INTERNATIONAL STANDARD

ISO/IEC 18000-4

First edition
2004-08-15

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 pour les communications d'une interface d'air à 2,45 GHz

Reference number
ISO/IEC 18000-4:2004(E)

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

Published in Switzerland

Contents

Page

Foreword

ISO (the International Organization for Standardization) 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 Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 31, *Automatic identification and data capture techniques*.

ISO/IEC 18000 consists of the following parts, under the general title *Information technology — Radio frequency identification for item management*:

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

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

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

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

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

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

Introduction

This part of ISO/IEC 18000 is one of a series of 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 sub-clauses 5.2 and 5.3.

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

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

Contact details	Patent number	Affected subclause(s) in this part of ISO/IEC 18000
Intermec Technologies Corporation, Attn.: Ronald D. Payne, Vice President, Contracts, 6001 36th Ave, West, Everett, WA 98203, USA	US 4,786,907; US 5,030,807; US 5,521,601; US 5,550,547; US 5,673,037; US 5,777,561; US 5,828,318; US 5,828,693; US 5,850,181; US 5,942,987; US 5,995,019	5.2
Koninklijke Philips Electronics N.V., Intellectual Property & Standards, Mr. Harald Röggla, Triester Strasse 64, A-1101 Vienna, Austria	PHAT010034; JP 03-502778; US2002/0186789A1; WO 02/099741A1	5.2
Siemens AG, Patent department, POB 221634, D-80506 Munich, Germany	DE 10137247.7; PCT/DE02/02769	5.3
Intercode/Spacecode, Mr. M. Pierre Raimbault; 12, Rue des Petits Ruisseaux; Z.I. des Godets; 91370 Verrières le Buisson; France	US 5,808,550; EP 96402555.5; Canada 2191794	5.2
Sterne, Kessler, Goldstein & Fox P.L.L.C. Attn. Mr. Rob Sokohl, 1100 New York Avenue NW, Washington, DC 20005-3934, USA for Matrics, Inc.	US 6,002,344	5.2, 5.3

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

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. The purpose of this part of ISO/IEC 18000 is to provide a common technical specification for RFID devices that may 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 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 while the second in 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*[1)]

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

---

1) To be published.

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

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.

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.

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.*

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 6.1.2.9.1
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 6.1.2.4
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

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

Table 2 *(continued)*

Ref.	Parameter name	Description
M2-Tag: 4	Transmit Spurious Emissions	Covered in M1-Int: 4a and M1-Int 4b
M2-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*
M2-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 6.1.2.9.1
M2-Tag: 6b	Receive to Transmit Turn Around Time	As determined by the communication protocol – refer to interrogator 6a.
M2-Tag: 6c	Dwell Time or Transmit Power On Ramp	Not applicable
M2-Tag: 6d	Decay Time or Transmit Power Down Ramp	Not applicable
M1-Tag: 7	Modulation	Backscatter. Details are defined in 6.1.2.5.
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

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.

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.

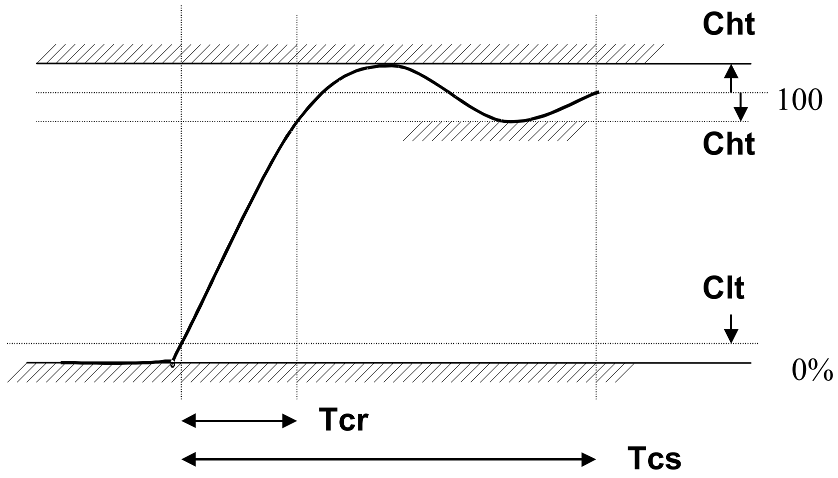


Figure 1 — Interrogator power-up waveform

Table 5 — Interrogator power-up waveform parameter values

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

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.

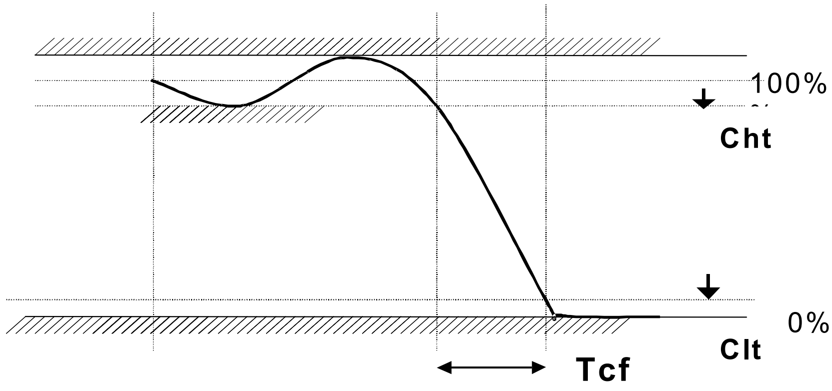


Figure 2 — Interrogator power-down waveform

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.

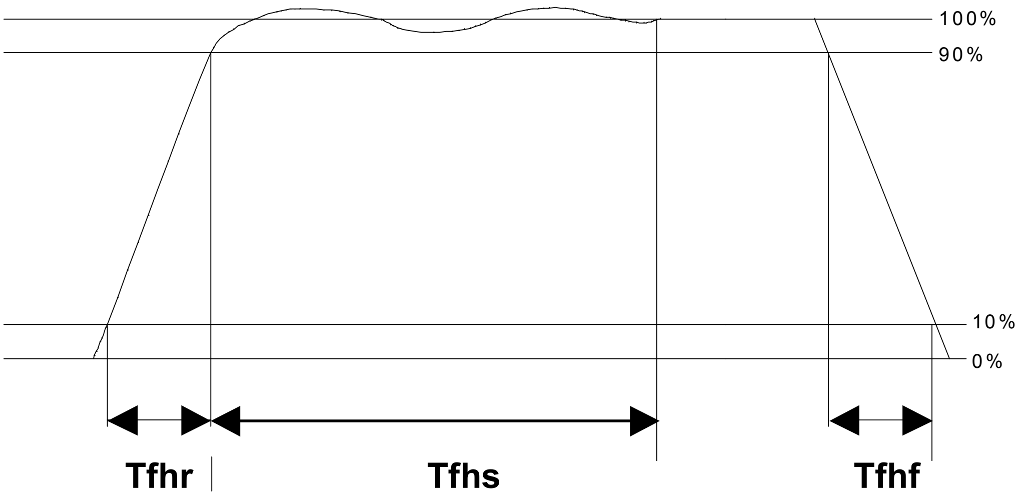


Figure 3 — FHSS carrier rise and fall characteristics

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.

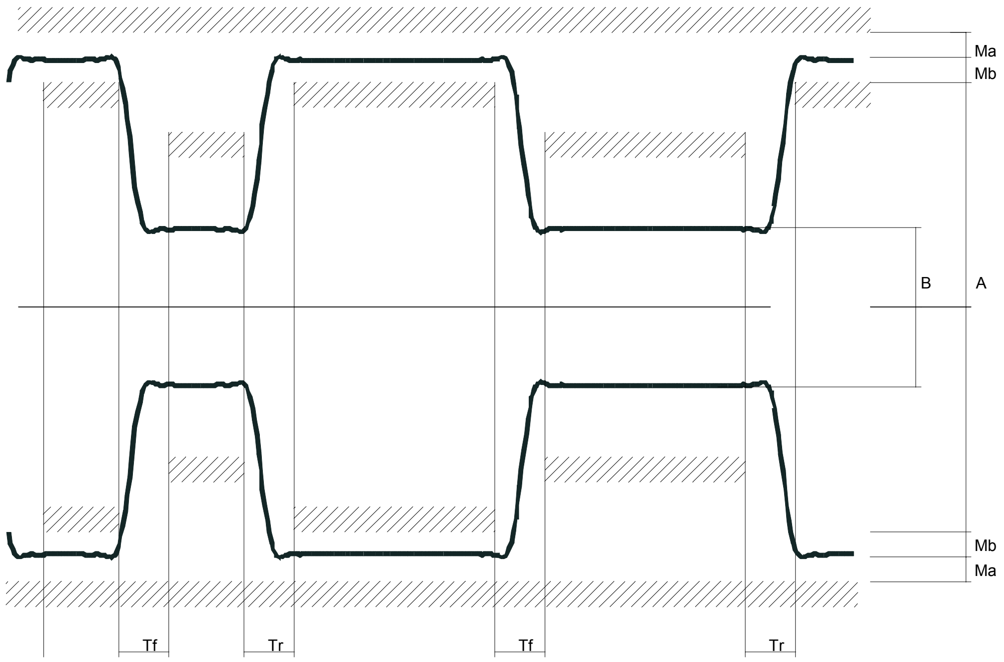


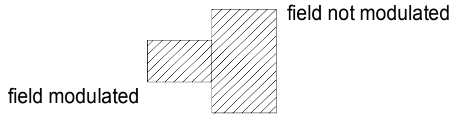
Figure 4 — Example of 40 kbit/s signal

Table 8 — Parameter for 99 % Modulation

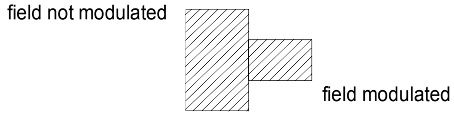
Parameter	Minimum	Nominal	Maximum
M = (A-B)/(A + B)	90	99	100
Ma	0		0,03 (A-B)
Mb	0		0,03 (A-B)
Tr	0 µs	1,8 µs	0,1 / $f_{bitrate}$
Tf	0 µs	1,8 µs	0,1 / $f_{bitrate}$

5.2.2.4.2 Bit coding of forward link fields

Data is Manchester encoded as per Figure 5.



Logic 0 = Manchester 0 … 01



Logic 1 = Manchester 1 … 10

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'.

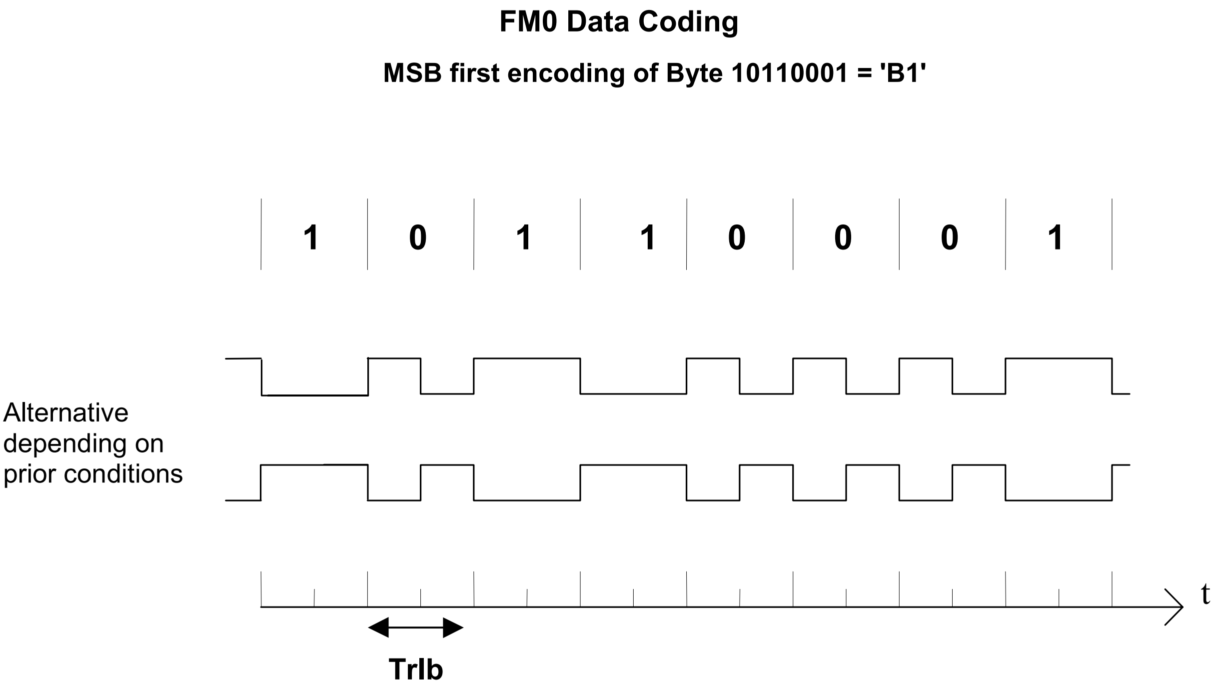


Figure 6 — Tag to interrogator data coding

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

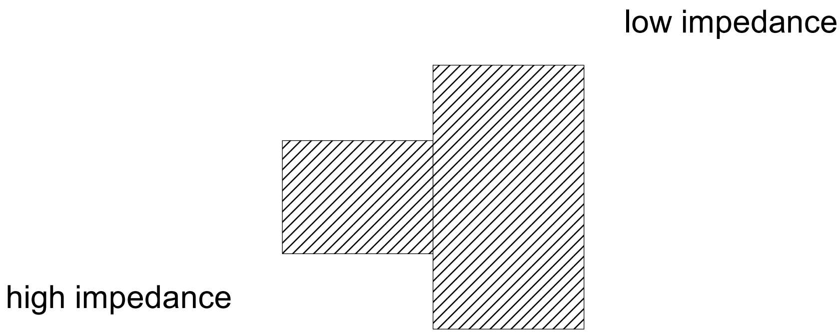
The return preamble is a sequence of backscatter modulation specified in Table 10.

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.

The tag shall execute backscatter, a half-bit 1 and half-bit 0 sent by the tag defined as follows:



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.

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).

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

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.

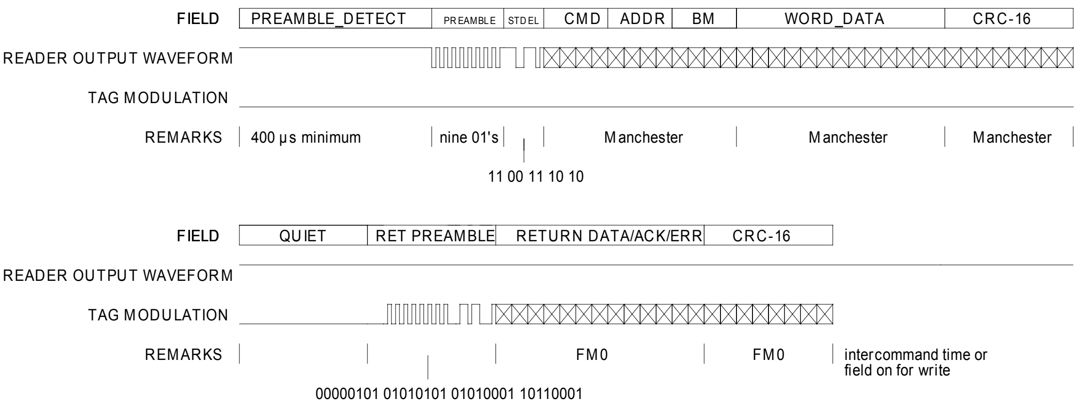


Figure 8 — Sample Command/Response Packets for (GROUP_SELECT) (40 kbit/s on forward and return link)

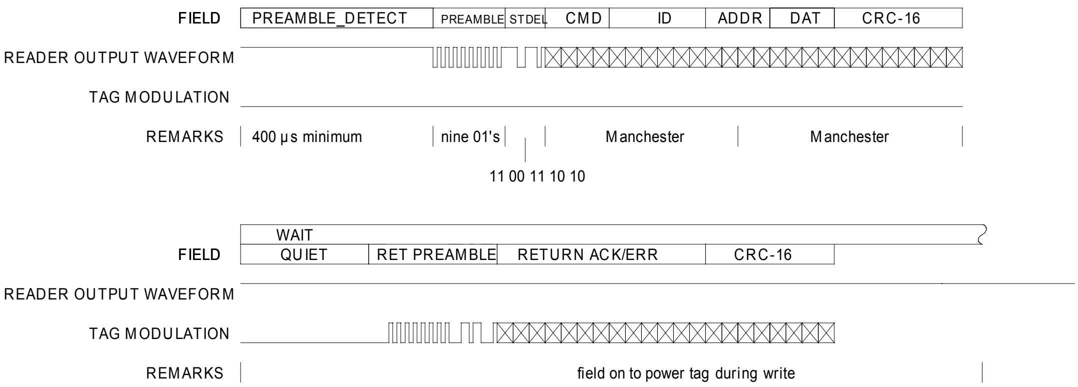


Figure 9 — Sample Command/Response Packets for WRITE (40 kbit/s on forward and return link)

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

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}.

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

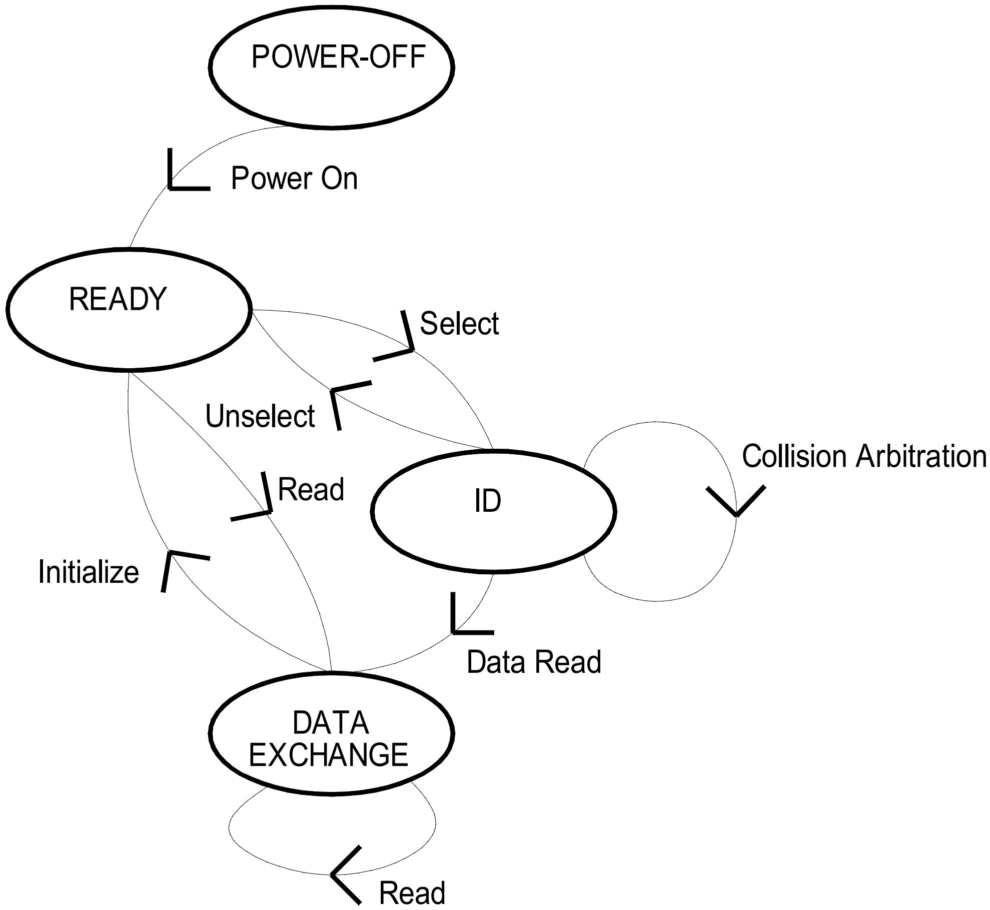
The tag has four major states:

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.



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

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

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

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.

For the collision arbitration the tag shall support two pieces of hardware on the tag:

- An 8-bit counter COUNT
- A random 1 or 0 generator.

In the beginning, a group of tags are moved to the ID state by GROUP_SELECT commands and shall set their internal counters to 0. Subsets of the group may be unselected by GROUP_UNSELECT commands back to the READY state. Other groups can be selected before the identification process begins. Simulation results show no advantage in identifying one large group or a few smaller groups.

After above described selection, the following loop should be performed:

1. All tags in the ID state with the counter COUNT at 0 shall transmit their ID. This set initially includes all the selected tags.

2. If more than one tag transmitted, the interrogator receives an erroneous response. The FAIL command shall be sent.

3. All tags receiving a FAIL command with COUNT not equal to 0 shall to increment COUNT. That is, they move further away from being able to transmit.

   All tags receiving FAIL a count of 0 (those that just transmitted) shall generate a random number. Those that roll a 1 shall increment COUNT and shall not transmit. Those that roll a zero shall keep COUNT at zero and shall send their UID again.

One of four possibilities now occurs:

4. If more than one tag transmits, the FAIL step 2 repeats. (Possibility 1)

5. If all tags roll a 1, none transmits. The interrogator receives nothing. It sends the SUCCESS command. All the counters decrement, and the tags with a count of 0 transmit. Typically, this returns to step 2. (Possibility 2)

6. If only one tag transmits and the ID is received correctly, the interrogator shall send the DATA_READ command with the ID. If the DATA_READ command is received correctly, that tag shall move to the DATA_EXCHANGE state and shall transmit its data.

   The interrogator shall sends SUCCESS. All tags in the ID state shall decrement COUNT.

