the conditions under which a write will occur are described in clause 5.2.3.6.2.5.4.) If a write operation is executed, the final field in the overall field sequence shall always be WAIT.

During the WAIT field, when the tag is writing data into the EEPROM, the interrogator must steadily power the tag. On-off key data shall not be sent during this time.

Details are shown in Figure 8 and in Figure 9.

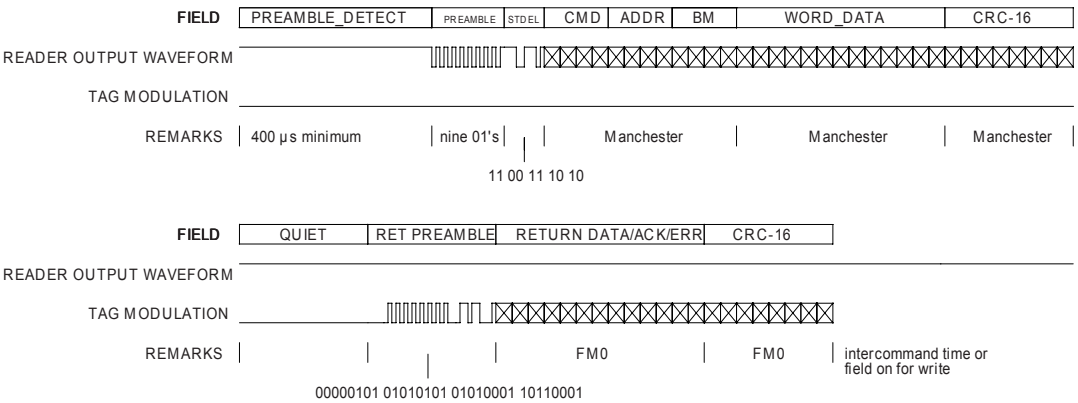

Figure 8 — Sample Command/Response Packets for (GROUP_SELECT) (40 kbit/s on forward and return link)

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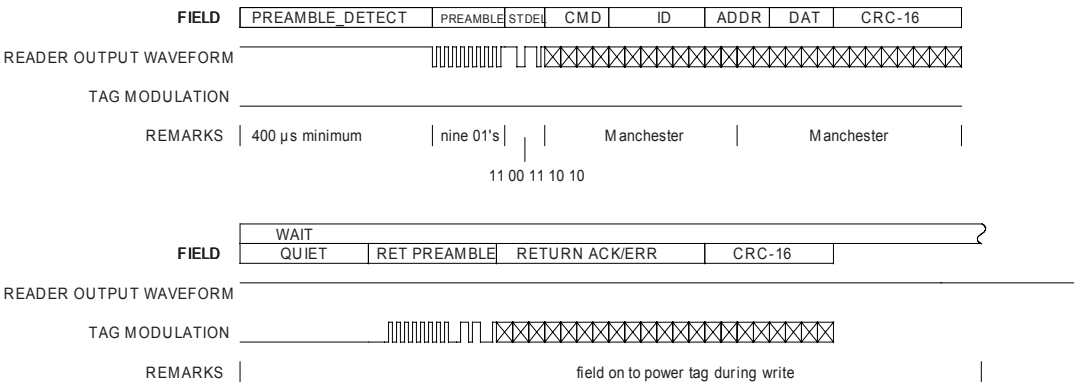

Figure 9 — Sample Command/Response Packets for WRITE (40 kbit/s on forward and return link)

5.2.2.11 Communication sequences at packet level

Figure 10 and Figure 11 show several examples of communication sequences at the packet level. Figure 10 depicts a packet sequence that includes a write command. The sequence includes a wait for write time, which provides the necessary time for the chip to complete its write operation. In addition, following the wait for write time, the interrogator issues a tag resync signal. This signal is composed of 10 consecutive 01 signals. The purpose of the tag resync signal is to initialise the tag data recovery circuitry. It is required after a write because the interrogator may output spurious edges during the wait for write time. Without the tag resync, tags may miscalibrate as a result of the spurious signals that may be generated.

Figure 11 depicts a packet sequence in which a frequency hop between commands is included. The tag resync signal is again required after the hop because spurious signals may be generated during the hop time.

In order to ensure that tags do not get confused, frequency hops between command and response should be avoided.

