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Information technology — Radio frequency identification for item management

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

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National foreword

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

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

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

*Partie 6: Paramètres de communications d'une interface d'air entre
860 MHz et 960 MHz*



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Foreword

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

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

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

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

ISO/IEC 18000-6 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 31, *Automatic identification and data capture techniques*.

This second edition cancels and replaces the first edition (ISO/IEC 18000-6:2004), which has been technically revised. It also incorporates the Amendment ISO/IEC 18000-6:2004/Amd.1:2006.

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 describes a passive backscatter radio frequency identification (RFID) system that supports the following system capabilities:

- identification and communication with multiple tags in the field;
- selection of a subgroup of tags for identification or with which to communicate;
- reading from and writing to or rewriting data many times to individual tags;
- user-controlled permanently lockable memory;
- data integrity protection;
- Interrogator-to-tag communications link with error detection;
- tag-to-Interrogator communications link with error detection;
- support for both passive back-scatter tags with or without batteries.

This part of ISO/IEC 18000 specifies the physical and logical requirements for a passive-backscatter, RFID system operating in the 860 MHz to 960 MHz frequency range. The system comprises Interrogators, also known as readers, and tags, also known as labels.

An Interrogator transmits information to a tag by modulating an RF signal in the 860 MHz to 960 MHz frequency range. The tag receives both information and operating energy from this RF signal. Passive tags are those which receive all of their operating energy from the Interrogator's RF waveform. If tags maintain a battery then they may operate using some passive principles; however, they do not necessarily get all their operating energy from the Interrogator's RF waveform.

An Interrogator receives information from a tag by transmitting a continuous-wave (CW) RF signal to the tag; the tag responds by modulating the reflection coefficient of its antenna, thereby backscattering an information signal to the Interrogator. The system is Interrogator-Talks-First (ITF) for Types A, B and C, meaning that a tag modulates its antenna reflection coefficient with an information signal only after being directed to do so by an Interrogator.

Interrogators and tags are not required to talk simultaneously; rather, communications are half-duplex, meaning that Interrogators talk and tags listen, or vice versa.

This part of ISO/IEC 18000 further contains an optional "tag only talks after listening" Type D, an enhanced Tag Talks Only (TTO) technique. Type D uses Pulse-Position Encoding (PPE) or Miller encoding in the return link and does not define a dedicated forward link. In fact, tags may implement one of the types defined in this part of ISO/IEC 18000 (A, B, or C) besides Type D in order to allow enhanced tag access techniques.

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.

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Information technology — Radio frequency identification for item management —

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

1 Scope

This part of ISO/IEC 18000 defines the air interface for radio frequency identification (RFID) devices operating in the 860 MHz to 960 MHz Industrial, Scientific, and Medical (ISM) band used in item management applications. It provides a common technical specification for RFID devices that can be used by ISO committees developing RFID application standards. This part of ISO/IEC 18000 is intended to allow for compatibility and to encourage inter-operability of products for the growing RFID market in the international marketplace. It defines the forward and return link parameters for technical attributes including, but not limited to, operating frequency, operating channel accuracy, occupied channel bandwidth, maximum effective isotropic radiated power (EIRP), spurious emissions, modulation, duty cycle, data coding, bit rate, bit rate accuracy, bit transmission order, and, where appropriate, operating channels, frequency hop rate, hop sequence, spreading sequence, and chip rate. It further defines the communications protocol used in the air interface.

This part of ISO/IEC 18000 specifies the physical and logical requirements for a passive-backscatter, Interrogator-Talks-First (ITF) or tag-talks-only-after-listening (TOTAL) RFID system. The system comprises Interrogators, and tags, also known as labels. An Interrogator receives information from a tag by transmitting a continuous-wave (CW) RF signal to the tag; the tag responds by modulating the reflection coefficient of its antenna, thereby backscattering an information signal to the Interrogator. The system is ITF, meaning that a tag modulates its antenna reflection coefficient with an information signal only after being directed to do so by an Interrogator, or TOTAL, meaning that a tag modulates its antenna reflection coefficient with an information signal upon entering an Interrogator's field after first listening for Interrogator modulation in order to determine if the system is ITF or not.

In detail, this part of ISO/IEC 18000 contains one mode with four types. The detailed technical differences between the four types are shown in the associated parameter tables.

Types A, B and C are ITF. Type A uses Pulse-Interval Encoding (PIE) in the forward link and an adaptive ALOHA collision-arbitration algorithm. Type B uses Manchester in the forward link and an adaptive binary-tree collision-arbitration algorithm. Type C uses PIE in the forward link and a random slotted collision-arbitration algorithm.

Type D is TOTAL based on Pulse Position Encoding or Miller M=2 encoded subcarrier.

This part of ISO/IEC 18000 specifies

- physical interactions (the signalling layer of the communication link) between Interrogators and tags,
- Interrogator and tag operating procedures and commands,
- the collision arbitration scheme used to identify a specific tag in a multiple-tag environment.

2 Conformance

2.1 Claiming conformance

To claim conformance with this part of ISO/IEC 18000, an Interrogator or tag shall comply with all relevant clauses of this part of ISO/IEC 18000, except those marked as "optional". The Interrogator or tag shall also operate within local radio regulations, which can further restrict operation.

Relevant conformance test methods are provided in ISO/IEC TR 18047-6.

Conformance can also require a license from the owner of any intellectual property utilized by said device.

2.2 Interrogator conformance and obligations

To conform to this part of ISO/IEC 18000, an Interrogator shall

- support at least one Type of A, B, C or D – it can optionally support two, three or all four;
- implement the mandatory commands defined in this part of ISO/IEC 18000;
- modulate/transmit and receive/demodulate a sufficient set of the electrical signals defined in the signalling layer of this part of ISO/IEC 18000 to communicate with conformant tags; and
- operate within the applicable local regulations.

To conform to this part of ISO/IEC 18000, an Interrogator may

- implement any subset of the optional commands defined in this part of ISO/IEC 18000, and
- implement any proprietary and/or custom commands in conformance with this part of ISO/IEC 18000.

To conform to this part of ISO/IEC 18000, the Interrogator shall not

- implement any command that conflicts with this part of ISO/IEC 18000, or
- require the use of an optional, proprietary, or custom command to meet the requirements of this part of ISO/IEC 18000.

2.3 Tag conformance and obligations

To conform to this part of ISO/IEC 18000, a tag shall:

- support at least one Type of A, B, C or D;
- operate over the frequency range from 860 MHz to 960 MHz, inclusive;
- implement the mandatory commands defined in this part of ISO/IEC 18000 for the supported types;
- modulate a backscatter signal only after receiving the requisite command from an Interrogator or, in the case of Type D, only after listening for the absence of ITF modulation; and
- conform to local radio regulations.

To conform to this part of ISO/IEC 18000, a tag may

- implement any subset of the optional commands defined in this part of ISO/IEC 18000; and

- implement any proprietary and/or custom commands as defined in Clauses 7, 8 and 9.

To conform to this part of ISO/IEC 18000, a tag shall not:

- implement any command that conflicts with this part of ISO/IEC 18000;
- require the use of an optional, proprietary, or custom command to meet the requirements of this part of ISO/IEC 18000; or
- modulate a backscatter signal unless commanded to do so by an Interrogator using the signalling layer defined in this part of ISO/IEC 18000 or, in the case of Type D, before listening for the absence of ITF modulation.