7. If only one tag has a count of 1 and transmits, step 5 or 6 repeats. If more than one tag transmits, step 2 repeats. (Possibility 3)

8. If only one tag transmits and the ID is received with an error, the interrogator shall send the RESEND command. If the ID is received correctly, step 5 repeats. If the ID is received again some variable number of times (this number can be set based on the level of error handling desired for the system), it is assumed that more than one tag is transmitting, and step 2 repeats. (Possibility 4)

5.2.3.6 Commands

Commands are divided into four functional groups:

— Selection commands

— Identification commands

— Data transfer commands

— Multiple commands

Further, commands have one of the following types:

— Mandatory

— Optional

— Custom

— Proprietary

5.2.3.6.1 Command types

All tags with the same IC manufacturer code and same IC version number shall behave the same.

5.2.3.6.1.1 Mandatory

The command codes range from '00' to '0A', '0C', '15',and '1E', '1F' and '20' to '3F'.

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

5.2.3.6.1.2 Optional

The command codes range from '0B', '0D' to '0F', '11' to '13', '17 to '1C', '1D' and from '40' to '9F'.

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.

If the tag does not support an optional command, it shall remain silent.

NOTE The command whose code ranges from '17' to '1C' are optional and not essential to operate the tag. However, their support by the tag is recommended for appropriate performance. To reflect this, they are reported as "recommended" in Table 17.

5.2.3.6.1.3 Custom

The command codes range from 'A0' to 'DF'.

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.

The only fields that can be customised are the parameters and the data fields.

Any custom command contains as its first parameter the IC manufacturer code. This allows IC manufacturers to implement custom commands without risking duplication of command codes and thus misinterpretation.

If the tag does not support a custom command it shall remain silent.

5.2.3.6.1.4 Proprietary

The command codes are '10', '14', '16' and the range from 'E0' to 'FF'.

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.

These commands are used by IC and tag manufacturers for various purposes such as tests, programming of system information, etc... The IC manufacturer may at its option document them or not. It is allowed that these commands are disabled after IC and/or tag manufacturing.

5.2.3.6.2 Command codes and format

Table 17 – Command codes and format

Command code	Type	Command name	Parameters		
'00'	Mandatory	GROUP_SELECT_EQ	ADDRESS	BYTE_MASK	WORD_DATA
'01'	Mandatory	GROUP_SELECT_NE	ADDRESS	BYTE_MASK	WORD_DATA
'02'	Mandatory	GROUP_SELECT_GT	ADDRESS	BYTE_MASK	WORD_DATA
'03'	Mandatory	GROUP_SELECT_LT	ADDRESS	BYTE_MASK	WORD_DATA
'04'	Mandatory	GROUP_UNSELECT_EQ	ADDRESS	BYTE_MASK	WORD_DATA
'05'	Mandatory	GROUP_UNSELECT_NE	ADDRESS	BYTE_MASK	WORD_DATA
'06'	Mandatory	GROUP_UNSELECT_GT	ADDRESS	BYTE_MASK	WORD_DATA
'07'	Mandatory	GROUP_UNSELECT_LT	ADDRESS	BYTE_MASK	WORD_DATA
'08'	Mandatory	FAIL	none	none	none
'09'	Mandatory	SUCCESS	none	none	none
'0A'	Mandatory	INITIALIZE	none	none	none
'0B'	Optional	DATA_READ	ID	ADDRESS	none
'0C'	Mandatory	READ	ID	ADDRESS	none
'0D'	Recommended	WRITE	ID	ADDRESS	BYTE_DATA
'0E'	Recommended	WRITE_MULTIPLE	none	ADDRESS	BYTE_DATA
'0F'	Recommended	LOCK	ID	ADDRESS	none
'10'	Proprietary	IC manufacturer dependant			
'11'	Recommended	QUERY_LOCK	ID	ADDRESS	none
'12'	Recommended	READ_VERIFY	ID	ADDRESS	none
'13'	Recommended	MULTIPLE_UNSELECT	ADDRESS	BYTE_DATA	none
'14'	Proprietary	IC manufacturer dependant			
'15'	Mandatory	RESEND	none	none	none
'16'	Proprietary	IC manufacturer dependant			
'17'	Recommended	GROUP_SELECT_EQ_ FLAGS	none	BYTE_MASK	BYTE_DATA
'18'	Recommended	GROUP_SELECT_NE_ FLAGS	none	BYTE_MASK	BYTE_DATA
'19'	Recommended	GROUP_UNSELECT_EQ_ FLAGS	none	BYTE_MASK	BYTE_DATA
'1A'	Recommended	GROUP_UNSELECT_NE_ FLAGS	none	BYTE_MASK	BYTE_DATA
'1B'	Recommended	WRITE4BYTE	ID	ADDRESS	BYTE_MASK
'1C'	Recommended	WRITE4BYTE_MULTIPLE	BYTE_MASK	ADDRESS	4BYTE_DATA
'1D'	Recommended	READ_VERIFY4BYTE	ID	ADDRESS	
'1E'-'1F'	Mandatory	RFU			
'20'-'3F'	Mandatory	RFU			
'40' – '9F'	Optional	RFU			
'A0' – 'DF'	Custom	IC Manufacturer dependent			
'E0' – 'FF'	Proprietary	IC Manufacturer dependent			

5.2.3.6.2.1 Command fields

Table 18 — Command fields

Field name	Field size
COMMAND	1 byte
ADDRESS	1 byte
BYTE_MASK	1 byte
ID	8 bytes
WORD_DATA	8 bytes
BYTE_DATA	1 byte
4BYTE_DATA	4 bytes

5.2.3.6.2.2 Tag responses

Table 19 — Tag responses

Response code	Response name	Response size
'00'	ACKNOWLEDGE	1 byte
	ACKNOWLEDGE_NOK	1byte
'01'	ACKNOWLEDGE_OK	1byte
'FE'	ERROR_NOK	1byte
'FF'	ERROR	1byte
	ERROR_OK	1byte
Not applicable	WORD_DATA	8 bytes
Not applicable	BYTE_DATA	1byte
‘02’ – ‘FD’	RFU	

5.2.3.6.2.3 Selection commands

Selection commands define a subset of tags in the field to be identified or written to and may be used as part of the collision arbitration.

5.2.3.6.2.3.1 Data comparison for selection command on memory

Each select command of the commands GROUP_SELECT_EQ, GROUP_SELECT_NE, GROUP_SELECT_GT, GROUP_SELECT_LT, GROUP_UNSELECT_EQ, GROUP_UNSELECT_NE, GROUP_UNSELECT_GT, GROUP_UNSELECT_LT has 3 arguments (parameter and data):

ADDRESS

BYTE_MASK

WORD_DATA

and the tag shall make one of 4 possible comparisons:

EQ M EQUAL D

NE M NOT EQUAL D

GT M GREATER THAN D

LT M LOWER THAN D

The arguments of the comparison are

M7 MSB	M6	M5	M4	M3	M2	M1	M0 LSB
Tag memory content at ADDRESS+0	Tag memory content at ADDRESS+1	Tag memory content at ADDRESS+2	Tag memory content at ADDRESS+3	Tag memory content at ADDRESS+4	Tag memory content at ADDRESS+5	Tag memory content at ADDRESS+6	Tag memory content at ADDRESS+7

$$M = M0 + M1 * 2^{8} + M2 * 2^{16} + M3 * 2^{24} + M4 * 2^{32} + M5 * 2^{40} + M6 * 2^{48} + M7 * 2^{56}$$

and the argument of the command

D7 MSB	D6	D5	D4	D3	D2	D1	D0 LSB
First byte after command							Last byte after command

$$D = D0 + D1 * 2^{8} + D2 * 2^{16} + D3 * 2^{24} + D4 * 2^{32} + D5 * 2^{40} + D6 * 2^{48} + D7 * 2^{56}$$

The argument BYTE_MASK defines what bytes to be considered for comparison.

Table 20 — Data masking for Group_Select and Group_Unselect commands

BYTE_MASK	WORD_DATA
Bit 7 (MSB) is set	Consider D7 and M7 for comparison
Bit 6 is set	Consider D6 and M6 for comparison
Bit 5 is set	Consider D5 and M5 for comparison
Bit 4 is set	Consider D4 and M4 for comparison
Bit 3 is set	Consider D3 and M3 for comparison
Bit 2 is set	Consider D2 and M2 for comparison
Bit 1 is set	Consider D1 and M1 for comparison
Bit 0 (LSB) is set	Consider D0 and M0 for comparison
Bit 7 (MSB) is cleared	Ignore D7 and M7 for comparison
Bit 6 is cleared	Ignore D6 and M6 for comparison
Bit 5 is cleared	Ignore D5 and M5 for comparison
Bit 4 is cleared	Ignore D4 and M4 for comparison
Bit 3 is cleared	Ignore D3 and M3 for comparison
Bit 2 is cleared	Ignore D2 and M2 for comparison
Bit 1 is cleared	Ignore D1 and M1 for comparison
Bit 0 (LSB) is cleared	Ignore D0 and M0 for comparison

5.2.3.6.2.3.2 Data comparison for selection command on flags

Each select command of the commands GROUP_SELECT_EQ_FLAGS GROUP_SELECT_NE_FLAGS, GROUP_UNSELECT_EQ_FLAGS, GROUP_UNSELECT_NE_FLAGS, has 2 arguments (parameter and data):

BYTE_MASK

BYTE_DATA

and the tag shall make of 2 possible comparisons:

EQ FLAGS EQUAL D

NE FLAGS NOT EQUAL D

The arguments of the comparison are FLAGS, as defined in clause 5.2.3.1.3 and the argument of the command D, consisting of the bits D7 (MSB) to D0 (LSB).

The argument BYTE_MASK defines what bits to be considered for comparison.

Table 21 — Data masking for Group_Select_Flags and Group_Unselect_Flags

BYTE_MASK	BYTE_DATA
Bit 7 (MSB) is set	Consider D7 and FLAG7 for comparison
Bit 6 is set	Consider D6 and FLAG6 for comparison
Bit 5 is set	Consider D5 and FLAG5 for comparison
Bit 4 is set	Consider D4 and FLAG4 for comparison
Bit 3 is set	Consider D3 and FLAG3 for comparison
Bit 2 is set	Consider D2 and FLAG2 for comparison
Bit 1 is set	Consider D1 and FLAG1 for comparison
Bit 0 (LSB) is set	Consider D0 and FLAG0 for comparison
Bit 7 (MSB) is cleared	Ignore D7 and FLAG7 for comparison
Bit 6 is cleared	Ignore D6 and FLAG6 for comparison
Bit 5 is cleared	Ignore D5 and FLAG5 for comparison
Bit 4 is cleared	Ignore D4 and FLAG4 for comparison
Bit 3 is cleared	Ignore D3 and FLAG3 for comparison
Bit 2 is cleared	Ignore D2 and FLAG2 for comparison
Bit 1 is cleared	Ignore D1 and FLAG1 for comparison
Bit 0 (LSB) is cleared	Ignore D0 and FLAG0 for comparison

Formula describing the EQUAL function:

The EQUAL comparison passes, if (!B7+(D7=FLAG7)) * (!B6+(D6=FLAG6)) * (!B5+(D5=FLAG5)) * * (!B4+(D4=FLAG4)) * (!B3+(D3=FLAG3)) * (!B2+(D2=FLAG2)) * (!B1+(D1=FLAG1)) * (!B0+(D0=FLAG0)) is true.

Formula describing the UNEQUAL function:

The UNEQUAL comparison passes, if B7*(D7!=FLAG7) + B6*(D6!=FLAG6) + B5*(D5!=FLAG5) + B4*(D4!=FLAG4) + B3*(D3!=FLAG3) + B2*(D2!=FLAG2) + B1*(D1!=FLAG1) + B0*(D0!=FLAG0) is true.

5.2.3.6.2.3.3 GROUP_SELECT_EQ

Command code = ‘00’

On receiving a GROUP_SELECT_EQ command, a tag which is READY state shall read the 8-byte memory content beginning at the specified address and compare it with the WORD_DATA sent by the interrogator. In the case that the memory content is <u>equal</u> to WORD_DATA the tag shall set its internal counter COUNT to 0, read its UID and send back the UID and go into the state ID.

On receiving a GROUP_SELECT_EQ command, a tag which is ID state shall set its internal counter COUNT to 0, read its UID and send back the UID and stay in the ID state.

In all other cases the tag shall not send a reply.

Table 22 — GROUP_SELECT_EQ command

Preamble	Delimiter	COMMAND	ADDRESS	MASK	WORD_DATA	CRC
		8 bits	8 bits	8 bits	64 bits	16 bits

Table 23 — GROUP_SELECT_EQ response in the case of NO error

Preamble	ID	CRC
	64 bits	16 bits

NOTE If the byte mask is zero, GROUP_SELECT_EQ selects all tags.

5.2.3.6.2.3.4 GROUP_SELECT_NE

Command code = '01'

On receiving a GROUP_SELECT_NE command, a tag which is in the READY state shall read the 8-byte memory content beginning at the specified address and compare it with the WORD_DATA sent by the interrogator. In the case that the memory content is not equal to WORD_DATA the tag shall set its internal counter COUNT to 0, read its UID and send back the UID and go into the state ID.

On receiving a GROUP_SELECT_NE command, a tag which is in the ID state shall set its internal counter COUNT to 0, read its UID and send back the UID and stay in the ID state.

In all other cases the tag shall not send a reply.

Table 24 — GROUP_SELECT_NE command

Preamble	Delimiter	COMMAND	ADDRESS	BYTE_MASK	WORD_DATA	CRC
		8 bits	8 bits	8 bits	64 bits	16 bits

Table 25 — GROUP_SELECT_NE response in the case of NO error

Preamble	ID	CRC
	64 bits	16 bits

5.2.3.6.2.3.5 GROUP_SELECT_GT

Command code = '02'

On receiving a GROUP_SELECT_GT command, a tag which is in the READY state shall read the 8-byte memory content beginning at the specified address and compare it with the WORD_DATA sent by the interrogator. In the case that the memory content is greater than WORD_DATA the tag shall set its internal counter COUNT to 0, read its UID and send back the UID and go into the state ID.

On receiving a GROUP_SELECT_GT command, a tag which is in the ID state shall set its internal counter COUNT to 0, read its UID and send back the UID and stay in the ID state.

In all other cases the tag shall not send a reply.

Table 26 — GROUP_SELECT_GT command

Preamble	Delimiter	COMMAND	ADDRESS	MASK	WORD_DATA	CRC
		8 bits	8 bits	8 bits	64 bits	16 bits

Table 27 — GROUP_SELECT_GT response in the case of NO error

Preamble	ID	CRC
	64 bits	16 bits

5.2.3.6.2.3.6 GROUP_SELECT_LT

Command code = ‘03’

On receiving a GROUP_SELECT_LT command, a tag which is in the READY state shall read the 8-byte memory content beginning at the specified address and compare it with the WORD_DATA sent by the interrogator. In the case that the memory content is <u>lower than</u> WORD_DATA the tag shall set its internal counter COUNT to 0, read its UID and send back the UID and go into the state ID, and stays in the ID state.

On receiving a GROUP_SELECT_LT command, a tag which is in the ID state shall set its internal counter COUNT to 0, read its UID and send back the UID and stay in the ID state.

In all other cases the tag shall not send a reply.

Table 28 — GROUP_SELECT_LT command

Preamble	Delimiter	COMMAND	ADDRESS	BYTE_MASK	WORD_DATA	CRC
		8 bits	8 bits	8 bits	64 bits	16 bits

Table 29 — GROUP_SELECT_LT response

Preamble	ID	CRC
	64 bits	16 bits

5.2.3.6.2.3.7 GROUP_UNSELECT_EQ

Command code = ‘04’

On receiving a GROUP_UNSELECT_EQ command, a tag which is in the ID state shall read the 8-byte memory content beginning at the specified address and compare it with the WORD_DATA sent by the interrogator. In the case that the memory content is <u>equal</u> to WORD_DATA the tag shall go into the state READY and not send any reply. In the case that the comparison fails, the tag shall set its internal counter COUNT to 0, read its UID and send back the UID, and shall stay in the ID state.

In all other cases the tag shall not send a reply.

Table 30 — GROUP_UNSELECT_EQ command

Preamble	Delimiter	COMMAND	ADDRESS	BYTE_MASK	WORD_DATA	CRC
		8 bits	8 bits	8 bits	64 bits	16 bits

Table 31 — GROUP_UNSELECT_EQ response

Preamble	ID	CRC
	64 bits	16 bits

NOTE If the byte mask is zero, GROUP_UNSELECT_EQ unselects all tags.

5.2.3.6.2.3.8 GROUP_UNSELECT_NE

Command code = '05'

On receiving a GROUP_UNSELECT_NE command, a tag which is in the ID state shall read the 8-byte memory content beginning at the specified address and compare it with the WORD_DATA sent by the interrogator. In the case that the memory content is not equal to WORD_DATA the tag shall go into the state READY and not send any reply. In the case the comparison fails, the tag shall set its internal counter COUNT to 0, read its UID and send back the UID, and shall stay in the ID state.

In all other cases the tag shall not send a reply.

Table 32 — GROUP_UNSELECT_NE command

Preamble	Delimiter	COMMAND	ADDRESS	BYTE_MASK	WORD_DATA	CRC
		8 bits	8 bits	8 bits	64 bits	16 bits

Table 33 — GROUP_UNSELECT_NE response

Preamble	ID	CRC
	64 bits	16 bits

5.2.3.6.2.3.9 GROUP_UNSELECT_GT

Command code = '06'

On receiving a GROUP_UNSELECT_GT command, a tag which is in the ID state shall read the 8-byte memory content beginning at the specified address and compare it with the WORD_DATA sent by the interrogator. In the case that the memory content is greater than to WORD_DATA the tag shall go into the state READY and not send any reply. In the case that the comparison fails, the tag shall set its internal counter COUNT to 0, read its UID and send back the UID, and shall stay in the ID state.

In all other cases the tag shall not send a reply.

Table 34 — GROUP_UNSELECT_GT command

Preamble	Delimiter	COMMAND	ADDRESS	BYTE_MASK	WORD_DATA	CRC
		8 bits	8 bits	8 bits	64 bits	16 bits

Table 35 — GROUP_UNSELECT_GT response in the case of NO error and comparison fails

Preamble	ID	CRC
	64 bits	16 bits

5.2.3.6.2.3.10 GROUP_UNSELECT_LT

Command code = '07'

On receiving a GROUP_UNSELECT_LT command, a tag which is in the ID state shall read the 8-byte memory content beginning at the specified address and compare it with the WORD_DATA sent by the interrogator. In the case that the memory content is lower than to WORD_DATA the tag shall go into the state READY and not send any reply. In the case that the comparison fails, the tag shall set its internal counter COUNT to 0, read its UID and send back the UID, and shall stay in the ID state.

In all other cases the tag shall not send a reply.

Table 36 — GROUP_UNSELECT_LT command

Preamble	Delimiter	COMMAND	ADDRESS	BYTE_MASK	WORD_DATA	CRC
		8 bits	8 bits	8 bits	64 bits	16 bits

Table 37 — GROUP_UNSELECT_LT response

Preamble	ID	CRC
	64 bits	16 bits

5.2.3.6.2.3.11 MULTIPLE_UNSELECT

Command code = '13'

On receiving a MULTIPLE_UNSELECT command, a tag which is in the ID state shall read the 1-byte memory content beginning at the specified address and compare it with the BYTE_DATA sent by the interrogator. In the case that the memory content is equal to BYTE_DATA and the flag WRITE_OK is set, then the tag shall go into the state READY and not send any reply. In the case that the comparison fails, the tag shall set its internal counter COUNT to 0, read its UID and send back the UID, and shall stay in the ID state.

In all other cases the tag shall not send a reply.

Table 38 — MULTIPLE_UNSELECT command

Preamble	Delimiter	COMMAND	ADDRESS	BYTE_DATA	CRC
		8 bits	8 bits	8 bits	16 bits

Table 39 — MULTIPLE_UNSELECT response

Preamble	ID	CRC
	64 bits	16 bits

This command may be used to unselect all tags that had a successful write, while tags that had a weak write or write problems stay selected.

5.2.3.6.2.3.12 GROUP_SELECT_EQ_FLAGS

Command code = ‘17’

On receiving a GROUP_SELECT_EQ_FLAGS command, a tag which is in the READY state shall compare the FLAGS with the BYTE_DATA sent by the interrogator. In the case that the FLAGS are equal to BYTE_DATA the tag shall set its internal counter COUNT to 0, read its UID and send back the UID and go into the state ID.

On receiving a GROUP_SELECT_EQ_FLAGS command, a tag which is in the ID state shall set its internal counter COUNT to 0, read its UID and send back the UID and stay in the ID state.

In all other cases the tag shall not send a reply.

Table 40 — GROUP_SELECT_EQ_FLAGS command

Preamble	Delimiter	COMMAND	BYTE_MASK	BYTE_DATA	CRC
		8 bits	8 bits	8 bits	16 bits

Table 41 — GROUP_SELECT_EQ_FLAGS response

Preamble	ID	CRC
	64 bits	16 bits

NOTE If the byte mask is zero, GROUP_SELECT_EQ_FLAGS selects all tags.

5.2.3.6.2.3.13 GROUP_SELECT_NE_FLAGS

Command code = ‘18’

On receiving a GROUP_SELECT_NE_FLAGS command, a tag which is in the READY state shall compare the FLAGS with the BYTE_DATA sent by the interrogator. In the case that the FLAGS are not equal to BYTE_DATA the tag shall set its internal counter COUNT to 0, read its UID and send back the UID and go into the state ID.

On receiving a GROUP_SELECT_NE_FLAGS command, a tag which is in the ID state shall set its internal counter COUNT to 0, read its UID and send back the UID and stay in the ID state.

In all other cases the tag shall not send a reply.