Action	COMMAND	RESPONSE	WAIT FOR WRITE	TAG RESYNC	COMMAND	RESPONSE
Component execution action	Interrogator	Tag	Interrogator	Interrogator	Interrogator	Tag
Notes	---	---	15 ms minimum	ten 01‘s	---	---

Figure 10 — Command sequence (including a write) with no hopping

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Action	COMMAND	RESPONSE	HOP	TAG RESYNC	COMMAND	RESPONSE
Component execution action	Interrogator	Tag	Interrogator	Interrogator	Interrogator	Tag
Notes	---	---	< 26 µs	ten 01's	---	---

Figure 11 — Command sequence with a hop between response and next command

5.2.3 Protocol and collision arbitration

5.2.3.1 Definition of data elements, bit and byte ordering

5.2.3.1.1 Unique ID

See Annex A, Clause A.2.

5.2.3.1.2 CRC

See clause 5.2.2.6 and Annex B.

5.2.3.1.3 FLAGS

The tag shall support a field of 8 flags. This field is called FLAGS.

Table 14 — FLAGS

Bit	Name
FLAG1 (LSB)	DE_SB (Data_Exchange Status Bit)
FLAG2	WRITE_OK
FLAG3	BATTERY_POWERED
FLAG4	BATTERY_OK
FLAG5	0 (RFU)
FLAG6	0 (RFU)
FLAG7	0 (RFU)
FLAG8 (MSB)	0 (RFU)

5.2.3.1.3.1 Data Exchange Status Bit (DE_SB)

The tag shall set this bit when the tag goes into the DATA_EXCHANGE state and keep it set unless it moves into the POWER-OFF state.

When the DE_SB is set and the tag comes into the POWER-OFF state, then the tag shall trigger a timer that will reset the DE_SB bit after t_{DE_SB}.

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t_{DE_SB} shall be at least 2 seconds in the temperature range –30 °C to 60 °C.

t_{DE_SB} shall be at least 4 seconds in the temperature range 0 °C to 50 °C.

When the tag receives the INITIALIZE command, then it shall reset the DE_SB immediately.

5.2.3.1.3.2 WRITE_OK

The WRITE_OK bit shall be set after a successful write access to the memory. (E.g. WRITE, LOCK)

The WRITE_OK bit is cleared after execution of the command following the write command.

5.2.3.1.3.3 BATTERY_POWERED

The BATTERY_POWERED bit shall be set when the tag should have a battery. It shall be cleared for passive tags.

5.2.3.1.3.4 BATTERY_OK

The BATTERY_OK bit shall be set when the battery has enough power to support the tag. It shall be cleared for passive tags.

5.2.3.2 Tag memory organisation

The functional memory shall be organised in blocks of one byte.

Up to 256 blocks of one byte can be addressed.

This leads to a maximum memory capacity of up to 2 kbit.

NOTE This structure allows future extensions of the maximum memory capacity.

5.2.3.3 Block security status

Each byte shall have a corresponding lock bit. The lock bits may be locked by use of the LOCK command. The status of the lock bit may be read by the QUERY_LOCK command. The tag shall not be allowed to reset any lock bit after leaving the final production site. In most cases this is the production site that defines the unique ID.

5.2.3.4 Overall protocol description

5.2.3.4.1 Tag states

The tag has four major states:

POWER-OFF The tag is in the POWER-OFF state when the interrogator cannot activate it. (For battery-assisted tags, it means that the level of RF excitation is insufficient to turn on the tag circuits.)

READY The tag is in the READY state when the interrogator first powers it up.

ID The tag is in the ID state when it is trying to identify itself to the interrogator.

DATA_EXCHANGE The tag is in the DATA_EXCHANGE state, when it is known to the interrogator and was selected.