3 Normative references

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

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

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

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

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

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

EPCglobal Tag Data Standards version 1.3 and above, EPCglobal Inc.

4 Terms, definitions, symbols and abbreviated terms

4.1 Terms and definitions

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

4.1.1

battery saver mode

battery saving functionality based on low power threshold detection with optional duty cycling

4.1.2

collision arbitration loop

algorithm used to prepare for and handle a dialogue between an Interrogator and a tag

NOTE This is also known as collision arbitration.

4.1.3

cover-coding

method by which an Interrogator obscures information that it is transmitting to a tag by requesting a random number from the tag, then performing a bit-wise EXOR of the data or password with the received random number, and, finally, transmitting the cover-coded (also called ciphertext) string to the tag, which uncovers the data or password by performing a bit-wise EXOR of the received cover-coded string with the original random number

4.1.4

Dense-Interrogator environment

operating environment within which most or all of the available channels are occupied by active Interrogators

EXAMPLE 25 active Interrogators operating in 25 available channels.

4.1.5

EPCglobal Application

application whose MB01 data structure includes a "0" bit in bit 17h and denotes an acceptance of EPCglobal standards and policies

ISO Application (4.1.6)

4.1.6

ISO Application

application whose MB01 data structure includes a "1" bit in bit 17h and where bits 18h through 1Fh encode an application family identifier as defined in ISO/IEC 15961-3

EPCglobal Application (4.1.5)

4.1.7

physical layer

data coding and modulation waveforms used in Interrogator-to-tag and tag-to-Interrogator signalling

4.1.8

slotted random anticollision

collision-arbitration algorithm where tags load a random (or pseudo-random) number into a slot counter, decrement this slot counter based on Interrogator commands, and reply to the Interrogator when their slot counter reaches zero

4.1.9

Activation

waking up a tag from the **hibernate** (4.1.19) state

4.1.10

battery assistance

battery support for radio frequency communication

4.1.11

battery assisted mode

working mode of battery-assisted tags with non-empty battery

4.1.12

Full Function Sensors

sensors that can be user configurable and reset, can produce a detailed set of sensor measurement observations, and can be connected to the RFID tag in a variety of ways

4.1.13

passive mode

working mode of passive tags or battery-assisted tags with battery drained below a manufacturer-specific threshold

4.1.14

PacketCRC

16-bit cyclic-redundancy check (CRC) code that a tag may dynamically calculate over its PC, optional XPC, and Ull and backscatter during inventory

StoredCRC (4.1.17)

4.1.15

Simple Sensors

sensors that are factory programmed and not user configurable, producing a single output observation such as a fail/pass condition or simple measurement of a particular sensor activity

4.1.16

Simple Sensor functionality

functionality whereby sensors provide a valid Simple Sensor data address and transmit Simple Sensor data subsequent to the Ull as part of the reply to the ACK command (Type C) or as part of the TagMsg (Type D)

4.1.17

StoredCRC

16-bit cyclic-redundancy check (CRC) code that a tag calculates over its StoredPC and Ull and stores in Ull memory at powerup, and can backscatter during inventory

PacketCRC (4.1.14)

4.1.18

recommissioning

significant altering of a tag's functionality and/or memory contents, as commanded by an Interrogator, typically in response to a change in the tag's usage model or purpose

4.1.19

hibernate

state of energy saving when the device is not required to be used

4.1.20

PacketPC

protocol-control information that a tag with nonzero-valued XI dynamically calculates and backscatters during inventory

StoredPC (4.1.21)

4.1.21

StoredPC

protocol-control information stored in Ull memory that a tag with zero-valued XI backscatters during inventory

PacketPC (4.1.20)

4.1.22

tag energized

tag in the **ready**, **arbitrate**, **reply**, **acknowledged**, **open**, or **secured** state

4.1.23

tag not energized

tag not in the **ready**, **arbitrate**, **reply**, **acknowledged**, **open**, or **secured** state

4.2 Symbols

BAP	battery-assisted passive
BLF	backscatter-link frequency ($BLF = 1/T_{pri} = DR/TR_{cal}$)
Cht	carrier high-level tolerance
Clf	carrier low-level tolerance
D	modulation depth of data coding pulse
DR	divide ratio
f_c	frequency of operating field (carrier frequency)
FDM	frequency-division multiplexing
FT	frequency tolerance
INACT_T	inactivity threshold
M	number of subcarrier cycles per symbol
Mi	modulation index
Ma	modulation upper tolerance Type A
Mb	modulation lower tolerance Type B
M_h	RF signal envelope ripple (overshoot)
M_{hh}	FHSS signal envelope ripple (overshoot)
M_{hl}	FHSS signal envelope ripple (undershoot)
M_{hs}	FHSS signal level during a hop
M_l	RF signal envelope ripple (undershoot)
M_s	RF signal level when OFF
Q	slot-count parameter. Q is an integer in the range (0,15)
R=>T	Interrogator-to-tag (reader-to-tag)
RTcal	Interrogator-to-tag (reader-to-tag) calibration symbol
T=>R	tag-to-Interrogator (tag-to-reader)
T_1	time from Interrogator transmission to tag response
T_2	time from tag response to Interrogator transmission
T_3	time an Interrogator waits, after T_1 , before it issues another command
T_4	minimum time between Interrogator commands
T_f or $T_{f,10-90\%}$	RF signal envelope fall time
T_{hf}	FHSS signal envelope fall time

T_{hr}	FHSS signal envelope rise time
T_{hs}	time for an FHSS signal to settle to within a specified percentage of its final value
T_{pri}	backscatter-link pulse-repetition interval ($T_{pri} = 1/BLF = TRcal/DR$)
T_r or $T_{r,10-90\%}$	RF signal envelope rise time
T_s	time for an RF signal to settle to within a specified percentage of its final value
T_{aq}	quiet time – Type A
T_{apf}	pulse fall time – Type A
T_{apr}	pulse rise time – Type A
T_{apw}	pulse width – Type A
T_{ari}	reference time interval for a data-0 in Interrogator-to-tag signalling
T_{bmf}	Manchester fall time – Type B
T_{bmr}	Manchester rise time – Type B
T_{cf}	carrier fall time
T_{cr}	carrier rise time
T_{cs}	carrier steady state time
T_f	fall time
T_{fhf}	carrier FHSS fall time
T_{fhr}	carrier FHSS rise time
T_{fhs}	carrier FHSS steady time
T_r	rise time
$TRcal$	tag-to-Interrogator (tag-to-reader) calibration symbol
$Trlb$	return link bit time
UII	unique item identifier
x_{fp}	floating-point value
$xxxx_2$	binary notation
$xxxx_h$	hexadecimal notation

4.3 Abbreviated terms

AC	activation code
AFI	application family identifier
AMSK	<u>Activation Mask</u>
ASF	application sub family
ASIC	application specific integrated circuit
BAM	battery-assisted mode