Table 42 — GROUP_SELECT_NE_FLAGS command

Preamble	Delimiter	COMMAND	BYTE_MASK	BYTE_DATA	CRC
		8 bits	8 bits	8 bits	16 bits

Table 43 — GROUP_SELECT_NE_FLAGS response

Preamble	ID	CRC
	64 bits	16 bits

5.2.3.6.2.3.14 GROUP_UNSELECT_EQ_FLAGS

Command code = '19'

On receiving a GROUP_UNSELECT_EQ_FLAGS command, a tag which is in the ID state shall compare the FLAGS with the BYTE_DATA sent by the interrogator. In the case that the FLAGS are equal to BYTE_DATA the tag shall go into the state READY and not send any reply. In the case that the comparison fails, the tag shall set its internal counter COUNT to 0, read its UID and send back the UID, and shall stay in the ID state.

In all other cases the tag shall not send a reply.

Table 44 — GROUP_UNSELECT_EQ_FLAGS command

Preamble	Delimiter	COMMAND	BYTE_MASK	BYTE_DATA	CRC
		8 bits	8 bits	8 bits	16 bits

Table 45 — GROUP_UNSELECT_EQ_FLAGS response

Preamble	ID	CRC
	64 bits	16 bits

NOTE If the byte mask is zero, GROUP_UNSELECT_EQ_FLAGS unselects all tags.

5.2.3.6.2.3.15 GROUP_UNSELECT_NE_FLAGS

Command code = '1A'

On receiving a GROUP_UNSELECT_NE_FLAGS command, a tag which is in the ID state shall compare the FLAGS with the BYTE_DATA sent by the interrogator. In the case that the FLAGS are not equal to BYTE_DATA the tag shall go into the state READY and not send any reply. In the case that the comparison fails, the tag shall set its internal counter COUNT to 0, read its UID and send back the UID, and shall stay in the ID state.

In all other cases the tag shall not send a reply.

Table 46 — GROUP_UNSELECT_NE_FLAGS command

Preamble	Delimiter	COMMAND	BYTE_MASK	BYTE_DATA	CRC
		8 bits	8 bits	8 bits	16 bits

Table 47 — GROUP_UNSELECT_NE_FLAGS response

Preamble	ID	CRC
	64 bits	16 bits

5.2.3.6.2.4 Identification commands

Identification commands are used to perform to run the multiple tag identification protocol.

5.2.3.6.2.4.1 FAIL

Command code = ‘08’

The identification algorithm uses FAIL when more than one tag tried to identify itself at the same time. Some tags back off and some tags retransmit.

A tag shall only accept a FAIL command if it is in the ID state. In the case that its internal counter COUNT is not zero or the random generator result is 1, then COUNT shall be increased by 1, unless it is FF.

If the resulting COUNT value is 0, then the tag shall read its UID and sent back it in the response.

Table 48 — FAIL command

Preamble	Delimiter	COMMAND	CRC
		8 bits	16 bits

Table 49 — FAIL response

Preamble	ID	CRC
	64 bits	16 bits

5.2.3.6.2.4.2 SUCCESS

Command code = ‘09’

SUCCESS initiates identification of the next set of tags. It is used in two cases:

- When all tags receiving FAIL backed off and did not transmit, SUCCESS causes those same tags to transmit again.
- After an e.g. DATA_READ moves an identified tag to DATA_EXCHANGE, SUCCESS causes the next subset of selected but unidentified tags to transmit.

A tag shall only accept a SUCCESS command if it is in the ID state. In the case that its internal counter COUNT is not zero it shall be decreased by 1.

If the resulting COUNT value is 0, then the tag shall read its UID and sent back it in the response.

Table 50 — SUCCESS command

Preamble	Delimiter	COMMAND	CRC
		8 bits	16 bits

Table 51 — SUCCESS response

Preamble	ID	CRC
	64 bits	16 bits

5.2.3.6.2.4.3 RESEND

Command code = ‘15’

The identification algorithm uses RESEND when only one tag transmitted but the UID was received in error. The tag that transmitted resends its UID.

A tag shall only accept a RESEND command if it is in the ID state. If the COUNT value is 0, then the tag shall read its UID and sent back it in the response.

Table 52 – RESEND command

Preamble	Delimiter	COMMAND	CRC
		8 bits	16 bits

Table 53 – RESEND response

Preamble	ID	CRC
	64 bits	16 bits

5.2.3.6.2.4.4 INITIALIZE

Command code = ‘0A’

On receiving an INITIALIZE command a tag shall go into the READY state and reset the Data_Exchange_Status_Bit.

It shall not send any response.

Table 54 — INITIALIZE command

Preamble	Delimiter	COMMAND	CRC
		8 bits	16 bits

5.2.3.6.2.5 Data Transfer commands

Data Transfer commands are used to read or write data from or to the tag memory.

5.2.3.6.2.5.1 READ

Command code = ‘0C’

On receiving the READ command, the tag shall compare the sent ID with its UID. In the case that the ID is equal to the UID, the tag shall from any state move to the DATA_EXCHANGE state, read the 8 byte memory content beginning at the specified address and send back its content in the response. In the case that ID is not equal to UID or any other error the tag shall not send a reply. Further, the tag makes the byte of ADDESS lockable.

The address is numbered from ‘00’ to ‘FF’ (0 to 255).

Table 55 — Read command

Preamble	Delimiter	COMMAND	ID	ADDRESS	CRC
		8 bits	64 bits	8 bits	16 bits

Table 56 — Read response

Preamble	WORD_DATA	CRC
	64 bits	16 bits

5.2.3.6.2.5.2 DATA_READ

Command code = ‘0B’

On receiving the DATA_READ command, the tag shall only if it is in either the state ID or the state DATA_EXCHANGE compare the sent ID with its UID. In the case that the ID is equal to the UID, the tag shall from any state except READY move to the DATA_EXCHANGE state, read the 8 byte memory content beginning at the specified address and send back its content in the response. In the case that the ID is not equal to UID or any other error the tag shall not send a reply. The tag also shall send no reply when it is in the state READY, independently of the value of ID. Further, the tag makes the byte of ADDESS lockable.

The address is numbered from ‘00’ to ‘FF’ (0 to 255).

Table 57 — DATA_READ command

Preamble	Delimiter	COMMAND	ID	ADDRESS	CRC
		8 bits	64 bits	8 bits	16 bits

Table 58 — DATA_READ response

Preamble	WORD_DATA	CRC
	64 bits	16 bits

5.2.3.6.2.5.3 READ_VERIFY

Command code = ‘12’

On receiving the READ_VERIFY command, the tag shall compare the sent ID with its UID. In the case that the ID is equal to the UID and the WRITE_OK flag is set, the tag shall from any state move to the DATA_EXCHANGE state, read the 1-byte memory content beginning at the specified address and send back its content in the response. Further, the tag shall mark the byte at ADDRESS lockable. In the case that ID is not equal to UID, WRITE_OK is not set, or any other error the tag shall not send a reply. Further, the tag makes the byte of ADDESS lockable.

The address is numbered from ‘00’ to ‘FF’ (0 to 255).

Table 59 — READ_VERIFY command

Preamble	Delimiter	COMMAND	ID	ADDRESS	CRC
		8 bits	64 bits	8 bits	16 bits

Table 60 — READ_VERIFY response

Preamble	BYTE_DATA	CRC
	8 bits	16 bits

5.2.3.6.2.5.4 READ_VERIFY4BYTE

Command code = '1D'

On receiving the READ_VERIFY4BYTE command, the tag shall compare the sent ID with its UID. In the case that the ID is equal to the UID and the WRITE_OK flag is set, the tag shall from any state move to the DATA_EXCHANGE state, read the 4-byte memory content beginning at the specified address and send back its content in the response.

In the case that ID is not equal to UID, WRITE_OK is not set, or any other error the tag shall not send a reply.

The address is numbered from '00' to 'FF' (0 to 255).

Table 61 – READ_VERIFY4BYTE command

Preamble	Delimiter	COMMAND	ID	ADDRESS	CRC-16
		8 bits	64 bits	8 bits	16 bits

Table 62 – READ_VERIFY4BYTE response

Preamble	4BYTE_DATA	CRC-16
	32 bits	16 bits

5.2.3.6.2.5.5 WRITE

Command code = '0D'

On receiving the WRITE command, the tag shall compare the sent ID with its UID. In the case that the ID is equal to the UID, the tag shall from any state move to the DATA_EXCHANGE state, read the lock information for the byte on the specified memory content beginning at the specified address. In the case that the memory is locked, it shall send back the ERROR response. In the case that the memory is unlocked, it shall send back the ACKNOWLEDGE and program the data into the specified memory address. Further, the tag makes the byte of ADDRESS lockable.

In all other cases the tag will not send any reply.

In the case that the write access was successful, the tag shall set the WRITE_OK bit. Otherwise it shall reset it.

The address is numbered from '00' to 'FF' (0 to 255).

Table 63 — Write command

Preamble	Delimiter	COMMAND	ID	ADDRESS	BYTE_DATA	CRC
		8 bits	64 bits	8 bits	8 bits	16 bits

Table 64 — WRITE response in the case of unlocked memory

Preamble	ACKNOWLEDGE	CRC
	8 bits	16 bits

Table 65 — WRITE response in the case of locked memory

Preamble	ERROR	CRC
	8 bits	16 bits

5.2.3.6.2.5.6 WRITE4BYTE

Command code = ‘1B’

On receiving the WRITE4BYTE command, the tag shall compare the sent ID with its UID. In the case that the ID is equal to the UID, the tag shall from any state move to the DATA_EXCHANGE state, read the lock information for the 4 bytes on the specified memory content beginning at the specified address. In the case that one of the bytes specified by the BYTE_MASK is locked, it shall send back the ERROR response. In the case that all bytes are unlocked, it shall send back the ACKNOWLEDGE and program the data into the specified memory.

In all other cases the tag will not send any reply.

Executing WRITE4BYTE a tags shall only write those bytes that are selected by the BYTE_MASK, which means that write could be done to 1 to 4 bytes (using the mask bits in the BYTE_MASK field).

BYTE_MASK of the command

ADDRESS bit of BYTE_MASK to select whether byte should be written

[ADDR+0] B7

[ADDR+1] B6

[ADDR+2] B5

[ADDR+3] B4

In the case that the write access was successful, the tag shall set the WRITE_OK bit. Otherwise it shall reset it.

The address is numbered from ‘00’ to ‘FF’ (0 to 255). The starting address for the WRITE4BYTE command must be on a 4-byte page boundary.

Table 66 — WRITE4BYTE command

Preamble	Delimiter	COMMAND	ID	ADDRESS	BYTE_MASK	4BYTEDATA	CRC
		8 bits	64 bits	8 bits	8 bits	32 bits	16 bits

Table 67 — WRITE4BYTE response in the case of unlocked memory

Preamble	ACKNOWLEDGE	CRC
	8 bits	16 bits

Table 68 — WRITE4BYTE response in the case that of locked memory

Preamble	ERROR	CRC
	8 bits	16 bits

5.2.3.6.2.5.7 LOCK

Command code = '0F'

On receiving a LOCK command, a tag which is in the DATA_EXCHANGE state shall read its UID and compare it with the ID sent by the interrogator. In the case that the UID is equal to ID, the ADDRESS is within the valid address range and the byte at ADDRESS is marked lockable, then the tag shall send back the ACKNOWLEDGE and program the lock bit of the specified memory address.

In all other cases the tag shall not send a reply.

In the case that the write access was successful, the tag shall set the WRITE_OK bit. Otherwise it shall reset it.

The address is numbered from '00' to 'FF' (0 to 255).

Table 69 — LOCK command

Preamble	Delimiter	COMMAND	ID	ADDRESS	CRC
		8 bits	64 bits	8 bits	16 bits

Table 70 — LOCK response in the case that locking was possible and performed

Preamble	ACKNOWLEDGE	CRC
	8 bits	16 bits

5.2.3.6.2.5.8 QUERY_LOCK

Command code = '11'

On receiving a QUERY_LOCK command, a tag shall read its UID and compare it with the ID sent by the interrogator. In the case that the UID is equal to ID, the ADDRESS is within the valid address range, then the tag shall move into the DATA_EXCHANGE state. Further, the tag shall read the lock bit for the memory byte at ADDRESS. In the case that this memory is not locked, then it shall response ACKNOWLEDGE_OK if WRITE_OK is set and ACKNOWLEDGE_NOK if WRITE_OK is cleared. In the case that this memory is locked, then it shall respond ERROR_OK if WRITE_OK is set and ERROR_NOK if WRITE_OK is cleared. Further, the tag makes the byte of ADDESS lockable.

In all other cases the tag shall not send a reply.

The address is numbered from ‘00’ to ‘FF’ (0 to 255).

Table 71 — QUERY_LOCK command

Preamble	Delimiter	COMMAND	ID	ADDRESS	CRC
		8 bits	64 bits	8 bits	16 bits

Table 72 — QUERY_LOCK response if memory address is not locked and WRITE_OK is set

Preamble	ACKNOWLEDGE_OK	CRC
	8 bits	16 bits

Table 73 — QUERY_LOCK response if memory address is not locked and WRITE_OK is cleared

Preamble	ACKNOWLEDGE_NOK	CRC
	8 bits	16 bits

Table 74 — QUERY_LOCK response if memory address is locked and WRITE_OK is set

Preamble	ERROR_OK	CRC
	8 bits	16 bits

Table 75 — QUERY_LOCK response if memory address is locked and WRITE_OK is cleared

Preamble	ERROR_NOK	CRC
	8 bits	16 bits

5.2.3.6.2.5.9 WRITE_MULTIPLE

Command code = ‘0E’

Write Multiple commands are used to write to and to verify multiple tags in parallel.

On receiving the WRITE_MULTIPLE command, a tag which is in the ID state or the DATA_EXCHANGE state shall read the lock information for the byte on the specified memory content beginning at the specified address. In the case that the memory is locked, it shall do nothing. In the case that unlocked, it shall program the data into the specified memory.

The tag shall not any response.

In the case that the write access was successful, the tag shall set the WRITE_OK bit. Otherwise it shall reset it.

The address is numbered from ‘00’ to ‘FF’ (0 to 255).

Table 76 — WRITE_MULTIPLE command

Preamble	Delimiter	COMMAND	ADDRESS	BYTE_DATA	CRC
		8 bits	8 bits	8 bits	16 bits

5.2.3.6.2.5.10 WRITE4BYTE_MULTIPLE

Command code = ‘1C’

Write Multiple commands are used to write to and to verify multiple tags in parallel.

On receiving the WRITE4BYTE_MULTIPLE command, a tag which is in the ID state or the DATA_EXCHANGE state shall read the lock information for the 4 bytes on the specified memory content beginning at the specified address. In the case that one of byte of the 4-byte block is locked, it shall do nothing. In the case that all bytes are unlocked, it shall program the data into the specified memory.

The tag shall not any response.

Executing WRITE4BYTE a tags shall only write those bytes that are selected by the BYTE_MASK, which means that write could be done to 1 to 4 bytes (using the mask bits in the BYTE_MASK field).

BYTE_MASK of the command WRITE4BYTE_MULTIPLE.

ADDRESS bit of BYTE_MASK to select whether byte should be written

[ADDR+0] B7

[ADDR+1] B6

[ADDR+2] B5

[ADDR+3] B4

In the case that the write access was successful, the tag shall set the WRITE_OK bit. Otherwise it shall reset it.

The address is numbered from ‘00’ to ‘FF’ (0 to 255). The starting address for the WRITE4BYTE command must be on a 4-byte page boundary.

Table 77 — WRITE4BYTE_MULTIPLE command

Preamble	Delimiter	COMMAND	ADDRESS	BYTE_MASK	4BYTEDATA	CRC
		8 bits	8 bits	8 bits	32 bits	16 bits

5.2.3.6.2.6 Response description (Binary Tree Protocol Type)

5.2.3.6.2.6.1 ACKNOWLEDGE

ACKNOWLEDGE indicates a successful acceptance of the WRITE or LOCK.

5.2.3.6.2.6.2 ERROR

ERROR indicates an error in the WRITE. E.g. a write to locked memory area.

5.2.3.6.2.6.3 ACKNOWLEDGE_OK

ACKNOWLEDGE_OK is the response to a QUERY_LOCK and indicates an unlocked memory byte and a successful preceding write command.

5.2.3.6.2.6.4 ACKNOWLEDGE_NOK

ACKNOWLEDGE_NOK is the response to a QUERY_LOCK and indicates an unlocked memory byte and an unsuccessful preceding write command.

5.2.3.6.2.6.5 ERROR_OK

ERROR_OK is the response to a QUERY_LOCK and indicates a locked memory byte and a successful preceding write command.

5.2.3.6.2.6.6 ERROR_NOK

ERROR_NOK is the response to a QUERY_LOCK and indicates as locked memory byte and an unsuccessful preceding write command.

5.2.3.6.2.6.7 WORD_DATA

WORD_DATA is 8 bytes returned in response to a READ, or DATA_READ command.

5.2.3.6.2.6.8 ID

ID is 8 bytes returned in response to a GROUP_SELECT, GROUP_UNSELECT, FAIL, SUCCESS or RESEND,

5.2.3.6.2.6.9 BYTE_DATA

BYTE_DATA is 1 byte returned in response to the READ_VERIFY command.

5.2.3.6.2.6.10 4BYTEDATA

4BYTEDATA are 4 bytes used as argument for commands WRITE4BYTE, WRITE4BYTE_MULTIPLE and READ_VERIFY4BYTE.

5.2.3.7 Transmission errors

There are two types of transmission errors: modulation coding errors (detectable per bit) and CRC errors (detectable per command). Both errors cause any command to be aborted. The tag shall not respond.

For all CRC errors, the tag returns to the ready state.

For all coding errors, the tag returns to the READY state if a valid start delimiter had been detected. Otherwise it maintains its current state.

5.3 MODE 2: Long range high data rate RFID system

This clause describes a RFID system, offering a gross data rate up to 384 kbit/s at the air interface in case of Read/Write (R/W) tag. In case of Read Only (R/O) tag the data rate is 76,8 kbit/s. By using of battery powered tags such a system is well designed for long-range RFID applications. This air interface description does not explicit claim for battery assistance in the tag.

5.3.1 MODE 2: Physical and media access control (MAC) parameters

5.3.1.1 MODE 2: Interrogator to tag link

Table 78 — Parameter Table for the Forward Link (Interrogator to Tag Link)

Ref.	Parameter name	Description
M2-Int:1	Operating Frequency Range	2 400 – 2 483,5 MHz
M2-Int:1a	Default Operating Frequency	Reference carrier: according to (2931+m)*f_{CH}, where f_{CH} = 819,2 kHz, and m is a channel number from 0 to 99, variable determined by each country's regulatory authority in which the system is being operated. Communication carrier: according to (2944+n)*f_{CH}, where f_{CH} = 819,2 kHz, and n is a channel number from -13 to 86, variable determined by each country's regulatory authority in which the system is being operated. The reference and the communication carrier frequency difference is fixed to f_{CH}*13 = 10,6496 MHz.
M2-Int:1b	Operating Channels (For Spread Spectrum systems)	Reference carrier: according to (2931+m)*f_{CH}, where f_{CH} = 819,2 kHz, and m is a channel number from 0 to 99, variable determined by each country's regulatory authority in which the system is being operated. Communication carrier: according to (2944+n)*f_{CH}, where f_{CH} = 819,2 kHz, and n is a channel number from -13 to 86, variable determined by each country's regulatory authority in which the system is being operated. The reference and the communication carrier frequency difference is fixed to f_{CH}*13 = 10,6496 MHz.
M2-Int:1c	Operating Frequency Accuracy	Maximum tolerance is ±200 ppm, however local tolerance may apply in case required by local regulations.
M2-Int:1d	Frequency Hop Rate (for Frequency Hopping [FHSS] systems)	The hop rate is variable determined by each country's regulatory authority in which the system is being operated.
M2-Int:1e	Frequency Hop Sequences (for Frequency Hopping [FHSS] systems)	Adaptive, not fixed but in conformance with the requirements defined by the country's regulatory authority within which the system is operated.
M2-Int:2	Occupied Channel Bandwidth	1 MHz
M2-Int:2a	Minimum Receiver Bandwidth	2 400 – 2 483,5 MHz
M2-Int:3	Interrogator Transmit Maximum EIRP	In accordance to local regulations.

Table 78 *(continued)*

Ref.	Parameter name	Description
M2-Int:4	Interrogator Transmit Spurious Emissions	The interrogator shall transmit in conformance with spurious emissions requirements defined by the country's regulatory authority within which the system is operated.
M2-Int:4a	Interrogator Transmit Spurious Emissions, In-Band (for Spread Spectrum systems)	The interrogator shall transmit in conformance with spurious emissions requirements defined by the country's regulatory authority within which the system is operated.
M2-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.
M2-Int:5	Interrogator Transmitter Spectrum Mask	Communication carrier: GMSK with BT=0,5 Reference carrier: CW
M2-Int:6	Timing	
M2-Int:6a	Transmit to Receive Turn Around Time	520,8 µs
M2-Int:6b	Receive to Transmit Turn Around Time	520,8 µs
M2-Int:6c	Dwell Time or Interrogator Transmit Power On Ramp	Not applicable (only relevant for systems with amplitude modulation in the forward link)
M2-Int:6d	Decay Time or Interrogator Transmit Power Down Ramp	Not applicable (only relevant for systems with amplitude modulation in the forward link)
M2-Int:7	Modulation	Communication carrier: GMSK @ BT=0,5 Reference carrier: CW
M2-Int:7a	Spreading Sequence (for Direct Sequence Spread Spectrum [DSSS] systems)	Not applicable
M2-Int:7b	Chip Rate (for Spread Spectrum systems)	Not applicable
M2-Int:7c	Chip Rate Accuracy (for Spread Spectrum systems)	Not applicable
M2-Int:7d	Modulation Index	Not applicable
M2-Int:7e	Duty Cycle	Not applicable
M2-Int:7f	FM Deviation	Less than 200 kHz
M2-Int:8	Data Coding	Source coding: no. Channel coding: shortened Fire codes Line coding: no.
M2-Int:9	Bit Rate	384 kbit/s
M2-Int:9a	Bit Rate Accuracy	± 200 ppm
M2-Int:10	Interrogator Transmit Modulation Accuracy	Not applicable

Table 78 *(continued)*

Ref.	Parameter name	Description
M2-Int:11	Preamble	Fix length of blocks
M2-Int:11a	Preamble Length	Depend on the physical channel.
M2-Int:11b	Preamble Waveform	Same as the normal part of the burst.
M2-Int:11c	Bit Sync Sequence	Part of preamble.
M2-Int:11d	Frame Sync Sequence	Not applicable.
M2-Int:12	Scrambling (for Spread Spectrum systems)	Not applicable.
M2-Int:13	Bit Transmission Order	MSB transmitted first.
M2-Int:14	Wake-up process	Self synchronised, time controlled without radiated communication carrier.
M2-Int:15	Polarization	Circular or linear.