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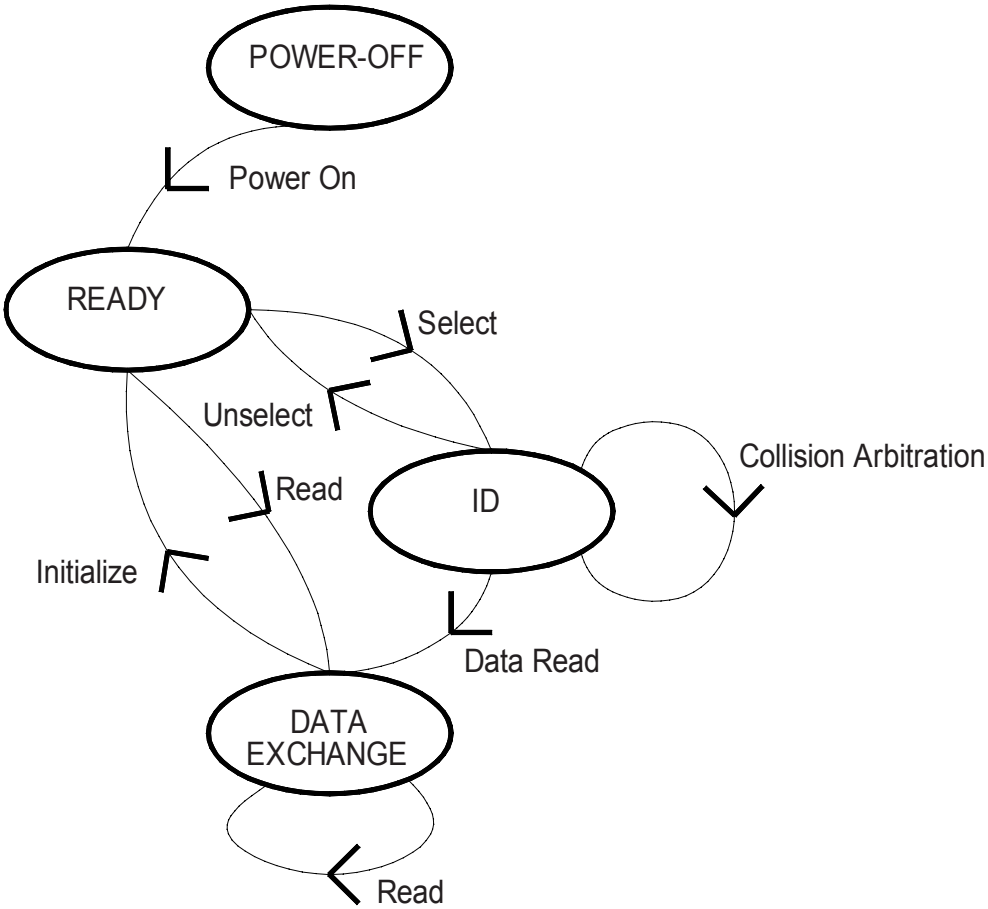

NOTE This diagram does not show that the tag goes into POWER-OFF from all states in the case that the interrogator field is permanently turned-off.

Figure 12 — State diagram

The state diagram only shows an overview of the possible transition. Details are specified in Table 16.

Power-On:

State change when interrogator field is turned on.

Select

State change due to selection of tag by GROUP_SELECT or READ commands

Unselect

State change due to deselection of tag by GROUP_UNSELECT commands or INITIALIZE command

Collision Arbitration

No state change during collision arbitration until single tag is identified.

Data_Read

State change due to first read access in collision arbitration process

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Read

State change due to read access independent of collision arbitration process.

Initialize

State change due to deselection of tag by INITIALIZE command

The transition between these states is specified in Table 16.

5.2.3.4.2 Detailed command processing

Commands shall be active in states marked with "X" and neither causes a state change, nor cause a response in the other states.

Table 15 – Detailed command processing

COMMAND	States		
	READY	ID	DATA EXCHANGE
GROUP_SELECT_EQ	X	X	
GROUP_SELECT_NE	X	X	
GROUP_SELECT_GT	X	X	
GROUP_SELECT_LT	X	X	
GROUP_SELECT_EQ_FLAGS	X	X	
GROUP_SELECT_NE_FLAGS	X	X	
GROUP_UNSELECT_EQ		X	
GROUP_UNSELECT_NE		X	
GROUP_UNSELECT_GT		X	
GROUP_UNSELECT_LT		X	
GROUP_UNSELECT_EQ_FLAGS		X	
GROUP_UNSELECT_NE_FLAGS		X	
MULTIPLE_UNSELECT		X	
FAIL		X	
SUCCESS		X	
RESEND		X	
INITIALIZE	X	X	X
READ	X	X	X
DATA_READ		X	X
READ_VERIFY	X	X	X
READ_VERIFY4BYTE	X	X	X
WRITE	X	X	X
WRITE4BYTE	X	X	X
WRITE4BYTE_MULTIPLE		X	X
WRITE_MULTIPLE		X	X
LOCK			X
QUERY_LOCK	X	X	X

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Table 16 — State Transition Table