BAT	battery-assisted tag
ciphertext	information that is cover-coded
CRC	cyclic redundancy check
CRC-16	sixteen bit CRC used in Type A, Type B, Type C and Type D commands and responses
CRC-5	five bit CRC used for Interrogator to tag commands, used in Types A and C
CW	continuous wave
dBch	decibels referenced to the integrated power in the reference channel
DBR	dead battery response
DSB	double sideband
DSB-ASK	double-sideband amplitude-shift keying
DSFID	data storage format identifier
DSSS	direct sequence spread spectrum
EOF	end of frame
EPC™	electronic product code
FCC	Federal Communications Commission
FHSS	frequency hopping spread spectrum
Handle	16-bit tag-authentication number
ITF	Interrogator-talks-first
	NOTE The common usage is RTF (Reader-talks-first) but the more precise term is ITF, which is used throughout this part of ISO/IEC 18000.
LSB	least significant bit
MSB	most significant bit
NoS	number of sensors
NRZ	non return to zero
NSI	numbering system identifier
OTP	one-time programmable
PC	protocol control
PIE	pulse interval encoding, used in Type A and Type C
Pivot	decision threshold differentiating an R=>T data-0 symbol from a data-1 symbol
Plaintext	information that is not cover-coded

PM	passive mode
PPE	pulse position encoding
ppm	parts per million
PR-ASK	phase-reversal amplitude shift keying
R/W	read/write
RFU	reserved for future use
RN16	16-bit random or pseudo-random number
RNG	random or pseudo-random number generator
RO	read only
RTC	real time clock
SDS	Sensor Directory System
SOF	start of frame
SS	Simple Sensor
SSB	single sideband
SSB-ASK	single-sideband amplitude-shift keying
SSD	simple sensor data
SUID	sub unique identifier
TCRS	Tag Capabilities Reporting and Setting
TEDS	Transducer Electronic Data Sheet
TEL	tag excitation level
TID	tag-identification or tag identifier, depending on context
TOTAL	tag only talks after listening
TTF	tag-talks-first
TTO	tag talks only
UMI	user-memory indicator
UTC	universal coordinated time
WC	wildcard
Word	16 bits
XI	XPC_W1 indicator
XPC	extended protocol control

XPC_W1	XPC word 1
XPC_W2	XPC word 2
XEB	XPC extension bit110

4.4 Notation

This part of ISO/IEC 18000 uses the following notational conventions for Type C.

- States and flags are denoted in bold. Example: **ready**.
- Commands are denoted in italics. Variables are also denoted in italics. Where there might be confusion between commands and variables, this part of ISO/IEC 18000 will make an explicit statement. Example: *Query*.
- Command parameters are underlined. Example: Pointer.
- For logical negation, labels are preceded by ‘~’. Example: If **flag** is true, then **~flag** is false.
- The symbol, R=>T, refers to commands or signalling from an Interrogator to a tag (reader-to-tag).
- The symbol, T=>R, refers to commands or signalling from a tag to an Interrogator (tag-to-reader).
- The term “address” is used as a synonym for “bit address”. All addresses specified in the Clauses denoted to Type C are bit-addresses, unless specified differently (e.g. by adding an according prefix such as “word” in “word address”). The same applies for figures, where all shown addresses are to be interpreted as bit-addresses, unless specified differently.
- The term “word” always refers to a 16-bit word.

5 Overview

5.1 General

This part of ISO/IEC 18000 specifies four communication types: Type A, Type B, Type C and Type D.

Figure 1, Figure 2, and Figure 3 show the architecture of each of the three Interrogator types. Figure 5, Figure 6, and Figure 7 show the architecture of each of the three tag types.

Table 1 provides an overview of the three communication types showing the protocol blocks from Interrogator input (demodulator) to Interrogator output (modulator) independent of the communication flow.