5.3.1.2 MODE 2: Tag to interrogator link

Table 79 — Parameter Table for the Return Link (Tag to Interrogator)

Ref.	Parameter name	Description
M2-Tag:1	Operating Frequency Range	2 400 – 2 483,5 MHz
M2-Tag:1a	Default Operating Frequency	Communication carrier from interrogator (tag only backscatter): according to (2931+n)*f_{CH}, where f_{CH} = 819,2 kHz, and n is a channel number from 0 to 99, variable determined by each country's regulatory authority in which the system is being operated.
M2-Tag:1b	Operating Channels (For Spread Spectrum systems)	Communication carrier from interrogator (tag only backscatter): according to (2931+n)*f_{CH}, where f_{CH} = 819,2 kHz, and n is a channel number from 0 to 99, variable determined by each country's regulatory authority in which the system is being operated.
M2-Tag:1c	Operating Frequency Accuracy	± 200 ppm maximum (same as the interrogator: due to back scattering)
M2-Tag:1d	Frequency Hop Rate (For Frequency Hopping [FHSS] systems)	Not applicable (Tag is back scattering)
M2-Tag:1e	Frequency Hop Sequence (For Frequency Hopping [FHSS] systems)	Not applicable (Tag is back scattering)
M2-Tag:2	Occupied Channel Bandwidth	1 MHz
M2-Tag:3	Transmit Maximum EIRP	Depending on the interrogator's reference carrier transmit power and propagation environment because tag is passive.
M2-Tag:4	Transmit Spurious Emissions	The tag shall transmit (backscatter) in conformance with spurious emissions requirements defined by the country's regulatory authority within which the system is operated.

Table 79 *(continued)*

Ref.	Parameter name	Description
M2-Tag:4a	Transmit Spurious Emissions, In-Band (for Spread Spectrum systems)	The tag shall transmit (backscatter) in conformance with spurious emissions requirements defined by the country's regulatory authority within which the system is operated.
M2-Tag:4b	Transmit Spurious Emissions, Out of Band	The tag shall transmit (backscatter) in conformance with spurious emissions requirements defined by the country's regulatory authority within which the system is operated.
M2-Tag:5	Transmit Spectrum Mask	R/W-tag: BPSK modulation with 384 kbit/s + Manchester coding R/O-tag: 76,8 kbit/s + Sub carrier coding + BPSK or OOK modulation
M2-Tag:6a	Transmit to Receive Turn Around Time	520,8 µs
M2-Tag:6b	Receive to Transmit Turn Around Time	520,8 µs
M2-Tag:6c	Dwell Time or Transmit Power On Ramp	Not applicable (only relevant for systems with amplitude modulation in the forward link)
M2-Tag:6d	Decay Time or Transmit Power Down Ramp	Not applicable (only relevant for systems with amplitude modulation in the forward link)
M2-Tag:7	Modulation	*Notification*: R/W-tag: sub carrier data coding, differential BPSK R/O-tag: sub carrier data coding, differential BPSK or OOK *Communication* (only for R/W-tag): Manchester data coding, differential BPSK
M2-Tag:7a	Spreading Sequence (for Direct Sequence Spread Spectrum [DSSS] systems)	Not applicable
M2-Tag:7b	Chip Rate (for Spread Spectrum systems)	Not applicable
M2-Tag:7c	Chip Rate Accuracy (for Spread Spectrum systems)	Not applicable
M2-Tag:7d	On-Off Ratio	R/W tag: Not applicable R/O tag: Not applicable in case of BPSK modulation Min. 15dB in case of OOK modulation
M2-Tag:7e	Sub-carrier Frequency	Notification: 153,6 kHz. Communication: 384 kHz.
M2-Tag:7f	Sub-carrier Frequency Accuracy	Notification: ± 300 ppm maximum Communication: ± 200 ppm maximum
M2-Tag:7g	Sub-Carrier Modulation	Notification: R/W-tag: DBPSK R/O-Tag: DBPSK or OOK Communication: DBPSK
M2-Tag:7h	Duty Cycle	Not applicable
M2-Tag:7i	FM Deviation	Not applicable

Table 79 *(continued)*

Ref.	Parameter name	Description
M2-Tag:8	Data Coding	Source coding: no Channel coding: shortened Fire codes Line coding: Manchester (communication) and twofold Manchester (notification).
M2-Tag:9	Bit Rate	Notification: 76,8 kbit/s Communication: 384 kbit/s
M2-Tag:9a	Bit Rate Accuracy	Notification: ± 300 ppm maximum Communication: ± 200 ppm maximum
M2-Tag:10	Tag Transmit Modulation Accuracy (for Frequency Hopping [FHSS] systems)	Not applicable
M2-Tag:11	Preamble	Fix length of blocks
M2-Tag:11a	Preamble Length	Depend on the physical channel.
M2-Tag:11b	Preamble Waveform	Same as the normal part of the burst.
M2-Tag:11c	Bit Sync Sequence	Part of preamble
M2-Tag:11d	Frame Sync Sequence	Not applicable
M2-Tag:12	Scrambling (for Spread Spectrum systems)	No scrambling is applied.
M2-Tag:13	Bit Transmission Order	MSB transmitted first.
M2-Tag:14	Reserved	
M2-Tag:15	Polarization	Circular or linear
M2-Tag:16	Minimum Tag Receiver Bandwidth	Same as the operating frequency range as far as the RF-bandwidth involved.

5.3.1.3 MODE 2: Protocol parameters

Table 80 — Protocol parameters

Ref.	Parameter name	Description
M2-P:1	Who talks first	Tags Talks First
M2-P:2	Tag addressing capability	Yes, tag can be addressed individually.
M2-P:3	Tag UID	Proprietary UID used, based on the used protocol
M2-P:3a	UID Length	32 Bit (can be extended in case of R/O-tag)
M2-P:3b	UID Format	Refer to Annex C
M2-P:4	Read size	Maximum 108 octets frame size, but fragmentation support gives unlimited read size
M2-P:5	Write size	Maximum 144 octets frame size, but fragmentation support gives unlimited read size
M2-P:6	Read Transaction Time	RW-tag: 7,3 ms R/O-tag: less then 15m (depends on the configuration)
M2-P:7	Write Transaction Time	7,3 ms (only for R/W-tag)
M2-P:8	Error detection	Different types of CRCs for detection are used (see clause 5.3.5.1)
M2-P:9	Error correction	Different types of Fire Codes for correction are used (see clause 5.3.5.1)
M2-P:10	Memory size	R/W-tag: 2 kbytes up to 256 kbytes R/O-tag: min 32 bits extendable up to 160 bits or more (depending on using the proprietary up link channel and the tag-data read channel)
M2-P:11	Command structure and extensibility	8 commands are defined, up to 29 commands are possible

5.3.1.4 MODE 2: Anticollision parameters

Table 81 — Anticollision parameters

Ref.	Parameter name	Description
M2-A:1	Type (Probabilistic or Deterministic)	Up to 64 tags deterministic
M2-A:2	Linearity	Non-linear
M2-A:3	Tag inventory capacity	Depends on settings during system installation (i.e. duty cycle of tag wake-up procedure and sleep time). The capacity is designed for secure communication with a small numbers of tags, but deterministic.

5.3.2 Modulation and coding

General: To avoid transmissions errors in case of data word 0 (data bits 0 have also CRC bits 0) on the air interface every transmitted data word from the interrogator shall be multiplied byte by byte with B9hex. This operation is done by a simple XOR. To minimise the hardware in the tag and to get the original data out of the tag the same operation shall also be used in the interrogator after receiving data from a tag.

Table 82 — Multiplication word

Multiplication word (8 bits)							
B7	B6	B5	B4	B3	B2	B1	B0
1	0	1	1	1	0	0	1

NOTE At tag manufacturing every data stored in the tag shall be pre-processed by that operation (this applies also for R/O-tags).

5.3.2.1 Forward link (only for R/W-tag)

The forward link modulation and coding format can be seen in Figure 13. Two carriers, a CW carrier and a GMSK modulated carrier shall be transmitted at the same time to the tag. This minimises the hardware on the tag, because the local oscillator for the down converter on the tag is generated in the interrogator.

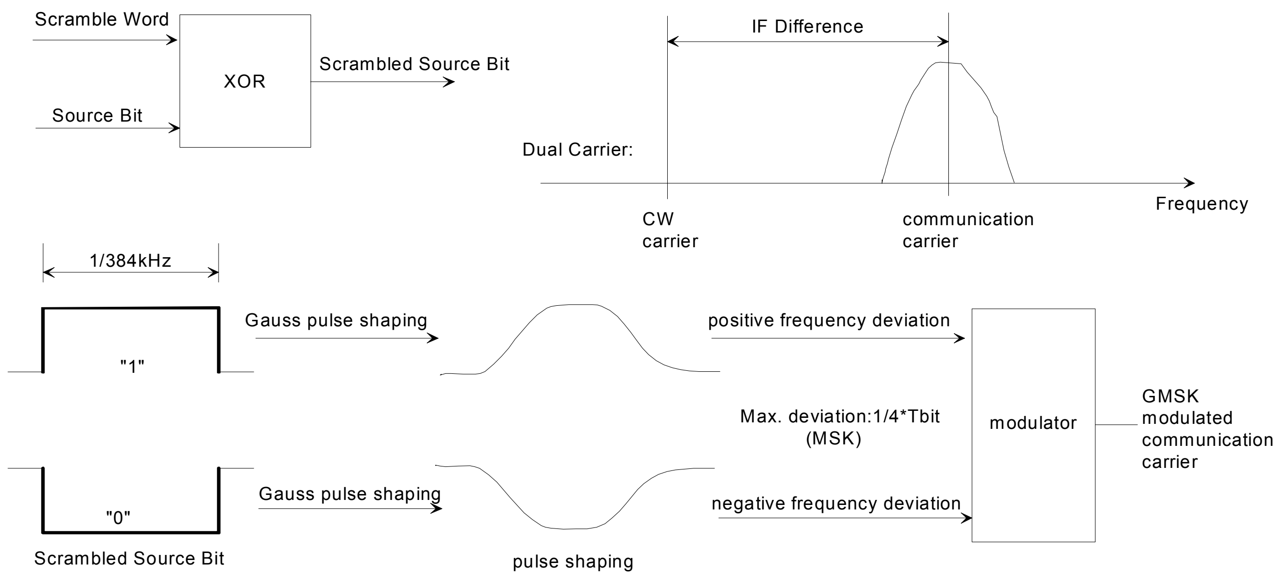


Figure 13 — Forward link modulation and coding

5.3.2.2 Return link for notification (for both types of the tag)

The return link modulation and coding format during the notification can be seen in Figure 14.

In case of R/O-tag an OOK modulation instead of BPSK modulation may also be used. Even in case of OOK the whole pre-processing like inverting, sub carrier modulation and differential encoding shall be applied.

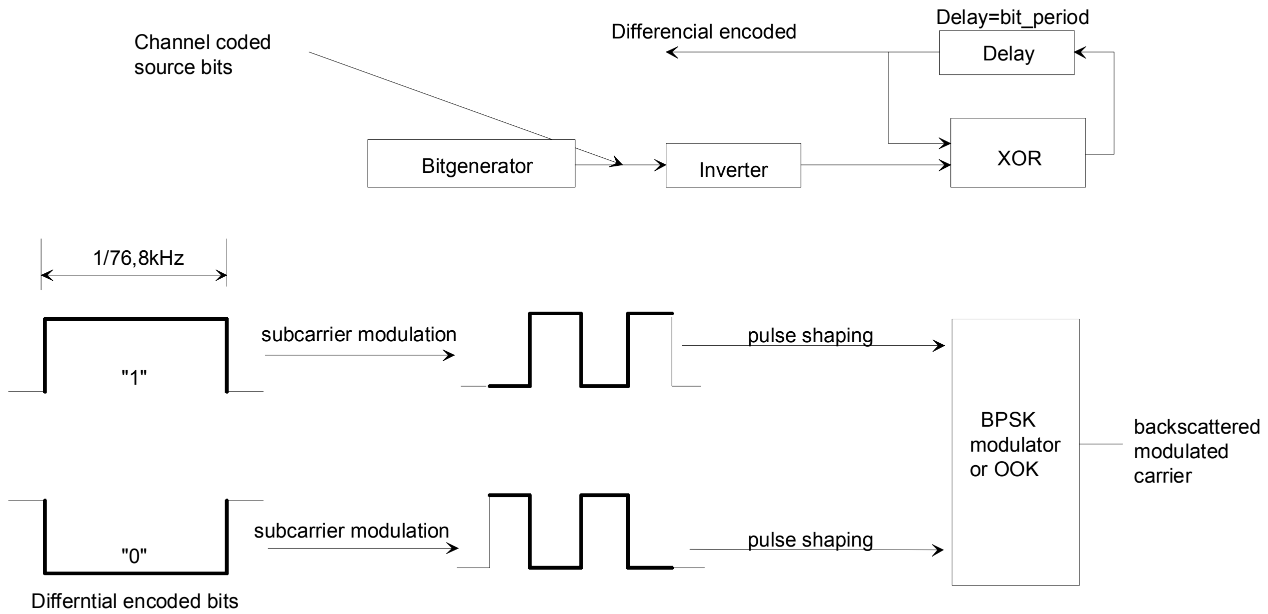


Figure 14 — Return link modulation and coding during notification

5.3.2.3 Return link for communication (only for R/W-tag)

The return link modulation and coding format during the communication can be seen in Figure 15.

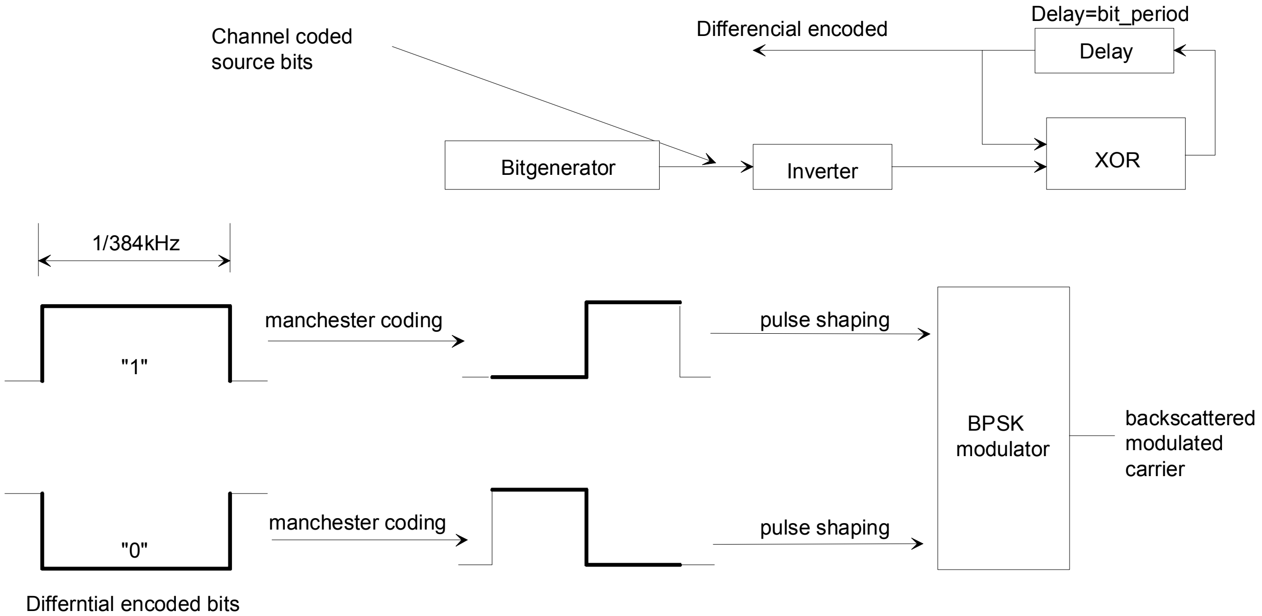


Figure 15 — Return link modulation and coding during communication

5.3.3 General system description

The system shall consist of an interrogator and at least one of 3 types of tags:

- A R/W-tag having read capability from and write capability to the tag.
- A R/O-tag behaving the same as a R/W-tag but only read capability from the tag.
- A special version of the R/O-tag with a short notification channel N-CH being useful in high-speed applications.

Mixed operation with different types of tags at the same time shall be possible. The interrogator shall operate at least with normal R/O-tags.

To be able to operate all tag types a TTF concept shall be used. Therefore all tags shall backscatter a fixed sequence (notification sequence) starting with synchronisation information and the tag data (including UserTagID, MfrTagID and MemoryID) to establish a communication. Depending on the content of the synchronisation information the interrogator shall evaluate the tag type. The total length of the sequence may be fixed or is depending on the MemoryID.

The repetition time may be set over the air interface individually according to application parameters like tag speed, tag identification rate or total amount of tags in the field of the interrogator. Anticollision is done by randomising the repetition time. Individual tags shall backscatter their sequence at an average repetition time but randomised (i.e. duty cycle of tag wake-up procedure and sleep time is random).

For the forward link of R/W tags two carriers are necessary, one modulated by GMSK (BT=0,5), the other carrier is CW. For the return link, the tag uses backscatter modulation of the communication carrier. Thus, the system uses two carriers of constant frequency difference. In case of R/O-tag there is only one carrier necessary. However, while the difference remains fixed, the two carriers may hop in the allowed frequency band during the communication takes place to reduce the impact of in-band interference on system performance. The hopping is governed by power measurements in free frequency channels between communication periods, and may also be used to conform to regulatory requirements.

Both the interrogator and the tag operate during small time intervals only when idle, the former to avoid interference for neighbouring RFID systems, and the latter to reduce power consumption. In these short overlapping wake-up periods, the interrogator listens if a tag modulates the transmitted reference carrier with a notification sequence. If this is the case, the interrogator initiates the notification procedure by synchronising to the individual tag's signal. After the notification procedure is completed, and the interrogator accepts the tag, the system enters the communication mode to perform exchange of data. To do so, and to enable or sustain communication with additional tags in the identification field, the interrogator is forced to synchronise to an arriving tag before the end of the notification mode. After completing the notification the interrogator turns back to the communication mode and continuous the existing transmission between the interrogator and tags. This allows the interrogator to organise all R/W-tags in the field in a time frame structure for subsequent service. All tag information from a R/O-tag shall be completely read out during the notification process. No additional communication is necessary. Generally, the communication between interrogator and tag is based on Time Division Duplexing/Time Division Multiplexing (TDD/TDM). The interrogator time multiplexes communications between an interrogator and several tags (TDM). The information exchange between interrogator and tag is based on time division multiplexing (TDD). Hence, data transmission is performed in time slots. Up to 64 sub frames, each consisting of 14 time slots, are combined to a frame. The number of sub frames actually used is fixed at system installation, but may be changed on maintenance occasions. During communication between tag and interrogator, a sub frame is assigned permanently and exclusively to a tag.

5.3.4 Frame structure

5.3.4.1 Hierarchical structure

The Protocol is frame-based. Each frame contains 1 to 64 sub frames and each sub frame contains 14 slots (see Figure 16). Each slot can be used for transmitting either 200 bits at a data rate of 384 kbit/s, or 40 bits at a data rate of 76,8 kbit/s. The length of a sub frame is consequently (1/384 kHz)*200*14 = 7,29 ms.

The length of a frame is SW-configurable and ranges from one sub frame (approx. 7,3 ms) to 64 sub frames (approx. 466,6 ms). This configuration is made by installation. It is possible to reconfigure this structure, but a dynamical reconfiguration during the operation is not possible. In the case of a forward link, there is no guard time between the slots. In the case of a return link, protection bits are inserted between the slots. The number of protection bits depends on the physical channel type.

The communication between interrogator and tag is based on Time Division Duplexing/Time Division Multiplexing (TDD/TDM). The interrogator time-multiplexes the communication between an interrogator and several tags. The information exchange between interrogator and tag is based on time division multiplexing. While the communication is going on, a sub frame is assigned permanently to a tag. It is not possible to assign a sub frame to more than one tag.

The same frame structure is being used for communication and spectrum check channels. For a notification channel, the frame structure is adapted to that of the service requesting tag, for as long as it takes until the notification channel is terminated. Once the notification channel is terminated, the original frame structure of the interrogator shall be re-established.