Current State	Command	Condition	New state
POWER-OFF	ANY COMMAND		POWER OFF
POWER-OFF	“Power up”		READY
READY	GROUP_SELECT_EQ	≠	READY
READY	GROUP_SELECT_NE	=	READY
READY	GROUP_SELECT_GT	≤	READY
READY	GROUP_SELECT_EQ_FLAGS	flag not set	READY
READY	GROUP_SELECT_NE_FLAGS	flag set	READY
READY	GROUP_SELECT_LT	≥	READY
READY	GROUP_SELECT_EQ	=	ID
READY	GROUP_SELECT_NE	≠	ID
READY	GROUP_SELECT_GT	>	ID
READY	GROUP_SELECT_LT	<	ID
READY	GROUP_SELECT_EQ_FLAGS	flag set	ID
READY	GROUP_SELECT_NE_FLAGS	flag not set	ID
READY	INITIALIZE		READY
READY	READ	ID no match	READY
READY	READ	ID match	DATA_EXCHANGE
READY	READ_VERIFY	ID no match or not WRITE_OK	READY
READY	READ_VERIFY	ID match and WRITE_OK	DATA_EXCHANGE
READY	READ_VERIFY4BYTE	ID no match or not WRITE_OK	READY
READY	READ_VERIFY4BYTE	ID match and WRITE_OK	DATA_EXCHANGE
READY	WRITE	ID no match	READY
READY	WRITE	ID match	DATA_EXCHANGE
READY	WRITE4BYTE	ID no match	READY
READY	WRITE4BYTE	ID match	DATA_EXCHANGE
READY	QUERY_LOCK	ID no match	READY
READY	QUERY_LOCK	ID match	DATA_EXCHANGE
ID	GROUP_UNSELECT_EQ	≠	ID
ID	GROUP_UNSELECT_NE	=	ID
ID	GROUP_UNSELECT_GT	≤	ID
ID	GROUP_UNSELECT_LT	≥	ID
ID	GROUP_UNSELECT_EQ_FLAGS	flag not set	ID
ID	GROUP_UNSELECT_NE_FLAGS	flag set	ID
ID	GROUP_UNSELECT_EQ	=	READY
ID	GROUP_UNSELECT_NE	≠	READY
ID	GROUP_UNSELECT_GT	>	READY
ID	GROUP_UNSELECT_LT	<	READY
ID	GROUP_UNSELECT_EQ_FLAGS	flag set	READY
ID	GROUP_UNSELECT_NE_FLAGS	flag not set	READY
ID	MULTIPLE_UNSELECT	≠ or notWRITE_OK	ID
ID	MULTIPLE_UNSELECT	= and WRITE_OK	READY
ID	GROUP_SELECT_EQ		ID
ID	GROUP_SELECT_NE		ID

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Table 16 *(continued)*

Current State	Command	Condition	New state
ID	GROUP_SELECT_GT		ID
ID	GROUP_SELECT_LT		ID
ID	GROUP_SELECT_EQ_FLAGS		ID
ID	GROUP_SELECT_NE_FLAGS		ID
ID	FAIL		ID
ID	SUCCESS		ID
ID	RESEND		ID
ID	INITIALIZE		READY
ID	READ	ID no match	ID
ID	READ	ID match	DATA_EXCHANGE
ID	DATA_READ	ID no match	ID
ID	DATA_READ	ID match	DATA_EXCHANGE
ID	READ_VERIFY	ID no match or not WRITE_OK	ID
ID	READ_VERIFY	ID match and WRITE_OK	DATA_EXCHANGE
ID	READ_VERIFY4BYTE	ID no match or not WRITE_OK	ID
ID	READ_VERIFY4BYTE	ID match and WRITE_OK	DATA_EXCHANGE
ID	WRITE	ID no match	ID
ID	WRITE	ID match	DATA_EXCHANGE
ID	WRITE4BYTE	ID no match	ID
ID	WRITE4BYTE	ID match	DATA_EXCHANGE
ID	WRITE_MULTIPLE		ID
ID	WRITE4BYTE_MULTIPLE		ID
ID	QUERY_LOCK	ID no match	ID
ID	QUERY_LOCK	ID match	DATA_EXCHANGE
DATA_EXCHANGE	INITIALIZE		READY
DATA_EXCHANGE	READ		DATA_EXCHANGE
DATA_EXCHANGE	DATA_READ		DATA_EXCHANGE
DATA_EXCHANGE	READ_VERIFY		DATA_EXCHANGE
DATA_EXCHANGE	READ_VERIFY4B YTE		DATA_EXCHANGE
DATA_EXCHANGE	WRITE		DATA_EXCHANGE
DATA_EXCHANGE	WRITE4BYTE		DATA_EXCHANGE
DATA_EXCHANGE	WRITE4BYTE_MULTIPLE		DATA_EXCHANGE
DATA_EXCHANGE	WRITE_MULTIPLE		DATA_EXCHANGE
DATA_EXCHANGE	LOCK		DATA_EXCHANGE
DATA_EXCHANGE	QUERY_LOCK		DATA_EXCHANGE

5.2.3.5 Collision arbitration

The interrogator may use the GROUP_SELECT and GROUP_UNSELECT commands to define all or a subset of tags in the field to participate in the collision arbitration. It then may use the identification commands to run the collision arbitration algorithm.

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