Figure 1 — Type A Interrogator architecture

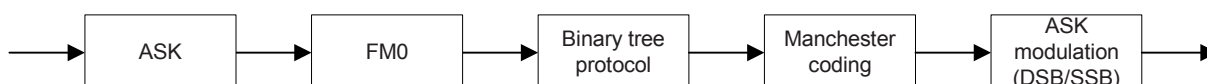


Figure 2 — Type B Interrogator architecture

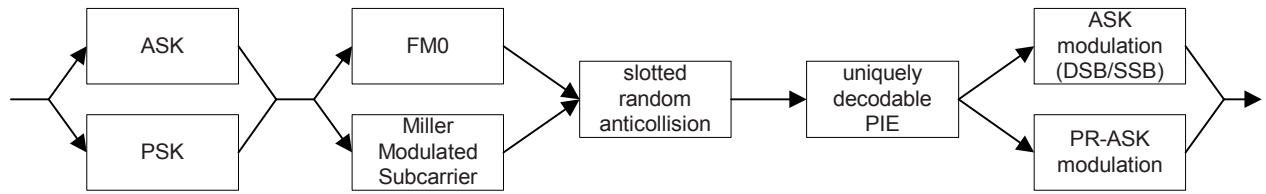


Figure 3 — Type C Interrogator architecture

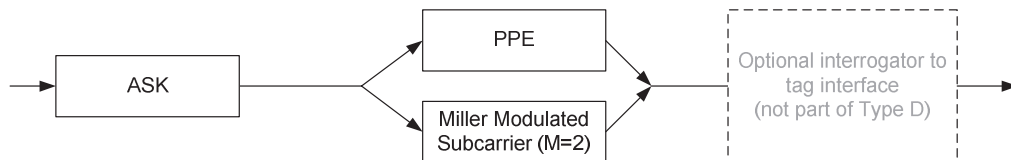


Figure 4 — Type D Interrogator architecture

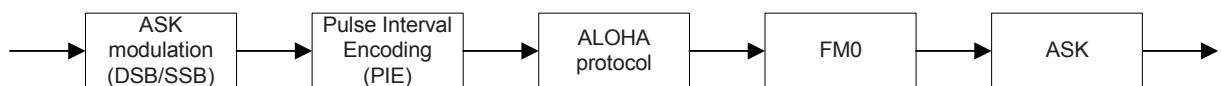


Figure 5 — Type A tag architecture

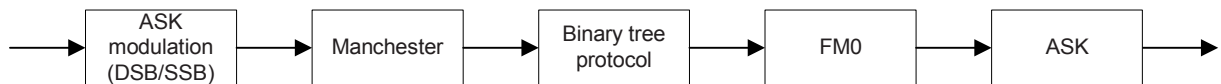


Figure 6 — Type B tag architecture

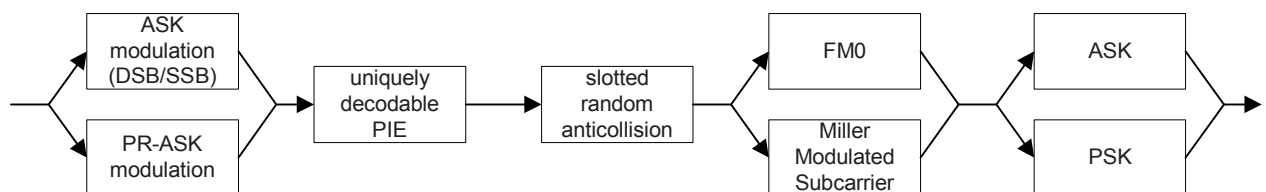


Figure 7 — Type C tag architecture

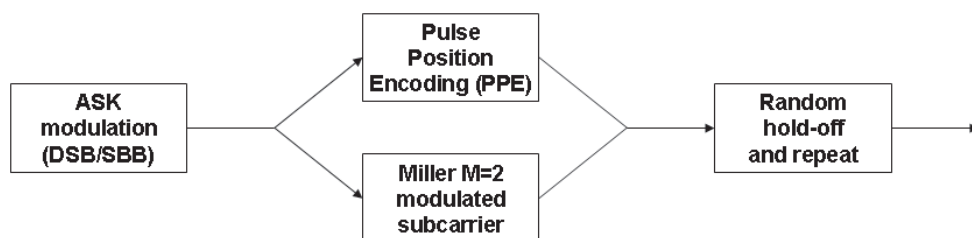


Figure 8 — Type D tag architecture

Table 1 — Overview of Types A, B, C and Type D

Parameter	Type A	Type B	Type C	Type D
Forward link encoding	PIE	Manchester	Uniquely decodeable PIE	Not applicable
Modulation depth	18% to 100%	10% or 100%	82% to 100%	N.A.
Data rate	33 kbit/s (assuming equiprobable data)	10 or 40 kbit/s (according to the local regulations)	26.7 kbit/s to 128 kbit/s (assuming equiprobable data)	N.A.
Return link encoding	FM0	FM0	FM0, Miller subcarrier	PPE, Miller subcarrier
Collision arbitration	ALOHA / FST	Binary Tree	random slotted collision-arbitration	Random hold-off and repeat
Tag unique identifier	64 bits (40 bit SUID)	64 bits	Variable: minimum 32 bits, maximum 192 bits	Variable: minimum 64 bits, maximum 192 bits
Memory addressing	Blocks up to 256 bits	Byte blocks, 1,2,3 or 4 byte writes	Bit, word (16-bit), or vendor-defined block boundaries (depending on command)	An unlimited number of pages of 64 bits each
Error detection, forward link	5-bit CRC for all commands (with an additional 16-bit CRC appended for all long commands)	16-bit CRC	16-bit CRC, 5-bit CRC, and/or unique command length	N.A.
Error detection, return link	16-bit CRC	16-bit CRC	16-bit CRC, except no error check for RN16	16-bit CRC on TID (Page 0) for unstructured data. 16-bit CRC on TID+UII for structured data, 16 bit CRC on structured data itself
Collision arbitration linearity	2048	Up to 2^{256}	Linear up to 2^{15} tags in the Interrogator's RF field; above that number, $N \log(N)$ for tags with unique UIIs	Nearly linear up to 500 tags depending on anti-collision parameter

5.2 Parameter tables

Table 2, Table 3, Table 4 and Table 5 contain the parameters for types A, B, C and Type D in accordance with ISO/IEC 18000-1. Detailed description of the operating modes and parameters are specified in the subsequent clauses.

Table 2 — Interrogator to tag link parameters

Ref.	Parameter Name	Description	Ref Type C
Int:1	Operating Frequency Range	Types A and B: 860 – 960 MHz The Interrogator operating frequency range shall be determined by the radio regulations in force in a particular regulatory jurisdiction and by the type approval requirements of the particular jurisdiction. Before an Interrogator may be used, it shall meet the local radio regulations of the country in which it is to be used. It is envisaged that there will be more than one version of Interrogator having different frequency and power characteristics in order to comply with the local regulations. NOTE Performance will vary according to bandwidth and power output permitted by the local regulations. Type C and Type D: 860 MHz – 960 MHz, as required by the local regulations	See clause 9.3.1.1
Int:1a	Default Operating Frequency	Types A, B and Type D: In accordance with the local radio regulations. See Int: 1 Type C: Determined by local radio regulations and by the radio-frequency environment at the time of the communication	See clause 9.3.1.1
Int:1b	Operating Channels (spread-spectrum systems)	Types A, B and Type D: In accordance with the local radio regulations. See Int: 1 Type C: In accordance with the local regulations; if the channelisation is unregulated, then as specified	See clause 9.3.1.2.10, Annex I
Int:1c	Operating Frequency Accuracy	Types A, B and Type D: In accordance with the local radio regulations See Int: 1 Type C: As specified	See clause 9.3.1.2.1
Int:1d	Frequency Hop Rate (frequency-hopping [FHSS] systems)	Types A and B: Not applicable for single fixed frequency or channelised Adaptive Frequency Agile systems. Where FHSS is permitted, the hop rate shall be in accordance with the local radio regulations. Type C and Type D: In accordance with the local regulations	See clause 9.3.1.2.9
Int:1e	Frequency Hop Sequence (frequency-hopping [FHSS] systems)	Types A and B: In accordance with the local radio regulations. Where not specified by such regulations a pseudo-random hopping sequence shall be used that ensures an even distribution of transmissions over the available channels. Type C and Type D: In accordance with the local regulations	See clause 9.3.1.2.9
Int:2	Occupied Channel Bandwidth	In accordance with the local regulations	

Ref.	Parameter Name	Description	Ref Type C
Int:2a	Minimum Receiver Bandwidth	In accordance with the local regulations	
Int:3	Interrogator Transmit Maximum EIRP	In accordance with the local regulations	
Int:4	Interrogator Transmit Spurious Emissions	Types A, B and Type D: In accordance with the local radio regulations. Type C: As specified; tighter emission limits may be imposed by the local regulations	See clause 9.3.1.2.11
Int:4a	Interrogator Transmit Spurious Emissions, In-Band (spread-spectrum systems)	Types A, B and Type D: In accordance with the local radio regulations. Type C: As specified; tighter emission limits may be imposed by the local regulations	See clause 9.3.1.2.11
Int:4b	Interrogator Transmit Spurious Emissions, Out-of-Band	Types A, B and Type D: In accordance with the local radio regulations. Type C: As specified; tighter emission limits may be imposed by the local regulations	See clause 9.3.1.2.11
Int:5	Interrogator Transmitter Spectrum Mask	Types A and B and Type D: As per Int: 2 and Int: 4a. Type C and Type D: As specified; tighter emission limits may be imposed by the local regulations	Figure 40, Figure 41
Int:6	Timing	Types A and B: See below Int: 6x. Type C: As specified Type D: Not applicable.	See clause 9.3.1.6, Figure 50, Table 193
Int:6a	Transmit-to-Receive Turn-Around Time	Types A and B: The Interrogator transmit/receive settling time shall not exceed 85 μ s. Type C: MAX(RT _{cal} , 10T _{pri}) nominal Type D: Not applicable.	See clause 9.3.1.6, Figure 50, Table 193
Int:6b	Receive-to-Transmit Turn-Around Time	Types A and B: As determined by the communication protocol – refer Tag: 6a. Type C: 3T _{pri} minimum; 20T _{pri} maximum when tag is in reply & acknowledged states; no limit otherwise Type D: Not applicable.	See clause 9.3.1.6, Figure 50, Table 193
Int:6c	Dwell Time or Interrogator Transmit Power-On Ramp	1500 μ s, maximum settling time	See clause 9.3.1.2.6, Figure 37, Table 186
Int:6d	Decay Time or Interrogator Transmit Power-Down Ramp	Types A and B: Maximum 1 ms. Type C: 500 μ s, maximum Type D: Not applicable.	Figure 37, Table 187
Int:7	Modulation	Types A and B: Amplitude Modulation. Type C: DSB-ASK, SSB-ASK, or PR-ASK Type D: Not applicable.	See clause 9.3.1.2.2
Int:7a	Spreading Sequence (direct-sequence [DSSS] systems)	Not applicable.	