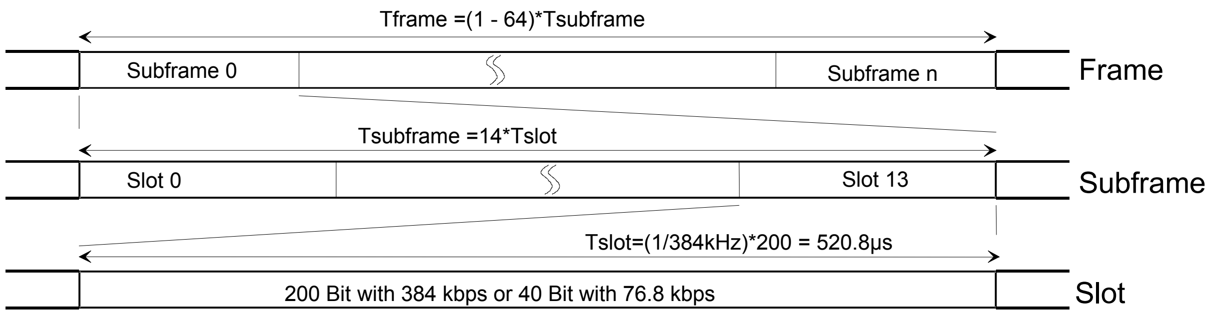


Figure 16 — Frame structure

5.3.4.2 Logical channels

Definition: Logical channels are the assignments between sub frames and the tasks to be performed and are controlled by the interrogator. There are three main groups of logical channels:

- Notification channel (N-CH)
- Communication channel (C-CH)
- Spectrum check channel (SC-CH).

Logical channels contain physical channels, which are explained in the following clauses. It is possible to chain logical channels, enabling the transmission of a super ordinate access to several frames at once (e.g.: write 2kBytes). Such a chain shall always start with a notification channel and end with a communication channel (in the case of R/W-tag). The last logical channel has to transmit an End of Communication (EOC) signal on the physical level.

In case of R/O-tag the whole information transmission from tag to interrogator shall take place in the notification channel. There is no communication channel to be built up. A spectrum check channel may or may not be used.

5.3.4.2.1 Notification channel (for both types of tags): N-CH

Function: On the notification channel, a new tag is inserted into the interrogator slot structure to carry out the bi-directional communication if it is a R/W-tag (see Figure 17), or all the information shall be read out from the tag if it is a R/O-tag (see Figure 18 and Figure 19). The notification channel shall be started at least in slot0 if a tag slot structure is detected. If neither communication nor spectrum check channel are used the notification channel can be started in every slot. The notification channel is terminated when the tag reads the first command in case of R/W-tag, or after all information is read out from an R/O-tag. The first command is transmitted in the sub frame assigned to and reserved for the communication channel.

Notification shall be cancelled if:

- The retrieved TagID is black listed (e.g. the interrogator does not want to communicate with the tag).
- The retrieved TagID contains errors (non-correctable CRC errors). The information on the logical confirmation channel contains errors (non-correctable CRC errors)
- The first command is not read and interpreted correctly by an R/W-tag (non-correctable CRC errors). In that case the interrogator does not get a response from this tag.
- All the sub frames are fully assigned (no command shall be transmitted).

5.3.4.2.2 Communication channel (only for R/W-tag): C-CH

Function: The communication channel is the medium where the read and write access operations between interrogator and tag are carried out (see Figure 20). Once the connection is set up, it is also possible to query the TagID. This channel shall be started after tag reads the first command and shall be terminated when interrogator sets the EOC (End of Communication) signal.

5.3.4.2.3 Spectrum check channel: SC-CH

Function: The spectrum check channel shall be used for searching free frequency channels (see Figure 19 and Figure 20). This channel may be activated if no notification or communication channel is being operated.

5.3.4.2.4 Priorities between the various logical channels

a) The first command is transmitted on the communication channel (same as termination of a notification)

Table 83 — Priorities when the first command is transmitted on the communication channels

Channel	Priority
Notification	2
Communication	1
Spectrum Check	3

This implies that a started notification shall be terminated before a new one can be started.

b) The first command is not transmitted on the communication channel

Table 84 — Priorities when the first command is not transmitted on the communication channels

Channel	Priority
Notification	1
Communication	2
Spectrum Check	3

This means that a notification shall interrupt the processing of the other two channels, unless it is the first command that is being transmitted on the communication channel (see a) above). In that case, an ARQ shall be initiated for the interrupted communication channel. Spectrum checks can be carried out only in an empty sub frame.

5.3.4.2.5 Frame structure for the notification channel in case of an R/W-tag

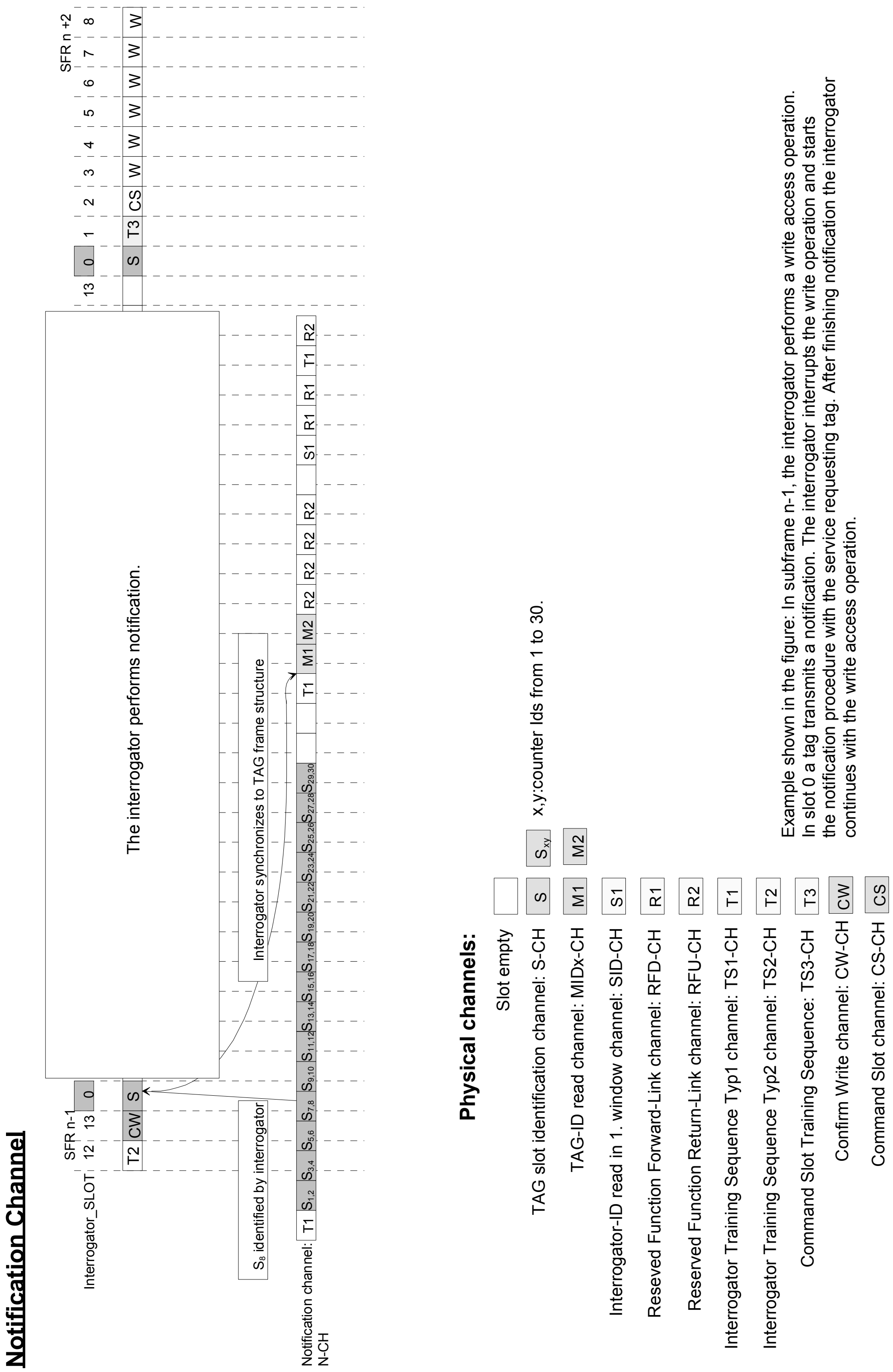


Figure 17 — Frame structure of the notification channel in case of an R/W-tag

5.3.4.2.6 Frame structure for the notification channel in case of an R/O-tag

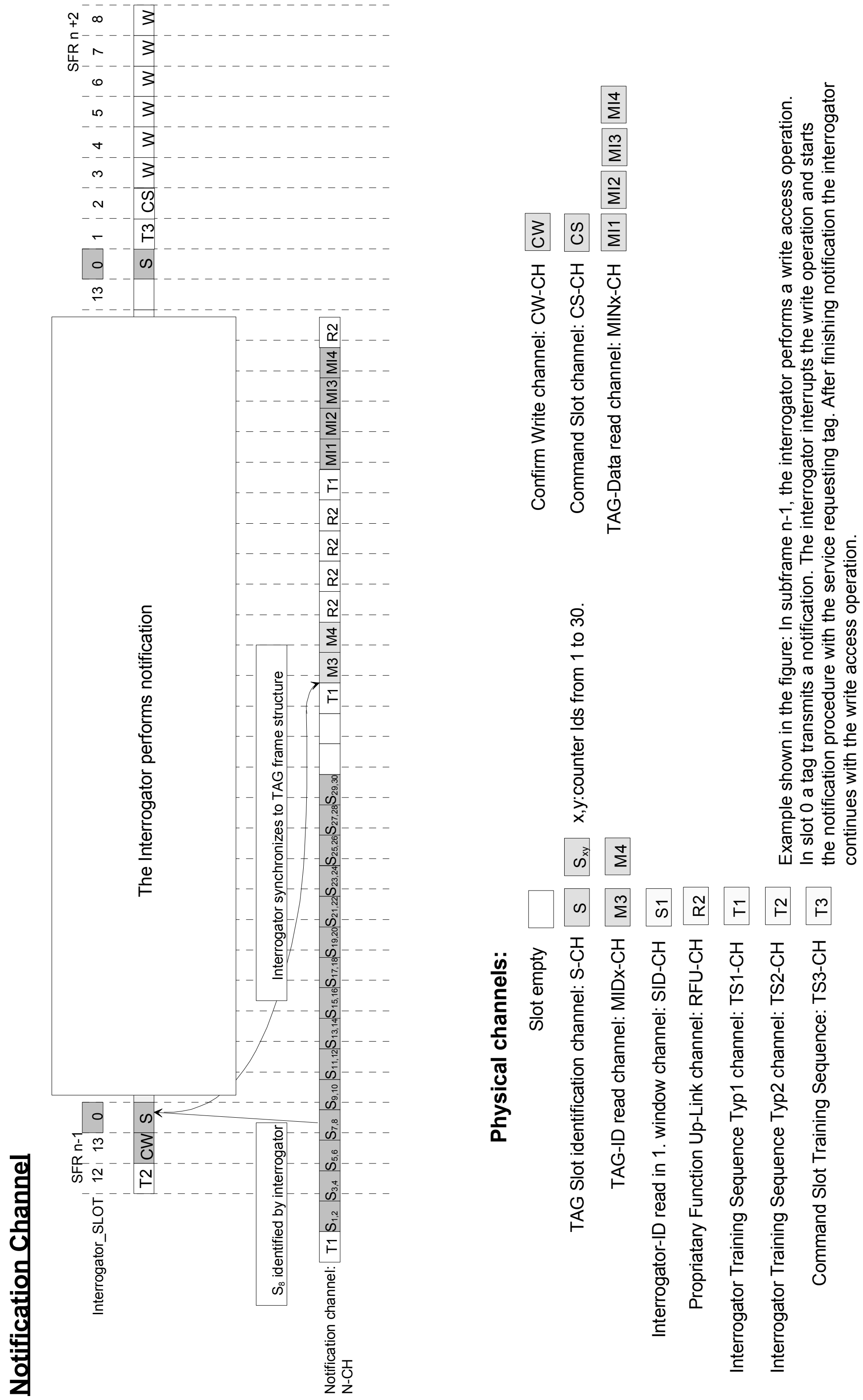


Figure 18 — Frame structure of the notification channel in case of an R/O-tag

5.3.4.2.7 Frame structure for the notification channel in case of an R/O-tag for high speed applications

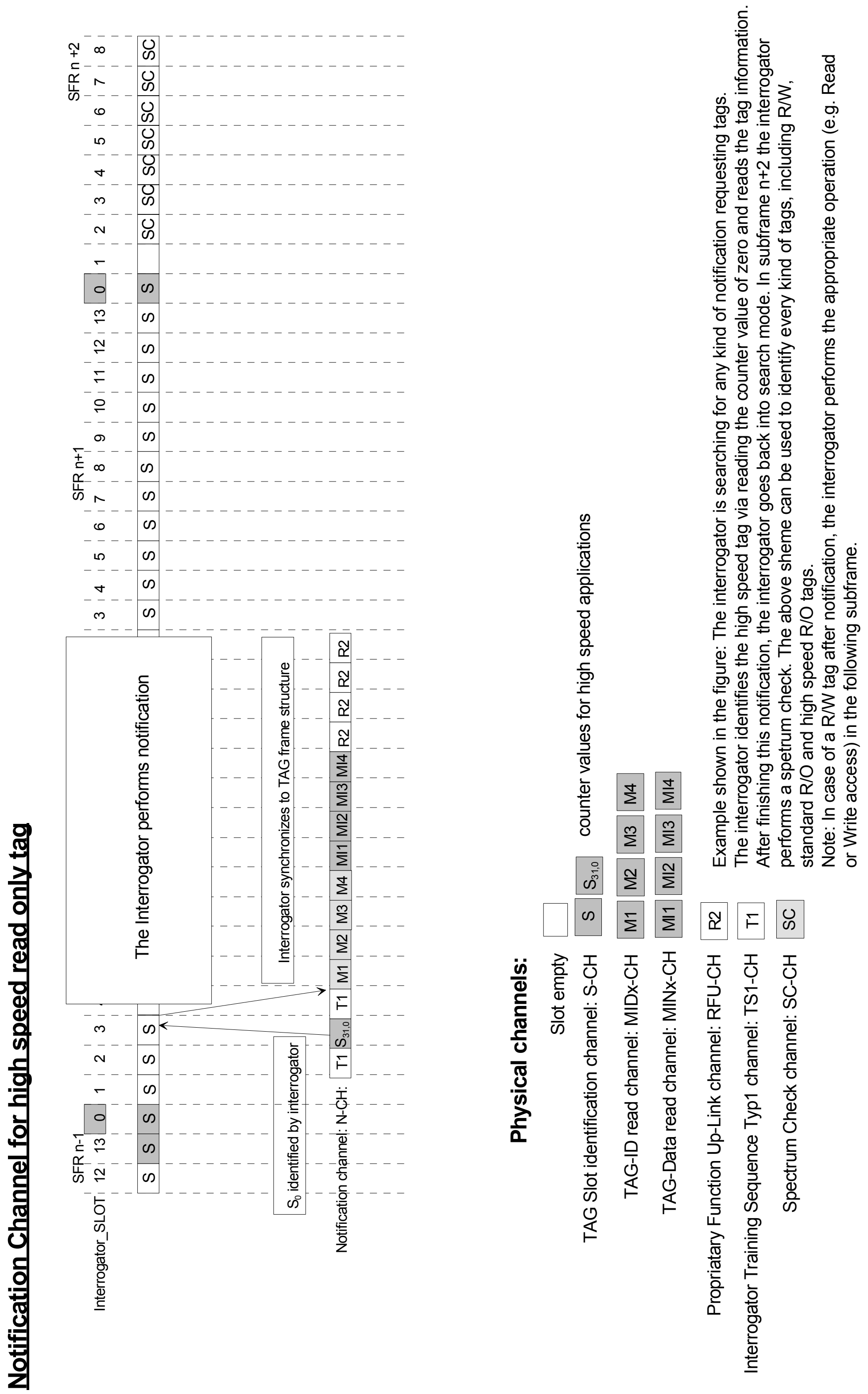


Figure 19 — Frame structure of the notification channel in case of an R/O-tag for high speed applications

5.3.4.2.8 Frame structure for the communication and spectrum check channels

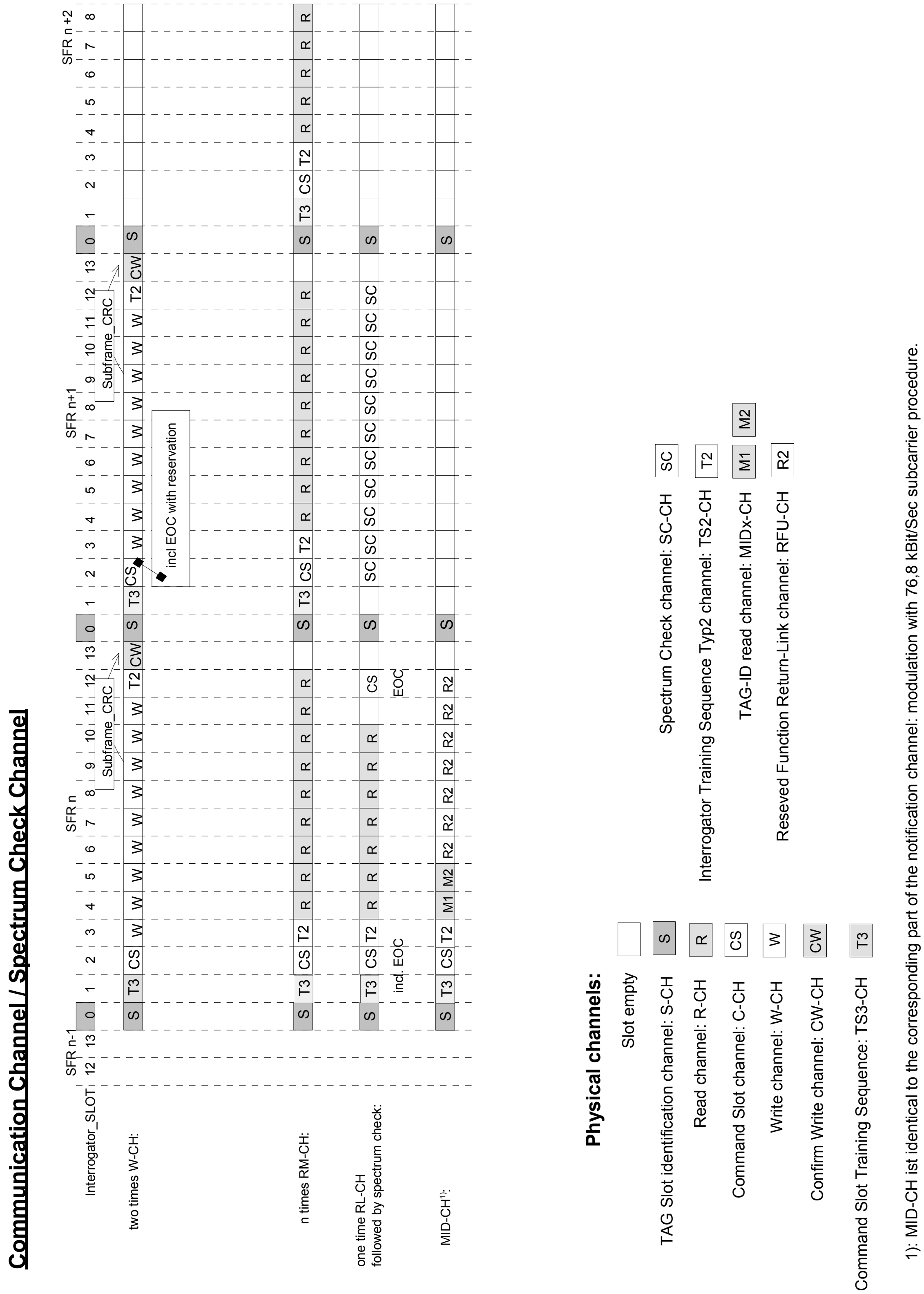


Figure 20 — Frame structure of the communication and spectrum check channels

5.3.4.3 Physical channels

Definition: Physical channels are the assignments between slots and modulation and coding procedures. As mentioned before the logical channels can contain physical channels. Table 85 shows the structure of the logical and the physical channels.

Table 85 — Logical and physical channels

Logical channel groups	Logical channel	Physical channel	Function
Notification channel N-CH	Tag Slot identification channel: S-CH (return link)	Tag Slot identification channel: S-CH (return link)	Tag sends in this channel synchronisation information that could be read by interrogator during search slot (e.g. slot0).
	TagID read channel: MID-CH (return link)	TagID read channel part 1: MID1-CH (return link)	This channel is used to transmit the first part of the 32-bit TagID.
		TagID read channel part 2: MID2-CH (return link)	This channel is used to transmit the second part of the 32-bit TagID.
		TagID read channel part 1: MID3-CH (return link)	This channel is used to transmit the first part of the 32-bit TagID.
		TagID read channel part 2: MID4-CH (return link)	This channel is used to transmit the second part of the 32-bit TagID.
	TagData read channel: MIN-CH (return link)	TagData read channel: MIN1-CH (return link)	This channel is used to transmit the first part of the 32-bit tag data.
		TagData read channel: MIN2-CH (return link)	This channel is used to transmit the second part of the 32-bit tag data.
		TagData read channel: MIN3-CH (return link)	This channel is used to transmit the first part of the second 32-bit tag data.
		TagData read channel: MIN4-CH (return link)	This channel is used to transmit the second part of the second 32-bit tag data.
	Interrogator-ID read channel: SID-CH (forward link)	Interrogator-ID read channel: SID-CH (forward link)	This channel is used to transmit the 10 bit long interrogator-ID and a 15-bit counter value to the tag.
	Reserved Function Forward link channel: RFD-CH (forward link)	Reserved Function Forward link channel: RFD-CH (forward link)	reserved for proprietary future use.
	Reserved Function Return link channel: RFU-CH (return link)	Reserved Function Return link channel: RFU-CH (return link)	reserved for proprietary future use.
		Interrogator Training Sequence Type 1 channel: TS1-CH (return link)	This channel is used only for ease the implementation of the hardware.

Table 85 *(continued)*

Logical channel groups	Logical channel	Physical channel	Function
Communication channel C-CH	Command Slot channel: CS-CH (forward link)	Command Slot channel: CS-CH (forward link)	This channel is used to transmit following commands from the interrogator to the tag: • write • long read • short read • init • wait • EOC
	Read More than 84 Byte channel: RM-CH (return link)	Read channel: R-CH (return link)	On this channel, up to 108 bytes can be transmitted in a single sub frame from tag to interrogator
	Read Less or equal than 84 byte Channel: RL-CH (return link)	Read channel: R-CH (return link)	On this channel, a maximum of 84 bytes can be transmitted in a single sub frame from tag to interrogator.
	Write channel: W-CH (forward link)	Write channel: W-CH (forward link)	On this channel, a maximum of 144 bytes can be transmitted in a single sub frame from interrogator to tag
	Confirm Write channel: CW-CH (return link)	Confirm Write channel: CW-CH (return link)	Signals whether the transmission of data from interrogator to tag in a given sub frame was free of errors or not.
		Interrogator Training Sequence Type 2 channel: TS2-CH (return link)	This channel is used only for ease the implementation of the hardware.
		Command Slot Training Sequence: TS3-CH (forward link)	This channel is used only for ease the implementation of the hardware.
Spectrum check channel SC-CH	Spectrum check channel SC-CH	Spectrum check channel SC-CH	The interrogator uses this channel to measure the RSSI values in the allowed frequency band within the allowed channels.

With regard to slot assignment, the bits are assigned as follows: MSB to LSB: from left to right. MSB is transmitted first, then LSB.

5.3.4.3.1 Tag Slot identification channel: S-CH (return link)

Function: During a slot identification channel (at minimum in slot0 of the interrogator), an interrogator shall read the synchronisation information of a new tag (if there is a new tag in the field). The S-CH is structured in such a way that the information required for synchronisation (time offset and time counters) is present twice in one slot. For each S-CH there are two blocks which each take half a slot long. The two blocks differ only by one increment of the time counter (the first block corresponds to the lower value). This ensures that this information shall be available for evaluation for any time position between tag and interrogator slot structure. For R/W-tags and for standard R/O-tags the time counter runs from 1 to 30, which means that 15 S-CH are sent consecutively on the N-CH. This ensures that the information required for synchronisation shall be available in two subsequent slots0. In case of R/O-tags for high speed applications the counter values of the two subsequent half slots are 31 followed by 0. For this type of applications the S-CH is not fixed to slot0. For a graphical representation, refer to Figure 21. Additionally the correlator word is the same sequence for an R/W-tag and for R/O-tags but inverted. Due to that fact the interrogator shall decide during the S-CH which type of tag starts communication.

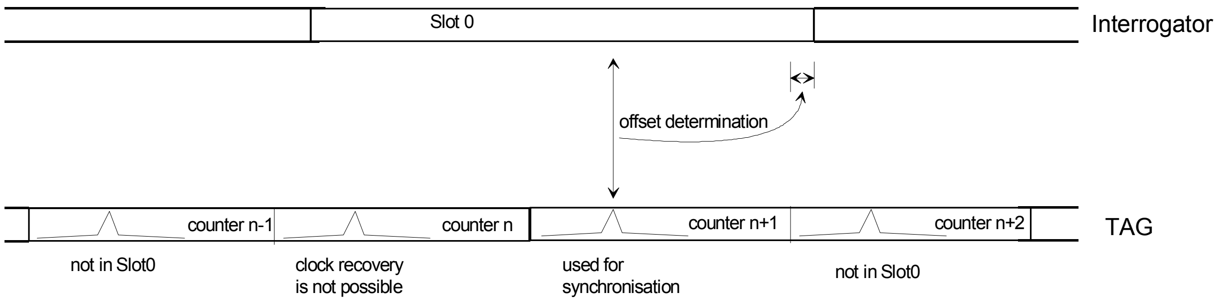


Figure 21 — S-CH position with regard to slot0

Data transmission: return link with 76,8 kbit/s

Table 86 — Sub frame assignment for S-CH in case of standard applications

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
•	–	–	–	–	–	–	–	–	–	–	–	–	–

Table 87 — Sub frame assignment for S-CH in case of R/O applications or if no communication or spectrum check channel is established

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
•	•	•	•	•	•	•	•	•	•	•	•	•	•

Slot assignment for R/W-tag:

Inverted time-reversed Barker sequence with a length of 13, which already contains the subsequence 0101 (B19…B16) for clock recovery. A parity bit is added after the 5 bit time counters.

Table 88 — Slot assignment for S-CH in case of R/W-tag

Correlator													**Time counters**	**Parity**	**Tail**
Clock recovery															
B19	B18	B17	B16	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6…B2	B1	B0
0	1	0	1	0	0	1	1	0	0	0	0	0			0

B6...B2: Time counters from 1 to 30.

Slot assignment for R/O-tag:

Time-reversed Barker sequence with a length of 13, which already contains the subsequence 0101 for clock recovery (B18...B15). A parity bit is added after the 5 bit time counters.

Table 89 — Slot assignment for S-CH in case of R/O-tag

Correlator													Time counters	Parity	Tail
Clock recovery															
B19	B18	B17	B16	B15	B14	B13	B12	B11	B10	B9	B8	B7	B6...B2	B1	B0
1	0	1	0	1	1	0	0	1	1	1	1	1			0

B6...B2: Time counters from 1 to 30 for standard R/O-tags, 31,0 for R/O-tags for high-speed applications.

Channel coding: Not applicable

B1: supplements B6...B2 to achieve even number parity (identical for both tag types).

Decoding: by means of a correlator. The correlation is executed in two steps to keep false alarms to a minimum. In the first step, only the bits in the correlator word (B19...B7) are included in the correlation. In the second step, the remaining known bits in an interrogator slot (e.g. slot0) are included in the correlation, too. S-CH is half as long as slot0, therefore there are still known bits. The number of known bits depends on where the correlation peak was found in the first step. This implies that the second correlation word has to be established dynamically, according to the Table 90. In the table only the values for the R/W-tag can be seen. The values for an R/O-tag are just simple inverted in the correlation field (in the field of the time reversed Barker sequence).

Table 90 — Second level correlation scheme

Position of half slot	Position of slot0																																								Number of correlation bits
	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
1	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N					P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N+1					P	22
2	0	1	0	1	0	0	1	1	0	0	0	0	0	#N					P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N+1					P	T	21
3	1	0	1	0	0	1	1	0	0	0	0	0	#N					P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N+1					P	T	0	20
4	0	1	0	0	1	1	0	0	0	0	0	#N					P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N+1					P	T	0	1	20
5	1	0	0	1	1	0	0	0	0	0	#N					P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N+1					P	T	0	1	0	20
6	0	0	1	1	0	0	0	0	0	#N					P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N+1					P	T	0	1	0	1	20
7	0	1	1	0	0	0	0	0	#N					P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N+1					P	T	0	1	0	1	0	20
8	1	1	0	0	0	0	0	#N					P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N+1					P	T	0	1	0	1	0	0	20
9	1	0	0	0	0	0	#N					P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N+1					P	T	0	1	0	1	0	0	1	20
10	0	0	0	0	0	#N					P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N+1					P	T	0	1	0	1	0	0	1	1	20
11	0	0	0	0	#N					P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N+1					P	T	0	1	0	1	0	0	1	1	0	20
12	0	0	0	#N					P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N+1					P	T	0	1	0	1	0	0	1	1	0	0	20
13	0	0	#N					P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N+1					P	T	0	1	0	1	0	0	1	1	0	0	0	20
14	0	#N					P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N+1					P	T	0	1	0	1	0	0	1	1	0	0	0	0	20
15	#N	#N				P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N+1					P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	21
16	#N	#N			P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N+1					P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N+2	22
17	#N	#N		P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N+1					P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N+2	#N+2	22
18	#N	#N	P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N+1					P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N+2		#N+2	22
19	#N	P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N+1					P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N+2			#N+2	22
20	P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N+1					P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N+2				#N+2	22
1	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N					P	T	0	1	0	1	0	0	1	1	0	0	0	0	0	#N+2					P	22

Dark Grey: Clock recovery Light Grey: Correlator bits P: Parity T: Tail
Boxed white: Bits with uncertainty Dashed boxed: Position of the correlation peak #N: Time counters

5.3.4.3.2 TagID read channel: MIDx-CH (return link, for both tag types)

Function: This channel is used to transmit the 32-bit ID_{31}, ….,ID_0 in two subsequent slots.

Data transmission: return link with 76,8 kbit/s

Sub frame assignment: not relevant, since MIDx-CH is a part of the notification channel. The position in the sub frame is not synchronous with the interrogator frame structure.

Slot assignment: A time reversed Barker sequence with a length of 11 is used for clock and word recovery.

Table 91 — Slot assignment for MID1 (for both types of tags) /MID3 (only for R/O-tags)

Word synch.											27 bit TagID	Tail
Clock recovery												
B39	B38	B37	B36	B35	B34	B33	B32	B31	B30	B29	B28...B2	B1...B0
0	1	0	0	1	0	0	0	1	1	1	First part of TagID ID_{31}, …. ID_5	0

Table 92 — Slot assignment for MID2 (for both types of tags) /MID4 (only for R/O-tags)

Word synch.											5 bit TagID	CRC over 32 bits	Tail
Clock recovery													
B39	B38	B37	B36	B35	B34	B33	B32	B31	B30	B29	B28...B24	B23...B2	B1...B0
0	1	0	0	1	0	0	0	1	1	1	ID_4, …., ID_0	CRC_{21},…,CRC_0	0

For a description of the memory mapping of the TagID refer to Annex C.

Channel coding: A shortened Fire code is used for TagID channel coding (54,32). After generation, the coded 54 bits (ID_{31}, …., ID_0, CRC_{21}, …, CRC_0) are transmitted in slots MID1/MID3 and MID2/MID4 beginning with the MSB ID_{31}. Generator polynomial:

$$g(x) = x^{22} + x^{17} + x^{13} + x^9 + x^4 + 1$$

The Channel Coding algorithm is as follows:

For Encoding:

- Initialize the CRC accumulator to all zeros – 0…..0h
- Divide in GF(2) the polynomial

  $ID_{31}x^{53}+ ID_{30}x^{52}+….+ID_0x^{22}$

  by the generator polynomial

  $x^{22} + x^{17} + x^{13} + x^9 + x^4 + 1$,

  obtain as remainder the polynomial

  $CRC_{21}x^{21}+…+CRC_0x^0$

- Attach the CRC bits (CRC_{21}, …, CRC_0) to the end of the TagID bits (ID_{31}, …., ID_0) and transmit the 54 codebits (ID_{31}, …., ID_0, CRC_{21}, …, CRC_0) MSB first

For Decoding:

- Divide the code polynomial

  $ID_{31}x^{53}+ \ldots +ID_0x^{22} +CRC_{21}x^{21}+ \ldots +CRC_0x^0$

  pre-multiplied with a certain factor (to account for the shortened code)

  by the generator polynomial

  $x^{22} + x^{17} + x^{13} + x^9 + x^4 + 1$,

  and use the remainder polynomial for error correction and error detection

5.3.4.3.3 TagData read channel: MINx-CH (return link, only for R/O-tag)

Function: This channel is used to transmit 64bits tag data in four subsequent slots. This can be done by sending two pairs of two consecutive slots.

Data transmission: return link with 76,8 kbit/s

Sub frame assignment: not relevant, since MINx-CH is a part of the notification channel. The position in the sub frame is not synchronous with the interrogator frame structure.

Slot assignment: A time reversed Barker sequence with a length of 11 is used for clock and word recovery.

Table 93 — Slot assignment for MIN1/MIN3

Word synch.											**27 bit tag data**	**Tail**
Clock recovery												
B39	B38	B37	B36	B35	B34	B33	B32	B31	B30	B29	B28...B2	B1...B0
0	1	0	0	1	0	0	0	1	1	1	First part of TagData $D_{31}, \ldots D_5$	0

Table 94 — Slot assignment for MIN2/MIN4

Word synch.											**5 bit tag data**	**CRC over 32 bits**	**Tail**
Clock recovery													
B39	B38	B37	B36	B35	B34	B33	B32	B31	B30	B29	B28...B24	B23...B2	B1...B0
0	1	0	0	1	0	0	0	1	1	1	$D_4, \ldots, D_0$	$CRC_{21},\ldots,CRC_0$	0

TagData bits: DATA63...DATA0

Note: This bits can be used to extend the UserTagID, or to store application related data in the tag.

Channel coding: For each pair of two consecutive slots transporting 32 data bits, a shortened Fire code is used for tag data channel coding (54,32). After generation, the coded 54 bits ($D_{31}, \ldots, D_0, CRC_{21}, \ldots, CRC_0$) are transmitted in slots MIN1/MIN3 and MIN2/MIN4 beginning with the MSB D_{31}. Generator polynomial:

$$g(x) = x^{22} + x^{17} + x^{13} + x^9 + x^4 + 1$$

The Channel Coding algorithm is as follows:

For Encoding:

- Initialize the CRC accumulator to all zeros – 0…..0h
- Divide in GF(2) the polynomial

  $D_{31}x^{53}+ D_{30}x^{52}+….+D_0x^{22}$

  by the generator polynomial

  $x^{22} + x^{17} + x^{13} + x^9 + x^4 + 1$,

  obtain as remainder the polynomial

  $CRC_{21}x^{21}+…+CRC_0x^0$

- Attach the CRC bits (CRC_{21}, …, CRC_0) to the end of the databits (D_{31}, …., D_0) and transmit the 54 codebits (D_{31}, …., D_0, CRC_{21}, …, CRC_0) MSB first

For Decoding:

- Divide the code polynomial

  $D_{31}x^{53}+ ….+D_0x^{22} +CRC_{21}x^{21} +…+CRC_0x^0$

  pre-multiplied with a certain factor (to account for the shortened code)

  by the generator polynomial

  $x^{22} + x^{17} + x^{13} + x^9 + x^4 + 1$,

  and use the remainder polynomial for error correction and error detection

5.3.4.3.4 Interrogator-ID read channel: SID-CH (forward link, only for R/W-tag)

Function: This channel is used to transmit the 10 bit long interrogator-ID and a 15-bit counter value to the tag. The counter value enables communication: it shows where the tag has to expect the first command on the communication channel.

Data transmission: forward link with 384kbit/s

Sub frame assignment: not relevant, since SID-CH is a part of the notification channel. The position in the sub frame is not synchronous with the interrogator frame structure.

Slot assignment: Only the first 112 bits out of 200 are assigned. The remaining 88 bits are not evaluated by the tag. For word synchronisation, a sequence (TSC1) with a length of 16 is used. The default correlator threshold for word synchronisation is 13 (the value must exceed 13: two bit errors maximum).

Table 95 — Slot assignment for SID-CH part1

Level detector (20 bits)								Wake-up and clock recovery (36 bits)							
B199	B198	B197	B196	....	B182	B181	B180	B179	B178	B177	B176	....	B146	B145	B144
0	1	0	1	....	1	0	1	0	1	0	1	....	1	0	1

Table 96 — Slot assignment for SID-CH part2

Word synch.: 16 bit sequence TSC1 (16 bits)															
B143	B142	B141	B140	B139	B138	B137	B136	B135	B134	B133	B132	B131	B130	B129	B128
1	0	1	1	1	0	0	0	0	1	0	0	0	1	0	0

Table 97 — Slot assignment for SID-CH part3

Interrogator-ID (10 bits)	Counter value (15 bits)	CRC over 25 bits (15 bits)	Not evaluated by tag
B127...B118	B117...B103	B102...B88	B87...B0
D_{24}, …. D_{15}	D_{14}, …. D_0	CRC_{14},…,CRC_0	

NOTE The sequence "0 1" is repeated for B195 – B183 and B175 – B147

Channel coding: A shortened Fire code is used for SID-CH channel coding (40,25). After generation, the coded 40 bits (D_{24}, …., D_0, CRC_{14}, …, CRC_0) are transmitted beginning with the MSB D_{24}. Generator polynomial:

$$g(x) = x^{15} + x^{10} + x^9 + x^6 + x + 1$$

The Channel Coding algorithm is as follows:

For Encoding:

- Initialize the CRC accumulator to all zeros – 0…..0h
- Divide in GF(2) the polynomial

  $D_{24}x^{39}+ D_{23}x^{38}+….+D_0x^{15}$

  by the generator polynomial

  $x^{15} + x^{10} + x^9 + x^6 + x + 1$,

  obtain as remainder the polynomial

  $CRC_{14}x^{14}+…+CRC_0x^0$

- Attach the CRC bits (CRC_{14}, …, CRC_0) to the end of the databits (D_{24}, …., D_0) and transmit the 40 codebits (D_{24}, …., D_0, CRC_{14}, …, CRC_0) MSB first

For Decoding:

- Divide the code polynomial

  $D_{24}x^{39}+ ….+D_0x^{15} +CRC_{14}x^{14} …+CRC_0x^0$

  pre-multiplied with a certain factor (to account for the shortened code)

  by the generator polynomial

  $x^{15} + x^{10} + x^9 + x^6 + x + 1$

  and use the remainder polynomial for error correction and error detection

5.3.4.3.5 Reserved function forward link channel: RFD-CH (forward link, only for R/W tags)

Function: reserved for proprietary future use.

5.3.4.3.6 Reserved function return link channel: RFU-CH (return link, for both types of tag)

Function: reserved for proprietary future use. The functionality can be different for the two tag types.

5.3.4.3.7 Interrogator training sequence type1 channel: TS1-CH (return link / without logical channel)

Function: This channel is used to ease the implementation of the hardware.

Data transmission: return link with a data rate out of 200 to 400 kbit/s. An alternating series of 0 and 1 started with 0.This signal is not differentially pre-coded, with the exception of the last bit. The last bit has to be differentially pre-coded to enable differential demodulation in the subsequent slot.

Sub frame assignment: set up before the S-CH, MID-CH, and RFU-CH channels.

Slot assignment: Not relevant.

5.3.4.3.8 Command slot channel: CS-CH (forward link)

Function: This channel is used to transmit the commands from the interrogator to the tag. The total amount per slot is 200 bits, with a net data bit content of 120 bits. The remaining bits are used for clock recovery, word synchronisation and for error protection.

Data transmission: forward link with 384 kbit/s.

Table 98 — Sub frame assignment for CS-CH in case of W-CH, RM-CH, MID-CH

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
		•											

Table 99 — Sub frame assignment for CS-CH in case of RL-CH

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
		•										•	

Slot assignment: 12 bits out of 200 are used for clock recovery. For word synchronisation, a sequence (TSC1) with a length of 26 is used. The default correlator threshold for word synchronisation is 24 (The value must 24: two bit errors maximum). The remaining 162 bits are coded net data bits.

Table 100 — Slot assignment for CS-CH part1

Clock recovery (12 bits)											
B199	B198	B197	B196	B195	B194	B193	B192	B191	B190	B189	B188
0	1	0	1	0	1	0	1	0	1	0	1

Table 101 — Slot assignment for CS-CH part2

B187...B162: Word synch (TSC1) (26 bits)																									
0	0	1	0	0	1	0	1	1	1	0	0	0	0	1	0	0	0	1	0	0	1	0	1	1	1

Table 102 — Slot assignment for CS-CH part3

Command type (4 bits)	**EOC** (1 bit)	**Interrogator frame structure** (7 bits)	**TagID** (18 bits)	**CRC protection over bits B161…B132** (44 bits)
B161...B158 D_{29}, …. D_{26}	B157 D_{25}	B156...B150 D_{24}, …. D_{18}	B149...B132 D_{17}, …. D_0	B131...B88 CRC_{43},…,CRC_0

Table 103 — Slot assignment for CS-CH part4

Block length (8 bits)	**Reserve** (1 bit)	**Start address** (18 bits)	**Reserve** (3 bits)	**CRC protection over bits B87 … B58** (44 bits)	**Reserve** (14 bits)
B87...B80 D_{29}, …. D_{22}	B79 D_{21}	B78...B61 D_{20}, …. D_3	B60...B58 D_2, …. D_0	B57...B14 CRC_{43},…,CRC_0	B13...B0

Description of fields:

Command type: refer to clauses 5.3.6.1 and 5.3.6.3.

EOC: End_Of_Communication (EOC) is signalled with one bit in the command field.

Interrogator frame structure: indicates the number of sub frames contained in a frame.

TagID: Only the ID31...ID14 range shall be transmitted in the command slot.

Block length: indicates how many bytes the transmitted block contains.

Start address: indicates where the first byte in the transmitted block should be written or read to. B79 shall be set to 0.

Channel coding: A shortened Fire code (74,30) is repeatedly used for coding the CS-CH data bits. After generation, the coded 74 bits (D_{29}, …., D_0, CRC_{43}, …, CRC_0) are transmitted beginning with the MSB D_{29}. Generator polynomial (same as for R-CH):

$$g(x) = x^{44} + x^{30} + x^{29} + x^{15} + x + 1$$

The Channel Coding algorithm is as follows:

For Encoding:

- Initialize the CRC accumulator to all zeros – 0…..0h
- Divide in GF(2) the polynomial

  $D_{29}x^{73} + D_{28}x^{72} + …. + D_0x^{44}$

by the generator polynomial

$$x^{44} + x^{30} + x^{29} + x^{15} + x + 1$$

obtain as remainder the polynomial

$$CRC_{43}x^{43}+\ldots+CRC_0x^0$$

- Attach the CRC bits (CRC_{43}, …, CRC_0) to the end of the databits (D_{29}, …., D_0) and transmit the 74 codebits (D_{29}, …., D_0, CRC_{43}, …, CRC_0) MSB first

For Decoding:

- Divide the code polynomial

  $$D_{29}x^{73}+ \ldots+D_0x^{44} +CRC_{43}x^{43} \ldots+CRC_0x^0$$

  pre-multiplied with a certain factor (to account for the shortened code)

  by the generator polynomial

  $$x^{44} + x^{30} + x^{29} + x^{15} + x + 1$$

  and use the remainder polynomial for error correction and error detection

5.3.4.3.9 Read channels: R-CH (return link)

Function: These channels are used to transmit the tag net data to interrogator. The total amount per slot is 200 bits, with a net data bit content of 96 bits. The remaining bits are used for clock recovery, word synchronisation and for error protection.