Ref.	Parameter Name	Description	Ref Type C
Int:7b	Chip Rate (spread-spectrum systems)	Not applicable.	
Int:7c	Chip Rate Accuracy (spread-spectrum systems)	Not applicable.	
Int:7d	Modulation Depth	Type A: Nominal 30 % to 100 %. See Table 11 and clause 7.1.1. Type B: Nominal 18% or 100% . Type C: 90% nominal Type D: Not applicable.	See clause 9.3.1.2.5, Figure 36, Table 185
Int:7e	Duty Cycle	Types A, B and Type D: In accordance with the local regulations. Type C: 48% – 82.3% (time the waveform is high)	See clause 9.3.1.2.3, Figure 35, Table 185
Int:7f	FM Deviation	Not applicable.	
Int:8	Data Coding	Type A: Pulse Interval Encoding Type B: Manchester bi-phase Type C: PIE Type D: Not applicable.	See clause 9.3.1.2.3, Figure 35
Int:9	Bit Rate	Type A: 33 kbit/s as constrained by the local radio regulations Type B: 10 kbit/s or 40 kbit/s as constrained by the local radio regulations. Type C: 26.7 kbit/s to 128 kbit/s (assuming equiprobable data) Type D: Not applicable.	See clause 9.3.1.2.4
Int:9a	Bit Rate Accuracy	Types A and B: 100 ppm Type C: +/- 1%, minimum Type D: Not applicable.	See clause 9.3.1.2.4
Int:10	Interrogator Transmit Modulation Accuracy	Types A and B: Not applicable. Type C: As specified Type D: Not applicable.	See clause 9.3.1.2.4
Int:11	Preamble	Type A: has no preamble Type B: See clause 8.1.4.3 Type C: Required Type D: Not applicable.	See clause 9.3.1.2.8
Int:11a	Preamble Length	Type A: not applicable. Type B: 9 bits. See clause 8.1.4.3. Type C: As specified Type D: Not applicable.	See clause 9.3.1.2.8
Int:11b	Preamble Waveform(s)	Type A: not applicable . Type B: See clause 8.1.4.3. Type C: As specified Type D: Not applicable.	See Figure 38
Int:11c	Bit Sync Sequence	Type A: not applicable. Type B: see clause 8.1.4.3 Type C: None Type D: Not applicable.	

Ref.	Parameter Name	Description	Ref Type C
Int:11d	Frame Sync Sequence	Types A and B: Not applicable. Type C: Required Type D: Not applicable.	See clause 9.3.1.2.8, Figure 38
Int:12	Scrambling (spread-spectrum systems)	Not Applicable.	
Int:13	Bit Transmission Order	MSB is transmitted first Type D: Not applicable.	See clause 9.3.1.4
Int:14	Wake-up process	Types A and B: Presence of an appropriate RF signal at the tag followed by a wake-up command as required by the tag type. See relevant clauses. Type C: As specified Type D: Not applicable.	See clause 9.3.1.2
Int:15	Polarization	Types A and B: Interrogator dependent. Not defined in this part of ISO/IEC 18000. Type C: Not specified Type D: Not applicable.	

Table 3 — Tag to Interrogator link parameters

Ref.	Parameter Name	Description	Ref Type C
Tag:1	Operating Frequency Range	860 MHz – 960 MHz, inclusive	See clause 9.3.1.1
Tag:1a	Default Operating Frequency	Types A, B and Type D: The tag shall respond to an Interrogator signal within the frequency range specified in Tag: 1. Type C: Tags respond to Interrogator signals that satisfy Int:1a	See clause 9.3.1.1
Tag:1b	Operating Channels (spread-spectrum systems)	Types A, B and Type D: The tag shall respond to an Interrogator signal within the frequency range specified in Tag: 1. Type C: Tags respond to Interrogator signals that satisfy Int:1b	See clause 9.3.1.2.10
Tag:1c	Operating Frequency Accuracy	Types A, B and Type D: The tag shall respond to an Interrogator signal within the frequency range specified in Tag: 1. Type C: As specified	See clause 9.3.1.3.3 Table 189
Tag:1d	Frequency Hop Rate (frequency-hopping [FHSS] systems)	Types A, B and Type D: Not applicable Type C: Tags respond to Interrogator signals that satisfy Int:1d	See clause 9.3.1.2.9
Tag:1e	Frequency Hop Sequence (frequency-hopping [FHSS] systems)	Types A, B and Type D: Not applicable Type C: Tags respond to Interrogator signals that satisfy Int:1e	See clause 9.3.1.2.9
Tag:2	Occupied Channel Bandwidth	In accordance with the local regulations	
Tag:3	Transmit Maximum EIRP	In accordance with the local regulations	
Tag:4	Transmit Spurious Emissions	In accordance with the local regulations	
Tag:4a	Transmit Spurious Emissions, In-Band (spread spectrum systems)	In accordance with the local regulations	

Ref.	Parameter Name	Description	Ref Type C
Tag:4b	Transmit Spurious Emissions, Out-of-Band	In accordance with the local regulations	
Tag:5	Transmit Spectrum Mask	In accordance with the local regulations	
Tag:6a	Transmit-to-Receive Turn-Around Time	Type A: The tag shall open its receive command window within 2 bit periods of the end of its response. Type B: 400 μs Type C: $3T_{pri}$ minimum, $20T_{pri}$ maximum in reply & acknowledged states; no limit otherwise Type D: Not applicable.	See clause 9.3.1.6, Figure 50, Table 193
Tag:6b	Receive-to-Transmit Turn-Around Time	Type A : Range from 150 to 1150 μs (see clause 7.5.3 and Table 28) Type B : Range 85 to 460 μs (see clause 8.1.5.2) Type C: $MAX(RT_{cal}, 10T_{pri})$ nominal Type D: Not applicable.	See clause 9.3.1.6, Figure 50, Table 193
Tag:6c	Dwell Time or Transmit Power-On Ramp	Types A and B: Not applicable. Type C: Receive commands 1.5 ms after power-up Type D: Not applicable.	See clause 9.3.1.2
Tag:6d	Decay Time or Transmit Power-Down Ramp	Not applicable.	
Tag:7	Modulation	Types A and B: Bi-state amplitude modulated backscatter. Type C and Type D: ASK and/or PSK modulation (selected by tag)	See clause 9.3.1.3.1
Tag:7a	Spreading Sequence (direct sequence [DSSS] systems)	Not applicable.	
Tag:7b	Chip Rate (spread spectrum systems)	Not applicable.	
Tag:7c	Chip Rate Accuracy (spread spectrum systems)	Not applicable.	
Tag:7d	On-Off Ratio	Types A and B: The tag Delta RCS (Varying Radar Cross Sectional area) affects system performance. A typical value is greater than $0.005m^2$. Type C and Type D: Not specified	
Tag:7e	Subcarrier Frequency	Types A and B: Not applicable. Type C: 40 kHz to 640 kHz Type D: 512 kHz	See clause 9.3.1.3.3 Table 189
Tag:7f	Subcarrier Frequency Accuracy	Types A and B: Not applicable. Type C and Type D: As specified	Table 189
Tag:7g	Subcarrier Modulation	Types A and B: Not applicable. Type C and Type D: Miller, at the data rate	See clause 9.3.1.3.2.3, Figure 47