Data transmission: return link with 384 kbit/s.

Sub frame assignment:

Table 104 — Sub frame assignment for R-CH in case of RM-CH

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
				•	•	•	•	•	•	•	•	•	

Table 105 — Sub frame assignment for R-CH in case of RL-CH

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
				•	•	•	•	•	•	•			

Slot assignment: a time reversed Barker sequence with a length of 11 is used for clock and word recovery. The remaining 189 bits are coded net data bits, split up into two identical parts.

Table 106 — Slot assignment for R-CH part 1

Word synch.										
Clock recovery										
B199	B198	B197	B196	B195	B194	B193	B192	B191	B190	B189
0	1	0	0	1	0	0	0	1	1	1

Table 107 — Slot assignment for R-CH part 2

Net data bits (48 bits)	**CRC over previous 48 bits** (44 bits)	**Net data bit** (48 bits)	**CRC over bits B96 … B49** (44 bits)	**Tail bit**
B188...B141 D_{47}, …. D_0	B140...B97 CRC_{43},…,CRC_0	B96...B49 D_{47}, …. D_0	B48...B5 CRC_{43},…,CRC_0	B4...B0

Channel coding: A shortened Fire code (92,48) is repeatedly used for coding the R-CH data bits. After generation, the coded 92 bits (D_{47}, …., D_0, CRC_{43}, …, CRC_0) are transmitted beginning with the MSB D_{47}. Generator polynomial:

$$g(x) = x^{44} + x^{30} + x^{29} + x^{15} + x + 1$$

The Channel Coding algorithm is as follows:

For Encoding:

- Initialize the CRC accumulator to all zeros – 0…..0h
- Divide in GF(2) the polynomial

  $D_{47}x^{91}+ D_{46}x^{90}+….+D_0x^{44}$

  by the generator polynomial

  $x^{44} + x^{30} + x^{29} + x^{15} + x + 1$

  obtain as remainder the polynomial

  $CRC_{43}x^{43}+…+CRC_0x^0$

- Attach the CRC bits (CRC_{43}, …, CRC_0) to the end of the databits (D_{47}, …., D_0) and transmit the 92 codebits (D_{47}, …., D_0, CRC_{43}, …, CRC_0) MSB first

For Decoding:

- Divide the code polynomial

  $D_{47}x^{91}+ ….+D_0x^{44} +CRC_{43}x^{43} …+ CRC_0x^0$

  pre-multiplied with a certain factor (to account for the shortened code)

  by the generator polynomial

  $x^{44} + x^{30} + x^{29} + x^{15} + x + 1$

  and use the remainder polynomial for error correction and error detection

5.3.4.3.10 Write channel: W-CH (forward link)

Function: This channel is used to transmit net data from interrogator to tag. The total amount per slot is 200 bits, with a net data bit content of 128 bits. The remaining bits are used for clock recovery, word synchronisation and for error protection.

Data transmission: forward link with 384 kbit/s.

Table 108 — Sub frame assignment for W-CH

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
			•	•	•	•	•	•	•	•	•		

Slot assignment: 12 bits out of 200 are used for clock recovery. For word synchronisation a sequence (TSC1) with a length of 16 is used. The remaining 172 bits are coded net data bits.

Table 109 — Slot assignment for W-CH part 1

Clock recovery (12 bits)											
B199	B198	B197	B196	B195	B194	B193	B192	B191	B190	B189	B188
0	1	0	1	0	1	0	1	0	1	0	1

Table 110 — Slot assignment for W-CH part 2

Word synch.: 16 bit sequence TSC1															
B187	B186	B185	B184	B183	B182	B181	B180	B179	B178	B177	B176	B175	B174	B173	B172
1	0	1	1	1	0	0	0	0	1	0	0	0	1	0	0

Table 111 — Slot assignment for W-CH part 3

Net data bits (128 bits)	**CRC over previous 128 bits** (44 bits)
B171... B44 D_{127}, …. D_0	B43... B0 CRC_{43},…, CRC_0

Channel coding: A shortened Fire code is used for W-CH channel coding (172,128). After generation, the coded 172 bits (D_{127}, …., D_0, CRC_{43}, …, CRC_0) are transmitted beginning with the MSB D_{127}. Generator polynomial (same as R-CH):

$$g(x) = x^{44} + x^{30} + x^{29} + x^{15} + x + 1$$

The Channel Coding algorithm is as follows:

For Encoding:

- Initialize the CRC accumulator to all zeros – 0…..0h
- Divide in GF(2) the polynomial

  $D_{127}x^{171} + D_{126}x^{170} + \ldots + D_0x^{44}$

by the generator polynomial

$x^{44} + x^{30} + x^{29} + x^{15} + x + 1$

obtain as remainder the polynomial

$CRC_{43}x^{43}+\ldots+CRC_0x^0$

- Attach the CRC bits (CRC_{43}, …, CRC_0) to the end of the databits (D_{127}, …., D_0) and transmit the 172 codebits (D_{127}, …., D_0, CRC_{43}, …, CRC_0) MSB first

For Decoding:

- Divide the code polynomial

  $D_{127}x^{171}+ \ldots +D_0x^{44} +CRC_{43}x^{43} \ldots +CRC_0x^0$

  pre-multiplied with a certain factor (to account for the shortened code)

  by the generator polynomial

  $x^{44} + x^{30} + x^{29} + x^{15} + x + 1$

  and use the remainder polynomial for error correction and error detection

5.3.4.3.11 Confirm write channel: CW-CH (return link)

Function: This channel signals whether the transmission of data from interrogator to tag in a given sub frame was free of errors or not. For a transmission to be error-free, all the slots must have been received without errors. A “not error-free” signal results in an ARQ procedure for this communication.

Data transmission: return link with 384 kbit/s.

Table 112 — Sub frame assignment for CW-CH

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
													•

Slot assignment: A time reversed Barker sequence with a length of 11 is used for clock and word recovery. In the case of W-CH, the CRCs are evaluated on a slot-by-slot basis. If all the slot CRCs are error-free (or feature correctable errors only), the CRC_OK bit shall be set. This bit is transmitted to interrogator with 2*26 bits consecutively (sequence TSC1). If the received CRC was not o.k., a word containing nothing but 0´s shall be generated with a length of 2*26. The interrogator does not evaluate the remaining bits.

Table 113 — Slot assignment for CW-CH part 1

Word synch.										
Clock recovery										
B199	B198	B197	B196	B195	B194	B193	B192	B191	B190	B189
0	1	0	0	1	0	0	0	1	1	1

Table 114 — Slot assignment for CW-CH part 2

<table>
<tr><td colspan="26">B188...B163: CRC_OK: true (TSC1) (26 bits)</td></tr>
<tr><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td colspan="26">B188...B163: CRC_OK: false</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>

Table 115 — Slot assignment for CW-CH part 3

<table>
<tr><td colspan="26">B162...B137: CRC_OK: true (TSC1) (26 bits)</td><td>B136...B0</td></tr>
<tr><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td><td>1</td><td rowspan="3">—</td></tr>
<tr><td colspan="26">B162...B137: CRC_OK: false</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>

Channel coding: none.

Decoding: by means of correlator. The default correlator threshold for CRC_OK word detection is 50 (The value must exceed 50: 2 bit errors maximum in 52 bits).

5.3.4.3.12 Interrogator training sequence type2 channel: TS2-CH (return link / without logical channel)

Function: This channel is used only for ease the implementation of the hardware.

Data transmission: return link with a data rate out of 200 to 400 kbit/s. An alternating series of 0 and 1 started with 0.

This signal is not differentially pre-coded with the exception of the last bit. The last bit has to be differentially pre-coded to enable differential demodulation in the subsequent slot.

Sub frame assignment: always transmitted before the return link slot if no physical return link slot was sent before the "first" return link slot. That means that this channel shall be inserted before the first return link slot, containing ‘real’ information shall be sent.

Table 116 — Sub frame assignment for TS2-CH in case of W-CH

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
												•	

Table 117 — Sub frame assignment for TS2-CH in case of RM-CH, RL-CH, MID-CH

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
			•										

Table 118 — Slot assignment for TS2-CH

<table>
<tr><th colspan="5">Interrogator Training sequence (200 bits)</th></tr>
<tr><td>B199</td><td>B198</td><td>...</td><td>B1</td><td>B0</td></tr>
<tr><td>0</td><td>1</td><td>...</td><td>0</td><td>1</td></tr>
</table>

5.3.4.3.13 Command slot training sequence: TS3-CH (forward link / without logical channel)

Function: This channel is used only for ease the implementation of the hardware.

Data transmission: forward link with 384kbit/s. Last 30 bits are an alternating series of 2 zeros and 2 ones started with 2 ones.

Sub frame assignment: always transmitted only before CS-CH if CS-CH transmitted in Slot2.

Table 119 — Sub frame assignment for TS3-CH in case of C-CH

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
	•												

Table 120 — Slot assignment for TS3-CH

Command Slot Training Sequence (30 bits)									
B199…B30	B29	B28	B27	B26	…	B3	B2	B1	B0
—	1	1	0	0	…	0	0	1	1

5.3.4.3.14 Spectrum check channel: SC-CH (return link / without carrier)

Function: The interrogator uses this channel to measure the RSSI values in the allowed frequency band within the allowed channels. The stored values are used for determining free frequencies for notification and communication.

Data transmission: none.

Sub frame assignment: only if there is neither communication nor notification.

Table 121 — Sub frame assignment for SC-CH

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
		•	•	•	•	•	•	•	•	•	•	•	

Slot assignment: Not applicable

Channel coding: None.

Decoding: Not relevant.

5.3.5 CCC 6.2.5 Channel coding and sequences

5.3.5.1 Synchronisation and CRC patterns

Table 122 — Clock and word synchronisation words for the physical channels

Channel type		Clock	Word	Description
N-CH	S-CH (R/W-tag)	0101	001100000	Word incl. clock
	S-CH * (R/O-tag)	1010	110011111	Word incl. clock
	MID-CH	0100	1000111	Word incl. clock
	MIN-CH	0100	1000111	Word incl. clock
	SID-CH	010101…010101 (36 bits)	1011100001000100	
	TS1-CH	Not relevant	Not relevant	
C-CH	R-CH	0100	1000111	Word incl. clock
	W-CH	010101010101	1011100001000100	
	CW-CH	0100	1000111	Word incl. clock
	TS2-CH	Not relevant	Not relevant	
	CS-CH	010101010101	0010010111000010001001 0111	
	TS3-CH	Not relevant	Not relevant	
SC-CH		Not relevant	Not relevant	
* The clock recovery can work also with the capital letters: 0101: the same sequence as for a R/W-tag				

Table 123 — CRC parameterisation for the physical channels

Channel type		n‘	k‘	Generator polynomial	Remarks
N-CH	S-CH	6	5	Even parity only	n’: total number of bits in a CRC block.
	MID-CH	54	32	$x^{22}+x^{17}+x^{13}+x^{9}+x^{4}+1$	k’: total number of net bits in a CRC block.
	MIN-CH	54	32	$x^{22}+x^{17}+x^{13}+x^{9}+x^{4}+1$	In case of correction only the data field shall be corrected. No wrap around shall be applied for the correction.
	SID-CH	40	25	$x^{15}+x^{10}+x^{9}+x^{6}+x+1$	
C-CH	TS1-CH	—	—	—	
	R-CH	92	48	$x^{44}+x^{30}+x^{29}+x^{15}+x+1$	
	W-CH	172	128	$x^{44}+x^{30}+x^{29}+x^{15}+x+1$	
	CW-CH	52	2	52 bit correlator	
	TS2-CH	—	—	—	
	CS-CH	74	30	$x^{44}+x^{30}+x^{29}+x^{15}+x+1$	
	TS3-CH	—	—	—	
SC-CH		—	—	—	

5.3.6 Command set for the command slot channel: CS-CH (only for R/W-tag)

5.3.6.1 Command types

All tags with the same IC manufacturer code and same IC version number shall behave the same.

5.3.6.1.1 Mandatory

Mandatory command shall be supported by all R/W-tags that claim to be compliant. Interrogators which claim compliance for R/W-operation shall support all mandatory commands.

5.3.6.1.2 Optional

If the tag does not support an optional command, it shall remain silent.

Optional commands are commands that are specified within the International Standard. Interrogators which claim compliance for R/W-operation 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). R/W-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.

5.3.6.1.3 Custom

Custom commands may be enabled by an International Standard, but they shall not be specified in that International Standard. A custom command shall not solely duplicate the functionality of any mandatory or optional command defined in the International Standard by a different method.

An interrogator shall only send a custom command to a tag if the manufacturer of the tag specifies such a command.

During the notification process the TagID is sent to the interrogator. All custom commands shall be addressed individually to therefore specific manufactured tags. This allows IC manufacturers to implement custom commands without risking duplication of command codes and thus misinterpretation.

5.3.6.1.4 Proprietary

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.

IC and tag manufacturers use these commands for various purposes such as tests, programming of system information, etc. They are not specified in this part of ISO/IEC 18000. The IC manufacturer may at its option document them or not. It is allowed that these commands are disabled after IC and/or tag manufacturing.

5.3.6.2 Command set

General notes:

If a command cannot be decoded, and provided this is not the first command (in order to repeat a read attempt, the information on the interrogator frame structure is needed, and this information is available only with the first correctly decoded command), the tag shall try ten more times (in the ten subsequent frames) to decode the command. If the tag does not succeed in decoding a command, it shall return to the sleep mode. If the tag cannot decode a first command, it shall return to the sleep mode immediately, without trying to repeat the operation.

5.3.6.2.1 Write

Function: This command shall transmit a maximum of 144 bytes in a sub frame to the tag

NOTE This command requires only bits B161 to B14 in CS-CH to be evaluated (the command has arguments).

5.3.6.2.2 Long_Read

Function: This command shall transmit more than 84 bytes in a sub frame to the interrogator.

NOTE For information on how to proceed further, refer to RM-CH. This command requires only bits B161 to B14 in CS-CH to be evaluated (the command has arguments).

5.3.6.2.3 Short_Read

Function: This command shall transmit a maximum of 84 bytes in a sub frame to the interrogator.

NOTE For information on how to proceed further, refer to RL-CH. This command requires only bits B161 to B14 in CS-CH to be evaluated (the command has arguments). The only exception is when EOC is detected to be active in slot2. In that case, only bits B161 to B88 need to be evaluated.

5.3.6.2.4 Init

Function: This command shall transmit one byte to the tag. In the tag, this byte is written into all RAM cells.

NOTE On the protocol, **Init** behaves in the same way as **Write**. That is why the interrogator expects a CW-CH in slot13. This command requires only bits B161 to B88 in CS-CH to be evaluated (the command has no arguments).

5.3.6.2.5 Wait

Function: This command signals to the tag that the tag has to wait – for the length of one frame - for a new command.

NOTE On the protocol, **Wait** behaves in the same way as **Short_Read** without a data field. This command requires only bits B161 to B88 in CS-CH to be evaluated (the command has no arguments).

5.3.6.3 Command codes

Table 124 — Command codes in slot 2

Name	Type	Command code				EOC	Function
		B161 ... B158				B157	
Wait	Mandatory	0	0	0	0	x	Sub frame is not filled with data. An EOC in slot12 is not to be expected. This is a NOP command. The tag shall decode the next command in the next frame. It shall not be possible to terminate the communication.
Short_Read	Mandatory	0	0	0	1	0	Sub frame filled with a maximum of 84 bytes of read data. An EOC is to be expected in slot12. After EOC has been received in slot12, the tag shall return to the sleep mode. If there is no EOC in slot12, the tag shall wait for a command to arrive in the next frame.
						1	Confirmation that a Long_Read, or Wait command was successfully transmitted in the previous frame. The tag shall immediately return to the sleep mode. This command requires only bits B161 to B88 to be evaluated (the command has no arguments).
Long_Read	Mandatory	0	0	1	1	x	Sub frame filled with read data. The communication in this sub frame cannot be terminated.

Table 124 *(continued)*

Name	Type	Command code				EOC	Function
		B161 ... B158				B157	
Write	Mandatory	1	1	0	0	0	Sub frame filled with write data. The communication in this sub frame shall not be terminated. A feedback on the validity of the data received by tag in this sub frame shall be sent to interrogator on the CW-CH channel.
						1	The communication in this sub frame shall be terminated when the CRCs signal valid data for all the slots. A feedback on the validity of the data received in this sub frame shall be sent to interrogator on the CW-CH channel. Once the data has been written to RAM, the tag shall return to the sleep mode.
Init	Optional	1	1	1	1	x	A feedback on the validity of the data received in this sub frame (INIT byte) shall be sent to interrogator on the CW-CH channel. The communication cannot be terminated during initialisation. During initialisation the tag must be polled in each respective sub frame to find out whether or not the initialisation has been terminated
Reserved for future use	Optional	0 1	1 0	0 1	1 0	x	
IC Mfg dependent	Custom	0 0 1 1 1	0 1 0 1 1	1 0 1 0 1	0 0 1 1 0	x	
IC Mfg dependent	Proprietary	0 0 1 1	1 1 0 0	1 1 0 0	0 1 0 1	x	

Table 125 — Command codes in slot 12

Name	Type	Command code				EOC	Function
		B161 ... B158				B157	
EOC	Mandatory	0	0	0	1	1	Confirmation that a Short_Read command was successfully transmitted in this frame. The tag shall immediately return to the sleep mode. This command requires only bits B161 to B88 to be evaluated (the command has no arguments). EOC=0 shall not be used (invalid operation)
Reserved for future use	Optional	0 1	1 0	0 1	1 0	x	
IC Mfg dependent	Custom	0 0 0 0 1 1 1 1 1	0 0 0 1 0 1 1 1 1	0 1 1 0 1 0 0 1 1	0 0 1 0 1 0 1 0 1	x	
IC Mfg dependent	Proprietary	0 0 1 1	1 1 0 0	1 1 0 0	0 1 0 1	x	

NOTES

- In the case of command decoding error, the tag shall try ten more times to decode the command. After the eleventh unsuccessful attempt, the tag shall return to the sleep mode. The exception to this rule shall be the "first" command. If the tag fails to decode the first command, it shall return to the sleep mode immediately.
- For mandatory and optional commands: in the case of 'x', the EOC bit shall not be evaluated.

6 Table of characteristic differences between the modes specified in this part of ISO/IEC 18000

Table 126 — Table of Characteristic Differences

Feature	MODE 1	MODE 2
Protocol	Interrogator talks first	Tag talks first
Characteristics	Passive backscatter RFID system	Battery assisted backscatter, long-range, high data-rate RFID system
Data rate	40 kbit/s	76,8 kbit/s or 384 kbit/s
Memory	To commercial demand	To commercial demand
Anti Collision	Yes, AC features defined by interrogator during collision arbitration	Yes, AC features defined at system installation on tag
Global Operation NOTE Local regulations may affect operational capabilities	Yes	Yes

Annex A
(informative)

Mode 1: Memory Map

A.1 Tag memory map

Tag Memory Map

The following table describes the overall memory map of the tags.

Table A.1 — Layout of tag memory map

Bytes	Field name	Written	Locked
0-7	Tag ID	Manufacturing	Manufacturing
8,9	Tag Manufacturer	Manufacturing	Manufacturing
10,11	Tag Hardware Type	Manufacturing	Manufacturing
12-17	Tag Memory Layout	Manufacturing or Application	As Required by Application
18 and above	User Data*	Application	As Required

* Definition and Format of User Data determined by Tag Memory Layout

The first eight bytes of the tag memory shall be programmed with unique Tag ID numbers. This field is hard-coded in the ASIC to allow tag sort algorithms to function properly, therefore it is important that these Tag Serial Numbers be unique.

A.2 Unique identifier

The tag serial number shall either be in accordance with A.2.1 or A.2.2.

Note: At the current time ANSI 256 has no established an IC manufacturing authority. Therefore UID "E0xxx" is preferred.

Differentiation is done by the leading bits in byte 0, which are 111 for unique identifiers as defined in A.2.1 and 000 for unique identifier as defined in A.2.2.

A.2.1 Default unique identifier

Table A.2 — Layout of default unique identifier

MSB							LSB
Byte 0 M L	Byte 1 M L	Byte 2 M L	Byte 3 M L	Byte 4 M L	Byte 5 M L	Byte 6 M L	Byte 7 M L
'E0' 8 bits	IC Mfg code acc. ISO/IEC 7816-6	Chip Manufacturer Assigned 48 bits					

A.2.1.1 'E0' (byte 0)

E0 is the header for unique identifier followed by the manufacturer code according ISO/IEC 7816-6.

A.2.1.2 IC Mfg code according ISO/IEC 7816-6 (byte 1)

ISO/IEC 7816-6 defines an 8 bit code for chip manufacturers.

A.2.1.3 Chip manufacturer assigned (bytes 2 – 7)

This is a 48-bit field that is defined and managed by the chip manufacturer. Different chip manufacturers will have different manufacturer codes (see below), thus eliminating the potential for duplicated collision arbitration data (Tag UID's). The numbering system employed by the chip manufacturer must ensure that all tags produced will have a unique and unambiguous number (used by the collision arbitration algorithm). This unique number will be "locked" prior to use. Maximum value for this field is 2^{48} -1.

Responsibility for ensuring uniqueness and for locking this unique number prior to use shall rest with the chip manufacturer.

A.2.2 Unique identifier according to ANSI 256

Table A.3 — Layout of Tag Serial Number (Bytes 0-7)

<table>
<tr><th>MSB</th><th></th><th></th><th></th><th></th><th></th><th></th><th colspan="2">LSB</th></tr>
<tr><th>Byte 0
MSB LSB</th><th>Byte 1
MSB LSB</th><th>Byte 2
MSB LSB</th><th>Byte 3
M S</th><th>Byte 4
MSB LSB</th><th>Byte 5
MSB LSB</th><th>Byte 6
MSB LSB</th><th colspan="2">Byte 7
MSB LSB</th></tr>
<tr><td rowspan="3">000
zero
3bits</td><td colspan="5">Chip Manufacturer Assigned</td><td>Manful.</td><td>FBA</td><td>KC</td></tr>
<tr><td colspan="5">47 bits</td><td>8 bits</td><td>4 bits</td><td>2 bits</td></tr>
<tr><td colspan="5">MSB LSB</td><td>M L</td><td>M L</td><td>M L</td></tr>
</table>

The Tag Serial Number shall be programmed and locked at the factory with a unique number for each tag.

A.2.2.1 Check sum (bits 0, 1)

It represents the truncated sum of the bits set to 1 for 62 bits preceding the check sum in the Tag Serial Number field. Valid values are 0, 1, 2, & 3.

A.2.2.2 Fab code (bits 2 – 5)

This four bit hexadecimal code is available to provide further segregation within a registered Manufacturer Code to accommodate multiple chip fabs. It is the responsibility of the registered manufacturer to administer this code (if used) in conjunction with the Serial Number (bits 14 – 63) field to ensure that all tags produced by the manufacturer will have a unique and unambiguous number (used by the collision arbitration algorithm).

A.2.2.3 Manufacturer code (bits 6 – 13)

This is an 8-bit hexadecimal field that has been included to meet anticipated ANSI/ISO standard requirements. This 8-bit hexadecimal field is required to segregate multiple producers of chips compliant with this air interface International Standard. All manufacturers will have a separate and unique number allowing them to produce chips with collision arbitration numbers that do not interfere through duplication.

Registration and management of this code shall be in accordance with the specified mechanism defined by ISO/IEC JTC 1/SC 31.

A.2.2.4 Chip manufacturer assigned (bits 14 – 63)

This is a 50-bit field that is defined and managed by the chip manufacturer. Different chip manufacturers will have different manufacturer codes (see below), thus eliminating the potential for duplicated collision arbitration data (Tag UID's). The numbering system employed by the chip manufacturer must ensure that all tags produced will have a unique and unambiguous number (used by the collision arbitration algorithm). This unique number will be "locked" prior to use. Maximum value for this field is $2^{50} - 1$.

Responsibility for ensuring uniqueness and for locking this unique number prior to use shall rest with the chip manufacturer.

A.3 Manufacturer ID and tag hardware

These bytes may be used for group select functions and/or warranty purposes. All these bytes are programmed and locked at the factory.

Table A.4 — Layout of Tag Manufacturer and Tag Hardware Type (Bytes 8-11)

Bytes	Field Name	Valid Range	Format
8, 9	Manufacturer ID	00 – 99, AA – ZZ	ASCII
10, 11	Tag Hardware Type	0000 – FFFF	HEX

Manufacturer ID (Bytes 8,9) – These two bytes have been reserved for encoding the Tag Manufacturer ID to provide some conformance to anticipated RFID standards. These fields shall initially be encoded with the following codes depending on the manufacturer of the tags.

Table A.5 — Manufacturer Codes

Manufacturer	ASCII Representation	Hexadecimal Code
Reserved	"AT"	4154
Reserved	"HT"	4854
Reserved	"AA"	4141
Reserved	"AS"	4153
Reserved	"AN"	414E

Tag Hardware Type (Bytes 10,11) – This is a 2-byte hexadecimal representation of the tag hardware design. This number shall be different for each type of hardware change made to the tag design that affects the function of the tag. This does not include differences in tag packaging, or colour, nor does it include differences in RF operational frequency. This field shall be used to distinguish differences in commands or command structure, block size, and data capacity. It shall also be used to distinguish differences in data protocol or optional features such as audio, or visual indicators.

Check Tags shall be programmed and locked at the factory with an 80xx hexadecimal for the Tag Hardware Type, where "xx" represents a "don't care" for the second byte. This second "don't care" byte shall initially be programmed with "00". An indication of Check Tag status for the tag is also provided in the Embedded Applications Code as described below.

A.4 Tag Memory layout

The Tag Memory Layout is used by an application to determine the format of the subsequent Application (User) Data. Bytes 12 through 17 are programmed to “FF” from the factory unless otherwise specified.

These next two fields may be programmed either at the factory, as a custom field, or by the customer after it is shipped from the factory. The owner of the tag may optionally decide to either lock these fields or keep them unlocked so that the data format may be altered throughout the life of the tag.

Table A.6 — Tag Memory Layout (Bytes 12-17)

Bytes	Field Name	Valid Range	Format
12	Embedded Application Code	00 – FF	Hexadecimal
13 – 17	Tag Memory Map Allocation	0000000000 – FFFFFFFFFF	Hexadecimal

Embedded Application Code (Byte 12) – This is the top-level hierarchy of tag memory layout. This field, in conjunction with the Tag Memory Allocation allows an application to determine the format and content of the user data. This field can be used to represent various formats of the tag data content.

Current hexadecimal assignments of the Embedded Application Code are as follows:

Table A.7 — Embedded Application Codes

Embedded Application Code	Description of Embedded Application Codes
00, FF	Unformatted, programmed to “FF” at manufacturer.
01	Reserved
02	Customer Specific Memory Allocation
03	File Allocation Table (Long Directory) – TBD in future
04	Check Tag
05	RFID Reader Configuration Tag
06	Reserved for future use
07	Reserved for Engineering Development
08	Reserved for future use
09	Reserved for future use
0A	ISO/IEC 15962 Compliant Data Format
0B	ANSI MH10.8.4 Compliant Data Format
0C – 0E	Reserved for future used
0F	UCC.EAN GTAG Compliant Data Format
0C – FE	To be allocated and registered by to application based needs.

Tag Memory Allocation Map (Bytes 13-17) – This field is based on a structured hierarchy that allows for an application to determine the format and content of the user data in conjunction with the Embedded Application Code in byte 12 defined above.

A.4.1 Embedded application code “01” - reserved

All other Tag Memory Allocation Map combinations for Embedded Applications Code “01” are currently considered undefined. These remaining characters may be used to further specify functions and/or applications that have been appended to the primary application.

A.4.2 Embedded application code “02” -customer specific memory allocation

Customer specific data and file allocation tables are not detailed in this specification. However, it is envisioned that customers must register a Customer Specific Memory Allocation Code (CSMAC) with the manufacturer’s marketing and obtain a configuration string to write their two byte CSMAC value as well as an embedded application code of “02” in tag memory location byte 12.

The following table provides a template for the listing of specific tag memory allocation fields for Customer Specific Tag Memory applications. already being used by customers. It should be noted that this table is not inclusive of all customer specific memory allocations, nor does it necessarily represent all the codes registered with marketing. It is recommended that the manufacturer’s Marketing department be contacted for obtaining a current listing and registering any additional codes.

Table A.8 — Customer Specific Memory Allocation Codes Bytes 13 & 14

Hexadecimal Code	ASCII Representation	Customer/Description

Other Customer Specific Tag Memory applications that may be added in the future include (but are not limited to):

- Theft Detection and Deterrence
- Emergency Warning Systems

A.4.3 Embedded application code “03” - file allocation table (Long Directory)

The Tag Memory Allocation for Embedded Applications Code “03”, File Allocation Table, has not yet been defined, and is only a placeholder at current. This format shall allow a user to view the tag memory similar to that of a floppy drive on a computer.

A.4.4 Embedded Application Code “04” - Check tag

The Check Tag architecture is made available so the interrogator may selectively read the check tag to verify the type of antenna attached and determines duty cycle and/or output power. This check tag function may also be used for providing end-to-end system diagnostic operational verification. These bytes are programmed and locked at the factory.

A.4.5 Embedded Application Code “05” - RFID reader configuration tag

The Tag Memory Allocation for Embedded Applications Code “05”, RFID Reader Configuration Tag, has been reserved to indicate a tag used for configuring a interrogator by means of a special diagnostic configuration mode. This tag can be used for setting various configuration parameters in an interrogator or group of interrogators simply by reading the tag in the configuration mode. Format of this data is to be defined by the interrogator specification or may be added in a future version of this document as an appendix.

A.4.6 Embedded application codes “06 through 09”

Reserved for future use.

A.4.7 Embedded applications code “0A” – ISO/IEC 15962 compliant data format

The Tag Memory Allocation for Embedded Applications Code “0C”, ISO/IEC 15962 Compliant Data Format, has been reserved to indicate a tag used in a fashion as defined by this part of ISO/IEC 18000.

A.4.8 Embedded application codes “0B” – ANSI MH10.8.4 compliant data format

The Tag Memory Allocation for Embedded Applications Code “0B”, ANSI MH10.8.4 Compliant Data Format, has been reserved to indicate a tag used in a fashion as defined by this application standard.

A.4.9 Embedded application codes “0C through 0E”

Reserved for future use.

A.4.10 Embedded application codes “0F” – EAN.UCC GTAG compliant data format

The Tag Memory Allocation for Embedded Applications Code “0F”, EAN.UCC GTAG Compliant Data Format, has been reserved to indicate a tag used in a fashion as defined by this application standard.

A.4.11 Embedded application codes “10 through FF”

Reserved for future use.

A.5 Application (USER) memory

Byte locations (depending on block size) 18 (12 hex) and above are designated for application (User) memory. The data format and contents are defined by the application/user.

Annex B
(informative)

Mode 1: CRC

B.1 Interrogator to tag and tag to interrogator CRC-16

The polynomial used to calculate the CRC-16 is $X^{16}+X^{12}+X^5+1$, which is the CRC-CCITT standard. The Cyclic Redundancy Check (CRC) is calculated on all data contained in a message, from the start of the command through to the end of data. This CRC is used from interrogator to tag and from tag to interrogator.

Table B.1 — CRC Definition

CRC Definition					
CRC type	**Length**	**Polynomial**	**Direction**	**Preset**	**Residue**
CRC-CCITT	16 bits	$X^{16} + X^{12} + X^5 + 1$	Forward	'FFFF'	'0'

The CRC algorithm is as follows:

For computing the CRC

initialize the CRC accumulator to all ones - FFFFh

accumulate, MSB first, data using the polynomial $X^{16} + X^{12} + X^5 + 1$

invert the resulting CRC value

attach the inverted CRC-16 to the end of the packet and transmit it MSB first

For checking the CRC:

compute the CRC on the incoming packet

invert the received CRC data bits

accumulate the “inverted CRC bits” in the CRC registers

verify that the accumulator is all zeroes

Example B.1 – Example C code to generate the CRC bits for the Type B success command.

```
unsigned int Calc_CRC (unsigned int CRCacc, unsigned int cword)

{

/*  Routine to calculate CRC for 1 byte (lower 8 bits of cword) */

/*  Initially, CRCacc should have been set to 0xffff */

int i;
```

```
unsigned int xorval;
printf("\n");
for (i=0; i<8; i++)
    {
    xorval = ((CRCacc>>8) ^ (cword << i)) & 0x0080;
    CRCacc = (CRCacc << 1) & 0xfffe;
    if (xorval)
        CRCacc ^= 0x1021;
    printf("%04x\n",CRCacc);
    }
return (CRCacc);
}
main()
{
unsigned int CRCacc = 0xffff;
int i;
unsigned char test_str[2];
test_str[0] = 0x09; /* Success Command */
test_str[1] = '\0';
for (i =0; i < strlen(test_str); i++)
        CRCacc = Calc_CRC(CRCacc, test_str[i]);
printf("\nCRC = %04x\n",CRCacc);
}
```

B.2 CRC calculation examples

This example refers to a Type B interrogator sending a SUCCESS command.

Command code. ‘09’

The packet sent from the interrogator to the tag consists of the following blocks, but only the SUCCESS command (09h), shown shaded, is used in the CRC calculation.

Table B.2 — CRC on forward link

Preamble detect 2 bytes field high	Preamble nine Manchester 0's	Start delimiter 11 00 11 10 10	SUCCESS command '09'	CRC-16

The CRC is calculated on the SUCCESS command as the field is transmitted MSB.

The following example shows the values of the 16 CRC registers as the data is shifted through the CRC registers.

SUCCESS command 0 0 0 0 1 0 0 1 ('09')

Table B.3 — Practical example of CRC calculation for a 'SUCCESS' command in the Interrogator

Step	Input (SUCCESS command)	Calculated CRC in interrogator
1	0	'EFDF'
2	0	'CF9F'
3	0	'8F1F'
4	0	'0E1F'
5	1	'0C1F'
6	0	'183E'
7	0	'307C'
8	1	'70D9'

Table B.4 — Practical example of CRC checking for a 'SUCCESS' command in the tag

Step	Input (Sent CRC-16)	Calculated CRC in tag
0		'70D9'
1	0	'E1B2'
2	1	'C364'
3	1	'86C8'
4	1	'0D90'
5	0	'1B20'
6	0	'3640'
7	0	'6C80'
8	0	'D900'
9	1	'B200'
10	1	'6400'
11	0	'C800'
12	1	'9000'
13	1	'2000'
14	0	'4000'
15	0	'8000'
16	1	'0000'

NOTE The CRC bits transmitted by the interrogator are inverted, '8F26', MSB first. The tag then inverts the received data bits and accumulates those 16 bits (i.e. '70D9').

Table B.5 — Practical example of CRC checking for a 'SUCCESS' command in the tag, without inversion of the received CRC bits, i.e. the received CRC bits ('8F26') are used

Step	Input (Sent CRC-16)	Calculated CRC in tag
0		'70D9'
1	1	'F193'
2	0	'F307'
3	0	'F62F'
4	0	'FC7F'
5	1	'F8FE'
6	1	'F1FC'
7	1	'E3F8'
8	1	'C7F0'
9	0	'9FC1'
10	0	'2FA3'
11	1	'4F67'
12	0	'9ECE'
13	0	'2DBD'
14	1	'4B5B'
15	1	'8697'
16	0	'1D0F'

Annex C
(normative)

Mode 2: Memory Map

C.1 Tag Memory map

The tag memory layout is part of the MIDx-CH and based on 32 bits according to ISO/IEC 15963 for application with a small number of tags. For the description of the MIDx-CH refer to clause 5.3.4.3.2.

Table C.1 — Tag ID layout

32 bit TagID				
ID31 … ID14 (18 bits)	ID13 ... ID6 (8 bits)	ID5 … ID2 (4 bits)	ID1 ... ID0 (2 bits)	Remarks
$\text{UserTagID}_{\text{reserved}}$		0000	MemoryID	Reserved for existing products
UserTagID	MfrTagID	UserTagID 0001 0010 0011 0100 0101 0110 0111 1000 1001 1010 1011 1100 1101 1110 1111	MemoryID	MfrTagID to be allocated and registered in ISO/IEC 7816-6

$\textit{UserTagID}_{\textit{reserved}}$: the ID31...ID6 range is used for authorisations.

UserTagID: the ID31...ID14 and ID5…ID2 range is used for authorisations. 0hex for ID5…ID2 is reserved for existing products and is allocated to:

SIEMENS AG
A&D SE PS3
P.O.Box 2355
D-90713 Fürth, Germany
Tel : +49-911 750-0
Fax : +49-911 750-2695

However an interrogator shall be capable to work with tags of both types of *TagIDs.*

NOTE *UserTagID* and $\textit{UserTagID}_{\textit{reserved}}$ are consecutive unique numbers, which get a fixed assignment during IC or tag manufacturing.

MfrTagID: ID13...ID6 for manufacturer identity.

MemoryID in case of R/W-tags: ID1...ID0 for memory configuration.

Table C.2 — MemoryID in case of R/W tags

ID1	ID0	Memory
0	0	min. 2kx8
0	1	min. 32kx8
1	0	min. 128kx8
1	1	min. 256kx8

MemoryID in case of R/O-tags for MID1 and MID2: ID1...ID0 for memory configuration.

Table C.3 — MemoryID in case of R/O tags

ID1	ID0	Memory
0	0	No further MID-CH and no proprietary return link channel (no MID-CH, no RFU-CH)
0	1	No further MID-CH bits but a proprietary return link channel (no MID-CH, only RFU-CH)
1	0	Further MID-CH but no proprietary return link channel (only MID-CH, no RFU-CH)
1	1	Further MID-CH and proprietary return link channel (MID-CH, RFU-CH)

NOTE To ease hardware implementation MID3 and MID4 is helpful if S-CH is assigned only in slot0.

MemoryID in case of R/O-tags for MID3 and MID4: ID1...ID0 for memory configuration.

Table C.4 — MemoryID in case of R/O tags for MID3 and MID4

ID1	ID0	Memory
0	0	No further data bits and no proprietary return link channel (no MIN-CH, no RFU-CH)
0	1	No further data bits but a proprietary return link channel (no MIN-CH, only RFU-CH)
1	0	Further data bits but no proprietary return link channel (only MIN-CH, no RFU-CH)
1	1	Further data bits and proprietary return link channel (MIN-CH, RFU-CH)

C.2 Tag Serial number – *UserTagID*

The *UserTagID* shall be programmed and locked at the factory with a unique number for each type of tag (3 types: 1 R/W-tag, 2 types of R/O-tags). The identification of the tag type shall be done by the interrogator during S-CH, for the description refer to 5.3.4.3.1.

C.3 Tag manufacturer's identifiers – *MfrTagID*

C.3.1 Allocation and registration of Tag manufacturer's identifier

MfrTagID (ID13…ID6) – These 8 bits have been reserved for encoding the IC Manufacturer ID to provide a unique numbering system worldwide. Therefore ID13…ID6 shall be programmed and locked at IC initialising by the IC or Tag manufacturer.

The MfrTagID shall be allocated and registered according to ISO/IEC 7816-6.

Annex D
(informative)

Mode 2: CRC

D.1 Cyclic redundancy check (CRC)

Data to and from the tag is checked for errors using a Cyclic Redundancy Code (CRC). The length of CRC and the used polynomial to build CRC depend on the type of logical channel.

Table D.1 — CRC Definitions

Logical channel	Number of net bits	CRC Definition		
		Length	Polynomial	Direction
MID-CH	32	22	$x^{22}+x^{17}+x^{13}+x^9+x^4+1$ = 0x221110	return link
MIN-CH	32	22	$x^{22}+x^{17}+x^{13}+x^9+x^4+1$ = 0x221110	return link
SID-CH	25	15	$x^{15}+x^{10}+x^9+x^6+x+1$ = 0x6130	forward link
R-CH	48	44	$x^{44}+x^{30}+x^{29}+x^{15}+x+1$ = 0xC0010006000	return link
W-CH	128	44	$x^{44}+x^{30}+x^{29}+x^{15}+x+1$ = 0xC0010006000	forward link
CS-CH	30	44	$x^{44}+x^{30}+x^{29}+x^{15}+x+1$ = 0xC0010006000	forward link

D.2 CRC calculation example

This example in C language illustrates one method of building the CRC for W-CH channel.

```
/*-----------------------------------------------------------------------------------------------------------*/

/*  Fire Encoder                                                   */

/*  (n,k) = (172,128)                                              */

/*  n = 172:   Number of Codeword Bits                             */

/*  k = 128:   Number of Info Bits to use for CRC Calculation      */

/*  n-k = 44:  Number of CRC- Bits                                 */

/*-----------------------------------------------------------------------------------------------------------*/

#define poly 0xc0010006000;   /* polynomial =  x44+x30+x29+x15+x+1  */

void main()

{

short *r0, buffer127[127];

__int64 akkum;
```

```
int i;

r0 = buffer127;           /*buffer with info bits*/

akkum=0;           /*shift register with 44 places*/

for (i=128-1;i>=0;i--)    /* 128 Info-Bits */

{

    if((*r0!=0 && (akkum&0x01)==0) || (*r0==0 && (akkum&0x01)!=0))

{

        akkum >>= 1;       /* shift right */

        akkum ^= poly      /* polynomial*/

        }

    else

        {

        akkum>>=1;         /* shift right */

        }

    r0++;

}

}

/* In the end, the CRC-bits shall be in the shift register  */
```

As an example for the SID-CH following calculated values can be found:

1) Interrogator ID=0x333; Counter Value=0x475e; CRC=0x30e3

2) Interrogator ID=0x123; Counter Value=0x4567; CRC=0x1c7a

3) Interrogator ID=0x3ff; Counter Value=0x7fff; CRC=0x73f6

Examples for public informative literature on Fire Codes are:

Shu Lin, Daniel J. Costello: "Error Control Coding: Fundamentals and Applications", Prentice Hall, 1983, ISBN: 0-13-283796-X

R. Blahut: "Theory and Practice of Error Control Codes", Addison-Wesley, 1984, ISBN: 0-201-10102-5

Bibliography

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

[2] ETSI EN 300 440-1 Electromagnetic compatibility and Radio spectrum Matters (ERM); Short range devices; Radio equipment to be used in the 1 GHz to 40 GHz frequency range; Part 1: Technical characteristics and test methods

[3] ETSI EN 300 440-2 Electromagnetic compatibility and Radio spectrum Matters (ERM); Short range devices; Radio equipment to be used in the 1 GHz to 40 GHz frequency range; Part 2: Harmonized EN under article 3.2 of the R&TTE Directive

[4] CEPT/ERC Recommendation 70-03: "Relating to the use of Short Range Devices (SRD)", Annex 11

[5] US Code of Federal Regulations (CFR) Title 47, Chapter I, Part 15. “Radio Frequency Devices”; U.S. Federal Communications Commission

[6] RCR STD-1 “RFID Equipment For Premises Radio Station”

[7] RCR STD-29 “RFID Equipment For Specified Low Power Radio Station”

[8] ARIB STD-T81 “RFID Equipment Using Frequency Hopping System For Specified Low Power Radio Station”

[9] ANS MH10.8.4, *American National Standard for Material Handling — Unit Loads and Transport Packages — RFID Tags for Returnable Containers*

ICS 35.040
Price based on 98 pages