Ref.	Parameter Name	Description	Ref Type C
Tag:7h	Duty Cycle	Types A and B: The tag shall transmit its response when commanded to do so by the Interrogator. Type C: FM0: 50%, nominal Subcarrier: 50%, nominal Type D: Random hold-off as specified	See clause 9.3.1.3.2.1, 9.3.1.3.2.3
Tag:7i	FM Deviation	Not applicable.	
Tag:8	Data Coding	Types A and B: Bi-phase space (FM0) Type C: Baseband FM0 or Miller-modulated subcarrier (selected by the Interrogator) Type D: PPE or Miller (M=2)	See clause 9.3.1.3.2
Tag:9	Bit Rate	Types A and B: Typical 40 kbit/s or 160 kbit/s (subject to tag clock tolerance see Table 9), The return bit rate selection for 160 kbit/s for Type B is defined in clause 8.1.4.4.5. Type C: FM0: 40 kbps to 640 kbps Subcarrier modulated: 5 kbps to 320 kbps Type D: 256 kbit/s	See clause 9.3.1.3.3 Table 189
Tag:9a	Bit Rate Accuracy	Types A and B: +/- 15% (refer to Table 9) Type C: Same as Subcarrier Frequency Accuracy; see Tag:7f Type D: +/- 20%	See clause 9.3.1.3.3, Table 189, Table 190
Tag:10	Tag Transmit Modulation Accuracy (frequency-hopping [FHSS] systems)	Not applicable.	
Tag:11	Preamble	Types A and B: The preamble is defined in clause 6.5.6 Type C: Required Type D: Required	See clause 9.3.1.3.2.2, See clause 9.3.1.3.2.4
Tag:11a	Preamble Length	Types A and B: 16 bits made up of a quiet period, followed by sync, followed by a code violation followed by an orthogonal code. Type C and Type D: As specified	See Table 189, See Figure 49
Tag:11b	Preamble Waveform	Types A and B: Bi-phase encoded data '1'. Type C and Type D: As specified	See Table 189, See Figure 49
Tag:11c	Bit-Sync Sequence	Types A and B: Included in the preamble. Type C and Type D: None	
Tag:11d	Frame-Sync Sequence	Types A and B: Included in the preamble. Type C and Type D: None	
Tag:12	Scrambling (spread-spectrum systems)	Not applicable.	
Tag:13	Bit Transmission Order	MSB is transmitted first	See clause 9.3.1.4
Tag:14	Reserved	Deliberately left blank.	
Tag:15	Polarization	Types A and B: Product design feature. Not defined in this part of ISO/IEC 18000. Type C and Type D: Tag dependent; not specified by this document	
Tag:16	Minimum Tag Receiver Bandwidth	Types A and B: 860 – 960 MHz Type C and Type D: Tag dependent; not specified by this document.	

Table 4 — Protocol parameters

Ref.	Parameter Name	Description	Ref Type C
P:1	Who talks first	TYPES A, B and C: Interrogator Type D: Tag after listening	See clause 9.3
P:2	Tag addressing capability	Type A see clause 7.3.1 Type B see clause 8.2.2 Type C and Type D: As specified	See clause 9.3.2.1
P:3	Tag ID	Types A and B: Contained in tag memory and accessible by means of a command. Type C and Type D: Contained in tag memory	See clause 9.3.2.1.3
P:3a	Tag ID Length	Type A: 64 bits. Type B: 64 bits Type C: Variable, as specified in clause 9.3.2.1.3 Type D: 64 bits	See clause 9.3.2.1.3
P:3b	Tag ID Format	See clause 7.2.1 for Type A . See clause B.1.2 for Type B . Type C: See clause 9.3.2.1.3 Type D: See clause 10.3.2	See clause 9.3.2.1.3
P:4	Read size	Type A: Addressable in blocks of up to 256 bits, but always an integer multiple of bytes. Type B: Addressable in byte blocks. Type C: Multiples of 16 bits. Type D: Not Applicable.	See clause 9.3.2.11.3.2 Table 214
P:5	Write Size	Type A: Addressable in blocks of up to 256 bits, but always an integer multiple of bytes. Type B: Addressable in byte blocks. Writing in blocks of 1, 2, 3 or 4 bytes. See details in relevant clauses. Type C: Multiples of 16 bits Type D: Not Applicable.	See clause 9.3.2.11.3.3, Table 216, See clause 9.3.2.11.3.7, Table 227
P:6	Read Transaction Time	Types A and B: A single tag can typically be identified and have its first 128 bits of user memory read in less than 10 ms. This time may vary depending on the data rate used as constrained by the local radio regulations. Type C: Varied with R=>T and T=>R link rate and number of bits being read Type D: Not Applicable.	See clause 9.3.2.11.3.2
P:7	Write Transaction Time	Types A and B: Once a tag has been identified and selected, a 32-bit data block can typically be written in less than 20 ms. This time may vary depending on the data rate used as constrained by the local radio regulations. Type C: 20 ms (maximum) after end of Write command Type D: Not Applicable.	See clause 9.3.2.11.3.3, See clause 9.3.2.11.3.7, Figure 56

Ref.	Parameter Name	Description	Ref Type C
P:8	Error detection	Type A: Interrogator to tag: 16-bit commands: CRC-5. Commands of more than 16 bits have an additional CRC-16, bit protection. Tag to Interrogator: CRC-16 Type B: Interrogator to tag: CRC-16 Tag to Interrogator: CRC-16 Type C: Interrogator-to-tag: Select command: CRC-16 Query command: CRC-5 Other Inventory commands: Command length Access commands: CRC-16 Tag-to-Interrogator: PC, UII: CRC-16 RN16: None or CRC-16 (varies with command) handle: CRC-16 All other: CRC-16 Type D: Tag to Interrogator : CRC-16 on TID Structured data uses 5 bit CRC with page down counter.	See clause 9.3.2.10 and its subsections
P:9	Error correction	Types A and B: No forward error correction code used. Errors are handled by signalling an error to the Interrogator that then repeats its last transmission. Type C and Type D: None	
P:10	Memory size	Types A and B: No minimum user memory size is specified, but if user memory is provided it shall be an integer multiples of 4 bytes. Type C: Tag dependent, extensible (size is neither limited nor specified by this document) Type D: Unlimited 64 bit pages	
P:11	Command structure and extensibility	Type A: Several command codes are reserved for future use. In addition, a Protocol extension flag allows for further extensions. Type B: Several command codes are reserved for future use. Type C: As specified. . Type D: Not Applicable.	Table 199

Table 5 — Anti-collision parameters

Ref.	Parameter Name	Description	Ref Type C
A:1	Type (Probabilistic or Deterministic)	Probabilistic	See clause 9.3.2.6
A:2	Linearity	Type A: Essentially linear using adaptive slot allocation up to 256 slots for 250 tags in an Interrogator zone. Type B: Essentially linear up to 2^{256} tags depending on size of data content. Type C: Linear up to 2^{15} tags in the Interrogator's RF field; above that number, $N \log N$ for tags with unique UIIs Type D: Nearly linear up to 500 tags depending on anti-collision parameter.	See clause 9.3.2.8
A:3	Tag inventory capacity	Types A and B: The algorithm permits the reading of not less than 250 tags in the reading zone of the Interrogator. Type C: Unlimited for tags with unique UIIs. Type D: Unlimited depending on anti-collision parameter.	See clause 9.3.2.8

6 Common elements of the physical layer for Types A, B, and D

6.1 General

Types A, B, and D have several common elements for the physical layers. They are specified in the following sub-clauses. For Type D, only sub-clauses 6.1 to 6.4 are applicable unless the Tag implements an optional Type A or B forward link."

6.2 Interrogator power-up waveform

The Interrogator power-up waveform shall comply with the mask specified in Figure 9 and Table 6.

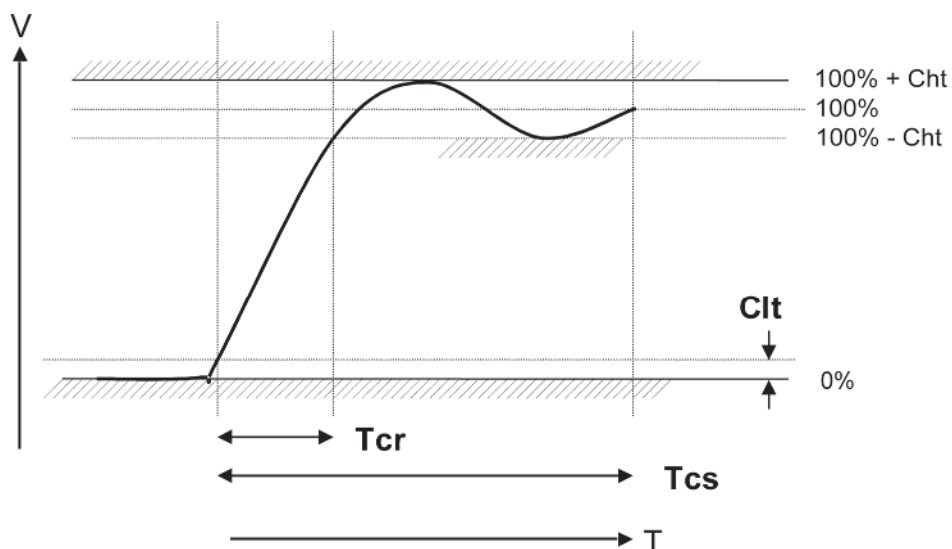


Figure 9 — Interrogator power-up waveform

Table 6 — Interrogator power-up waveform parameter values

Parameter	Min	Max
Tcs		1500µs
Tcr	1 µs	500 µs
Cht		10%
Clf		1%

6.3 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 10 and Table 7.

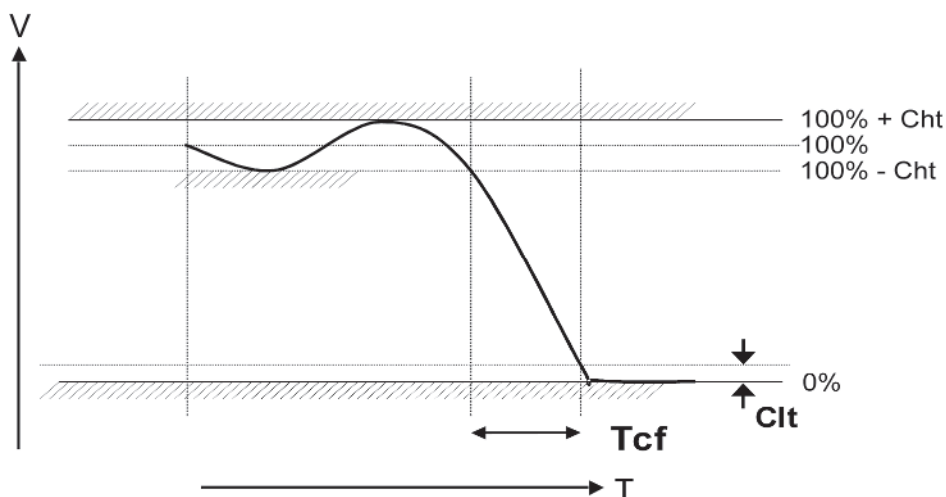


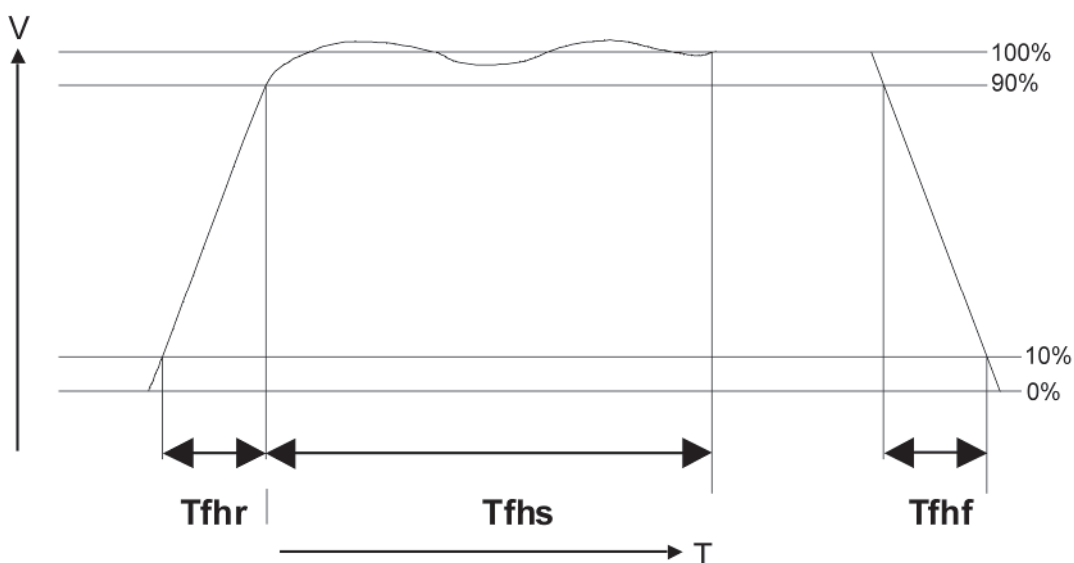
Figure 10 — Interrogator power-down waveform

Table 7 — Interrogator power-down timings

Parameter	Min	Max
Tcf	1 μ s	500 μ s
Cht		$\pm$ 5% of steady state (100 %) level
Clt		1 %

6.4 Frequency hopping carrier rise and fall times

When the Interrogator operates in the frequency operating hopping spread spectrum mode (FHSS), the carrier rise and fall times shall conform to the characteristics specified in Figure 11 and Table 8. The Interrogator shall complete a frequency hop in a time not exceeding 30 μ s (to ensure that the tag is not reset by the frequency hop). The frequency hop is measured from the beginning of Tfhf to the end of Tfhr.



NOTE Ripple is $\pm 5\%$ of 100 % of steady state level

Figure 11 — FHSS carrier rise and fall characteristics

Table 8 — FHSS carrier rise and fall parameters

Parameter	Min	Max
Tfhr		30 μ s
Tfhs	400 μ s	
Tfhf		30 μ s

6.5 FM0 return link

6.5.1 FM0 return link general

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

6.5.2 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.

6.5.3 Data rate

The return link datarate shall be 40 or 160 kbit/s, which may be selected at the time of tag configuration. The Interrogator shall be able to read and decode the tag reply at either datarate without the need to have prior knowledge of the tag configuration in order to handle mixed populations.

6.5.4 Data coding

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

One symbol period Trlb, as specified in Table 9, 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	Note
40kbit/s	25 μ s	+/-15%	Chip set to 40kbit/s Return Link Data Rate
160kbit/s	6.25 μ s	+/-15%	Chip set to 160kbit/s Return Link Data Rate

Coding of data is MSB first. Figure 12 illustrates the coding for the 8 bits of 'B1'.

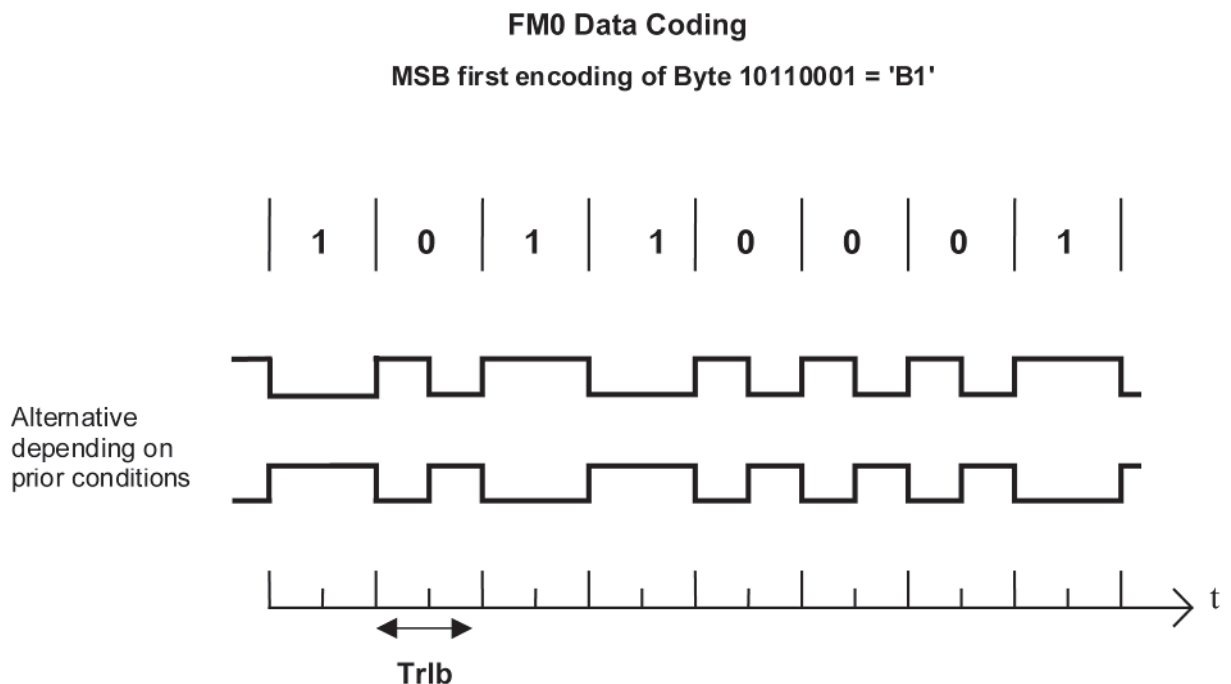


Figure 12 — Tag to Interrogator data coding

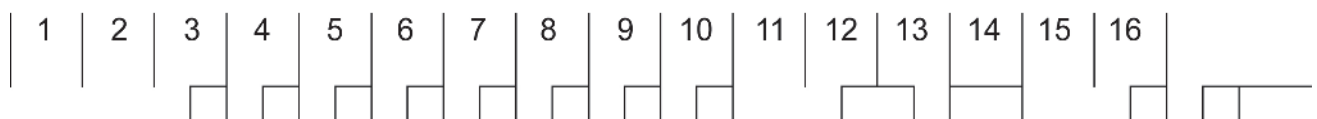
6.5.5 Message format

A return Link Message consists of n data bits preceded by the Preamble. 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 Figure 13. There are multiple code violations (sequences not conforming to FM0 rules) that act as a frame marker for the transition from Preamble to Data.

6.5.6 Return preamble

The return preamble is a sequence of backscatter modulation specified in Figure 13.



NOTE The high state represents high reflectivity and the low state represents low reflectivity.

Figure 13 — Preamble waveform

Changing the tag's modulator switch from the high impedance state to the low impedance state causes a change in the incident energy to be back-scattered, see Figure 14.

The tag shall execute backscatter, a half-low and half-high sent by the tag defined as follows:

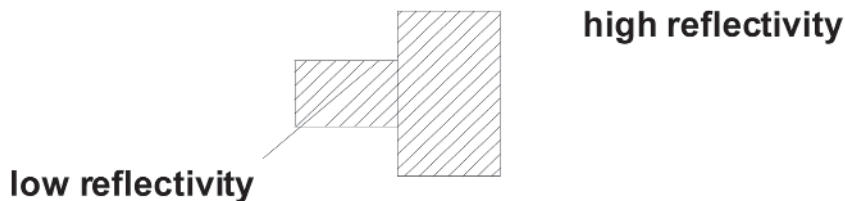


Figure 14 — Return link bit coding

6.5.7 Cyclic redundancy check (CRC)

6.5.7.1 CRC General

Types A and B use the same CRC-16 for the forward and the return links. In addition, Type A uses CRC-5 for short commands when it satisfies the required level of protection against errors.

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.

6.5.7.2 Interrogator to tag 5-bit CRC-5

The 5-bit CRC shall be calculated on all the command bits after the SOF up to but not including the first CRC bit.

The polynomial used to calculate the CRC is $x^5 + x^3 + 1$.

A possible implementation is using a 5-bit shift register as defined in Clause A.1. The 5-bit CRC register is named Q4 to Q0, with Q4 being the MSB and Q0 being the LSB. The 5-bit register must be preloaded with '01001' (MSB to LSB) or in hexadecimal notation 0x09 (HEX), as shown in Table A.1

The 11 bits of data must be clocked through the CRC register, using the MSB first. The 5 CRC bits are then sent, MSB first. After the LSB of the CRC-5-bit is clocked through, the 5-bit CRC register should contain all zero's.

NOTE A schematic of a possible implementation is provided in Annex A.

6.5.7.3 Interrogator to tag 16-bit CRC-16

6.5.7.3.1 Interrogator to tag CRC-16 general

The 16-bit CRC shall be calculated on all the command bits after the SOF up to but not including the first CRC bit.

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.

NOTE A schematic of a possible implementation is provided in Annex A.

The CRC may be implemented in one of two ways: