BS ISO/IEC 18000-61:2012

BSI Standards Publication

Information technology — Radio frequency identification for item management

Part 61: Parameters for air interface communications at 860 MHz to 960 MHz Type A

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National foreword

This British Standard is the UK implementation of ISO/IEC 18000-61:2012. Together with BS ISO/IEC 18000-6:2013, BS ISO/IEC 18000-62:2012, BS ISO/IEC 18000-63:2012, and BS ISO/IEC 18000-64:2012, it supersedes BS ISO/IEC 18000-6:2010, which is withdrawn.

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

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

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

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INTERNATIONAL STANDARD

ISO/IEC 18000-61

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2012-07-15

Information technology — Radio frequency identification for item management —

Part 61: Parameters for air interface communications at 860 MHz to 960 MHz Type A

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

Partie 61: Paramètres de communications d'une interface radio entre 860 MHz et 960 MHz, Type A

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ISO/IEC 18000-61:2012(E)

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Foreword

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

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

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

ISO/IEC 18000-61 was prepared by Joint 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 General*

— *Part 61: Parameters for air interface communications at 860 MHz to 960 MHz Type A*

— *Part 62: Parameters for air interface communications at 860 MHz to 960 MHz Type B*

— *Part 63: Parameters for air interface communications at 860 MHz to 960 MHz Type C*

— *Part 64: Parameters for air interface communications at 860 MHz to 960 MHz Type D*

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

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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), 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.

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.

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

The holders of these patent rights have assured 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.

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Information technology — Radio frequency identification for item management —

Part 61: Parameters for air interface communications at 860 MHz to 960 MHz Type A

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) systems. The system comprises Interrogators, also known as readers, 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.

In detail, this part of ISO/IEC 18000 contains Type A.

Type A is ITF. Type A uses Pulse-Interval Encoding (PIE) in the forward link and an adaptive ALOHA collision-arbitration algorithm.

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.

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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 Type A

— 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 any of the parts 62, 63 and 64, 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 Type A;

— 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; 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 6.9 and 6.10.

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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 or any of the parts 62, 63 and 64;

— 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.

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

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

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

4.1.2
physical layer
data coding and modulation waveforms used in Interrogator-to-tag and tag-to-Interrogator signalling

4.1.3
battery assistance
battery support for radio frequency communication

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4.1.4
battery assisted mode
working mode of battery-assisted tags with non-empty battery

4.1.5
passive mode
working mode of passive tags or battery assisted tags with battery drained below a manufacturer-specific threshold

4.2 Symbols

BAP	battery assisted passive
BLF	backscatter link frequency
Cht	carrier high-level tolerance
Clt	carrier low-level tolerance
D	modulation depth of data coding pulse
Taq	quiet time
Tapf	pulse fall time
Tapr	pulse rise time
Tapw	pulse width
Tari	reference time interval for a data-0 in Interrogator-to-tag signalling
Tcf	carrier fall time
Tcr	carrier rise time
Tcs	carrier steady state time
Tfhf	carrier FHSS fall time
Tfhr	carrier FHSS rise time
Tfhs	carrier FHSS steady time
Trlb	return link bit time
$xxxx_2$	binary notation
$xxxx_h$	hexadecimal notation

4.3 Abbreviated terms

AFI	application family identifier
ASF	application sub family
BAP	battery assisted passive
CRC	cyclic redundancy check
CRC-16	sixteen bit CRC
CRC-5	five bit CRC
CW	continuous wave

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DSFID data storage format identifier

DSSS direct sequence spread spectrum

EOF end of frame

FCC Federal Communications Commission

FHSS frequency hopping spread spectrum

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

PIE pulse interval encoding

ppm parts per million

RFU reserved for future use

SOF start of frame

SUID sub unique identifier

TEL tag excitation level

5 Overview

5.1 Parameter tables

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

Table 1 — Interrogator to tag link parameters

Ref.	Parameter Name	Description
Int:1	Operating Frequency Range	860 MHz – 960 MHz, as required by the local regulations
Int:1a	Default Operating Frequency	In accordance with the local radio regulations.
Int:1b	Operating Channels (spread-spectrum systems)	In accordance with the local radio regulations.
Int:1c	Operating Frequency Accuracy	In accordance with the local radio regulations.
Int:1d	Frequency Hop Rate (frequency-hopping [FHSS] systems)	In accordance with the local radio regulations.
Int:1e	Frequency Hop Sequence (frequency-hopping [FHSS] systems)	In accordance with the local radio regulations.
Int:2	Occupied Channel Bandwidth	In accordance with the local radio regulations.
Int:2a	Minimum Receiver Bandwidth	In accordance with the local radio regulations.
Int:3	Interrogator Transmit Maximum EIRP	In accordance with the local radio regulations.

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Ref.	Parameter Name	Description
Int:4	Interrogator Transmit Spurious Emissions	In accordance with the local radio regulations.
Int:4a	Interrogator Transmit Spurious Emissions, In-Band (spread-spectrum systems)	In accordance with the local radio regulations.
Int:4b	Interrogator Transmit Spurious Emissions, Out-of-Band	In accordance with the local radio regulations.
Int:5	Interrogator Transmitter Spectrum Mask	In accordance with the local radio regulations.
Int:6	Timing	See below Int: 6x.
Int:6a	Transmit-to-Receive Turn-Around Time	The Interrogator transmit/receive settling time shall not exceed 85 µs.
Int:6b	Receive-to-Transmit Turn-Around Time	As determined by the communication protocol – refer Tag: 6a.
Int:6c	Dwell Time or Interrogator Transmit Power-On Ramp	1500 µs, maximum settling time
Int:6d	Decay Time or Interrogator Transmit Power-Down Ramp	Maximum 1 ms.
Int:7	Modulation	Amplitude Modulation.
Int:7a	Spreading Sequence (direct-sequence [DSSS] systems)	Not applicable.
Int:7b	Chip Rate (spread-spectrum systems)	Not applicable.
Int:7c	Chip Rate Accuracy (spread-spectrum systems)	Not applicable.
Int:7d	Modulation Depth	Nominal 30 % to 100 %. See Table 11 and clause 7.1.1.
Int:7e	Duty Cycle	In accordance with the local regulations.
Int:7f	FM Deviation	Not applicable.
Int:8	Data Coding	Pulse Interval Encoding
Int:9	Bit Rate	33 kbit/s as constrained by the local radio regulations
Int:9a	Bit Rate Accuracy	100 ppm
Int:10	Interrogator Transmit Modulation Accuracy	Not applicable.
Int:11	Preamble	Has no preamble
Int:11a	Preamble Length	Not applicable.
Int:11b	Preamble Waveform(s)	Not applicable.
Int:11c	Bit Sync Sequence	Not applicable.
Int:11d	Frame Sync Sequence	Not applicable.
Int:12	Scrambling (spread-spectrum systems)	Not Applicable.
Int:13	Bit Transmission Order	MSB is transmitted first
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. See relevant clauses.
Int:15	Polarization	Interrogator dependent. Not defined in this part of ISO/IEC 18000.

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Table 2 — Tag to Interrogator link parameters

Ref.	Parameter Name	Description
Tag:1	Operating Frequency Range	860 MHz – 960 MHz, inclusive
Tag:1a	Default Operating Frequency	The tag shall respond to an Interrogator signal within the frequency range specified in Tag: 1.
Tag:1b	Operating Channels (spread-spectrum systems)	The tag shall respond to an Interrogator signal within the frequency range specified in Tag: 1.
Tag:1c	Operating Frequency Accuracy	The tag shall respond to an Interrogator signal within the frequency range specified in Tag: 1.
Tag:1d	Frequency Hop Rate (frequency-hopping [FHSS] systems)	Not applicable.
Tag:1e	Frequency Hop Sequence (frequency-hopping [FHSS] systems)	Not applicable.
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
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	The tag shall open its receive command window within 2 bit periods of the end of its response.
Tag:6b	Receive-to-Transmit Turn-Around Time	Range from 150 to 1150 µs (see clause 7.5.3 and Table 28)
Tag:6c	Dwell Time or Transmit Power-On Ramp	Not applicable.
Tag:6d	Decay Time or Transmit Power-Down Ramp	Not applicable.
Tag:7	Modulation	Bi-state amplitude modulated backscatter.
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	The tag Delta RCS (Varying Radar Cross Sectional area) affects system performance. A typical value is greater than 0.005m2.
Tag:7e	Subcarrier Frequency	Not applicable.
Tag:7f	Subcarrier Frequency Accuracy	Not applicable.
Tag:7g	Subcarrier Modulation	Not applicable.
Tag:7h	Duty Cycle	The tag shall transmit its response when commanded to do so by the Interrogator.
Tag:7i	FM Deviation	Not applicable.
Tag:8	Data Coding	Bi-phase space (FM0)

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Ref.	Parameter Name	Description
Tag:9	Bit Rate	Typical 40 kbit/s or 160 kbit/s (subject to tag clock tolerance see Table 9),
Tag:9a	Bit Rate Accuracy	+/- 15% (refer to Table 9)
Tag:10	Tag Transmit Modulation Accuracy (frequency-hopping [FHSS] systems	Not applicable.
Tag:11	Preamble	The preamble is defined in clause 6.5.6
Tag:11a	Preamble Length	16 bits made up of a quiet period, followed by sync, followed by a code violation followed by an orthogonal code.
Tag:11b	Preamble Waveform	Bi-phase encoded data ‘1’.
Tag:11c	Bit-Sync Sequence	Included in the preamble.
Tag:11d	Frame-Sync Sequence	Included in the preamble.
Tag:12	Scrambling (spread-spectrum systems)	Not applicable.
Tag:13	Bit Transmission Order	MSB is transmitted first
Tag:14	Reserved	Deliberately left blank.
Tag:15	Polarization	Product design feature. Not defined in this part of ISO/IEC 18000.
Tag:16	Minimum Tag Receiver Bandwidth	860 – 960 MHz

Table 3 — Protocol parameters

Ref.	Parameter Name	Description
P:1	Who talks first	Interrogator
P:2	Tag addressing capability	see clause 7.3.1
P:3	Tag ID	Contained in tag memory and accessible by means of a command.
P:3a	Tag ID Length	64 bits.
P:3b	Tag ID Format	See clause 7.2.1
P:4	Read size	Addressable in blocks of up to 256 bits, but always an integer multiple of bytes.
P:5	Write Size	Addressable in blocks of up to 256 bits, but always an integer multiple of bytes.
P:6	Read Transaction Time	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.
P:7	Write Transaction Time	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.

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Ref.	Parameter Name	Description
P:8	Error detection	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
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. None
P:10	Memory size	No minimum user memory size is specified, but if user memory is provided it shall be an integer multiples of 4 bytes.
P:11	Command structure and extensibility	Several command codes are reserved for future use. In addition, a Protocol extension flag allows for further extensions.

Table 4 — Anti-collision parameters

Ref.	Parameter Name	Description
A:1	Type (Probabilistic or Deterministic)	Probabilistic
A:2	Linearity	Essentially linear using adaptive slot allocation up to 256 slots for 250 tags in an Interrogator zone.
A:3	Tag inventory capacity	The algorithm permits the reading of not less than 250 tags in the reading zone of the Interrogator.

6 Type A

6.1 Physical layer and data coding

6.1.1 Interrogator power-up waveform

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

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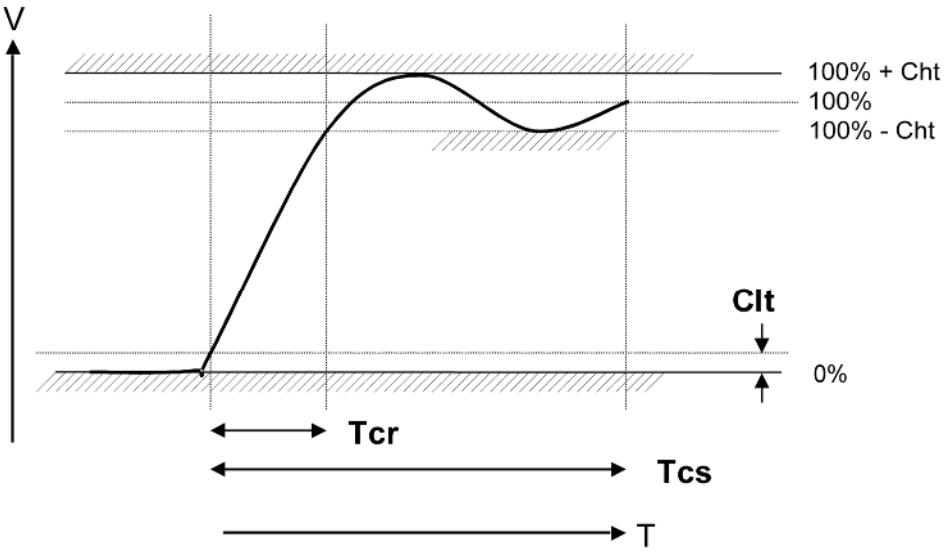

Figure 1 — Interrogator power-up waveform

Table 5 — Interrogator power-up waveform parameter values

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

6.1.2 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.

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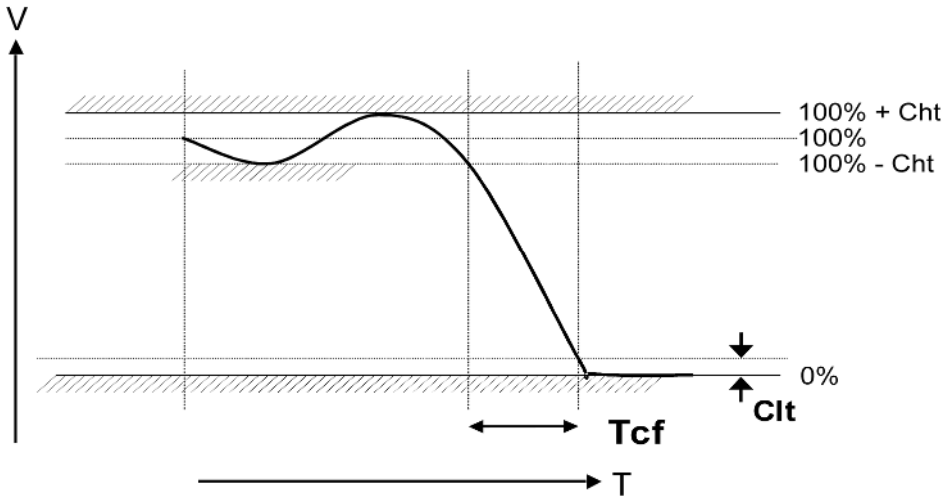


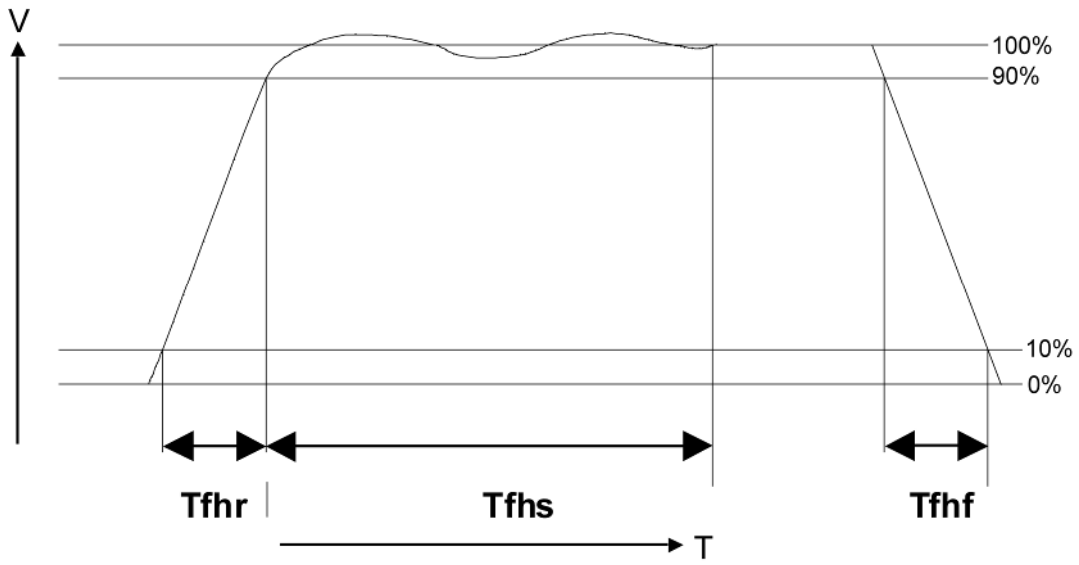
Figure 2 — Interrogator power-down waveform

Table 6 — Interrogator power-down timings

Parameter	Min	Max
Tcf	1 µs	500 µs
Cht		± 5% of steady state (100 %) level
Clt		1 %

6.1.3 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 3 and Table 7. The Interrogator shall complete a frequency hop in a time not exceeding 30 µs (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 ± 5 % of 100 % of steady state level

Figure 3 — FHSS carrier rise and fall characteristics

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Table 7 — FHSS carrier rise and fall parameters

Parameter	Min	Max
Tfhr		30 µs
Tfhs	400 µs	
Tfhf		30 µs

6.1.4 FM0 return link

6.1.4.1 FM0 return link general

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

6.1.4.2 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.

6.1.4.3 Data rate

The return link data rate 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 data rate without the need to have prior knowledge of the tag configuration in order to handle mixed populations.

6.1.4.4 Data coding

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

One symbol period Trlb, as specified in Table 8, 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 8 — Return link parameters

Data rate	Trlb	Tolerance	Note
40kbit/s	25 µs	+/-15%	Chip set to 40kbit/s Return Link Data Rate
160kbit/s	6.25 µs	+/-15%	Chip set to 160kbit/s Return Link Data Rate

Coding of data is MSB first. Figure 4 illustrates the coding for the 8 bits of 'B1'.

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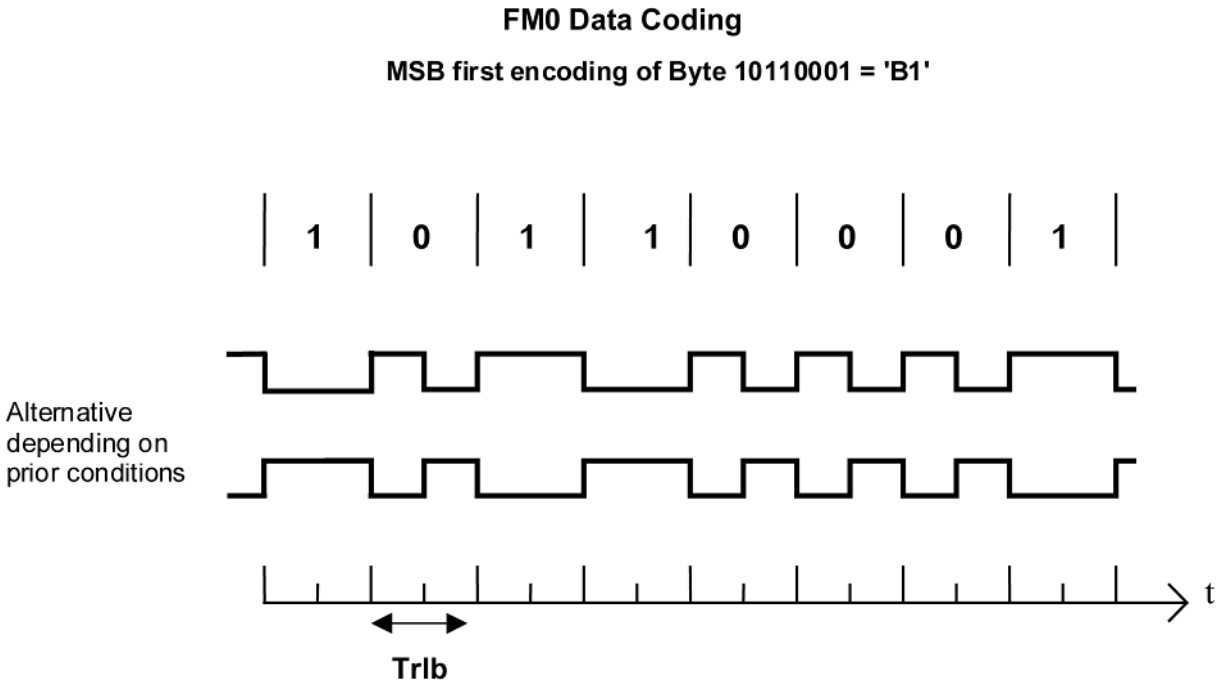


Figure 4 — Tag to Interrogator data coding

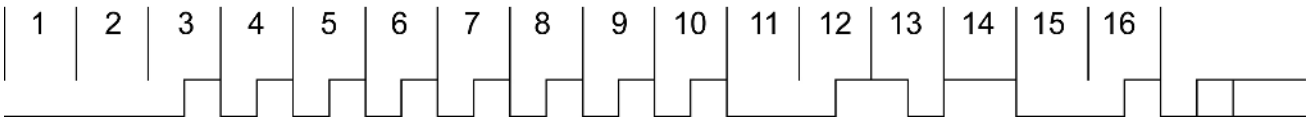
6.1.4.5 Message format

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 5. There are multiple code violations (sequences not conforming to FM0 rules) that act as a frame marker for the transition from Preamble to Data.

6.1.4.6 Return preamble

The return preamble is a sequence of backscatter modulation specified in Figure 5.



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

Figure 5 — 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 6.

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

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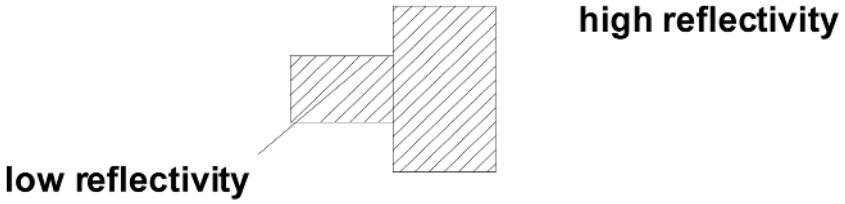

Figure 6 — Return link bit coding

6.1.4.7 Cyclic redundancy check (CRC)

6.1.4.7.1 CRC General

The same CRC-16 is used for the forward and the return links. In addition, short commands use a CRC-5 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.

6.1.4.7.2 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.

6.1.4.7.3 Interrogator to tag 16-bit CRC-16

6.1.4.7.3.1 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:

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6.1.4.7.3.2 Inversion of incoming CRC bits by the tag

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

6.1.4.7.3.3 Non-inversion of incoming CRC bits by the tag

If the received CRC bits are not inverted before clocking into the register, then after the LSB CRC bit is clocked into the register the 16-bit CRC register will have the value 0x1D0F (HEX)

6.1.4.7.4 Tag to Interrogator 16-bit CRC-16

6.1.4.7.4.1 Tag to Interrogator CRC-16 general

The 16-bit CRC shall be calculated on all data bits 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 0xFFFF (HEX). The resulting CRC value shall be inverted, attached to the end of the packet and transmitted.

The most significant byte shall be transmitted first, see Table 9. The most significant bit of each byte shall be transmitted first.

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.

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

Table 9 — 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	

The CRC may be implemented in one of two ways.

6.1.4.7.4.2 Inversion of incoming CRC bits by the Interrogator

At the Interrogator receiver, the incoming CRC bits are inverted and then clocked into the register. After the LSB CRC bit is clocked into the register the 16-bit CRC register should contain all zero's.

6.1.4.7.4.3 Non-inversion of incoming CRC bits by the Interrogator

If the received CRC bits are not inverted before clocking, the CRC register will have the value 0x1D0F (HEX).

6.1.5 PIE (Pulse interval encoding) forward link

6.1.5.1 Carrier modulation pulses

The data transmission from the Interrogator to the tag is achieved by modulating the carrier amplitude (ASK). The data coding is performed by generating pulses at variable time intervals. The duration of the interval between two successive pulses carries the data coding information.

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The tag shall measure the inter-pulse time on the high to low transitions (falling) edges of the pulse as shown in Figure 7.

The carrier modulation pulses are negative-going raised cosine shaped, their characteristics are specified in Figure 8 and Table 10.

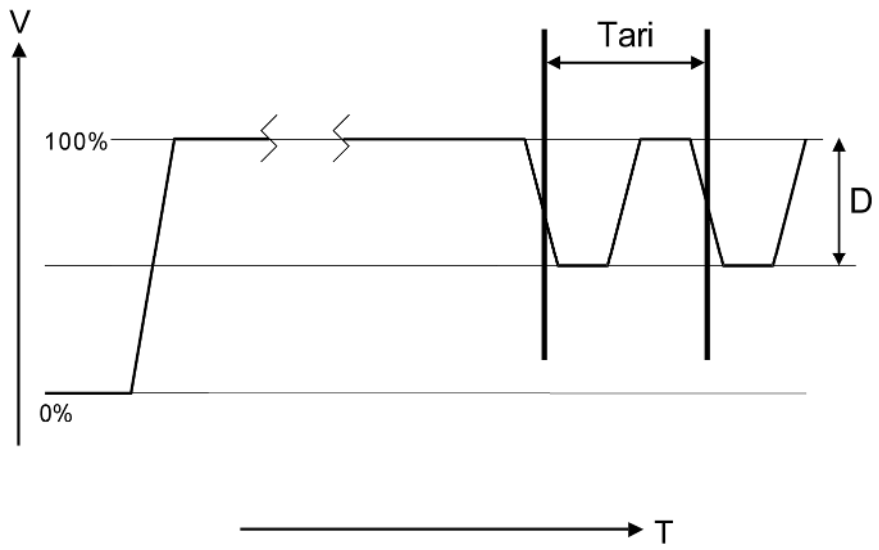
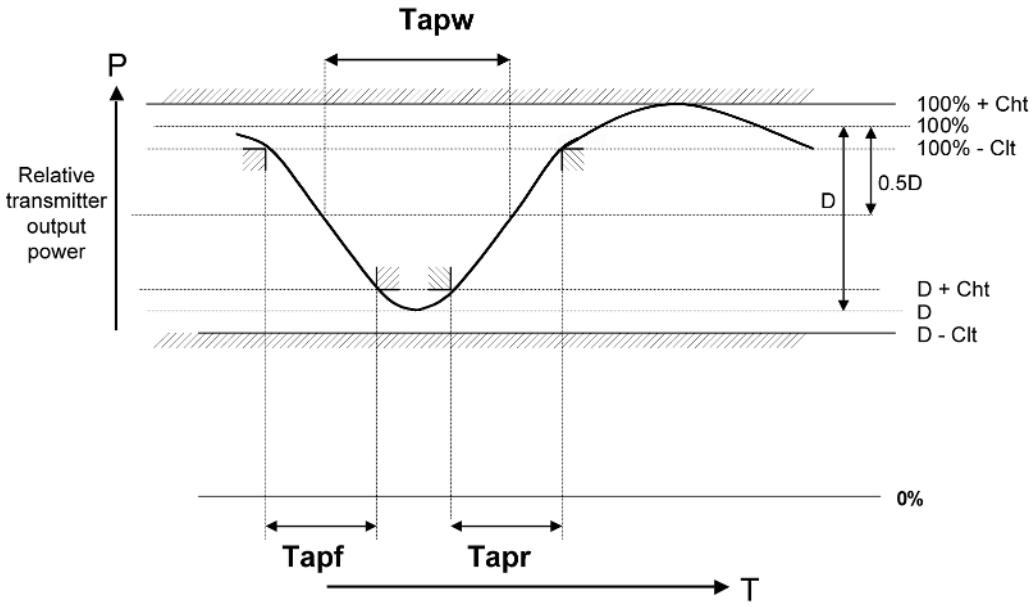


Figure 7 — Inter-pulse mechanism



NOTE The vertical lines occur at the half power (3dB) point on the modulation carrier dip.

Figure 8 — Modulation shaping

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Table 10 — Modulation parameters

Parameter	Min	Nominal	Max
Tapw		10µs	
D	27% See NOTE 1		See NOTE 2
Tapf		4µs	
Tapr		4µs	
Cht			0.1 D
Clt			0.1 D
NOTE 1 The minimum modulation depth value is the absolute limit over the Interrogator's operating temperature range. NOTE 2 The maximum modulation depth may be in the range of 0.27 to 1 times the steady state value and will depend on the radio regulatory environment.			

The Interrogator shall maintain a constant modulation depth during the transmission of a command, within the Cht and Clt tolerances.

6.1.5.2 Data coding and framing

The time Tari specifies the reference interval between the falling edges of two successive pulses representing the symbol '0' as transmitted by the Interrogator; its value is specified in Table 11.

Table 11 — Reference interval timing

Tari	Stability
10 to 20 µs	±100 ppm

Four symbols are defined as shown as shown in Table 12 and Figure 9. The symbols are referenced to the interval Tari and have a duration of 1 Tari, 2 Tari, and 4 Tari being integer multiples of Tari and shall have a tolerance with respect to Tari as defined in Table 12. The Start of Frame, SOF symbol is a combinational symbol made up by concatenating a ‘0’ symbol with a symbol having a duration of 3 Tari, for an overall length of 4 Tari.

Table 12 — PIE symbols, coding

Symbol	Duration	Tolerance with respect to 1 Tari
0	1 Tari	
1	2 Tari	± 100 ppm
SOF	1 Tari followed by 3 Tari	± 100 ppm
EOF	4 Tari	± 100 ppm

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Symbol	Number of Tari
'0'	1
'1'	2
SOF	4
EOF	4

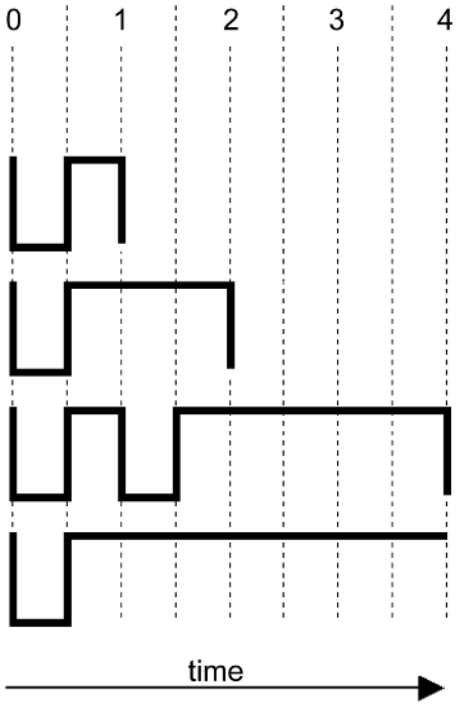

Figure 9 — PIE symbols

6.1.5.3 Decoding of PIE symbols by the tag

The tag shall be able to decode a PIE encoded transmission having symbols of duration as specified in Table 13.

Table 13 — PIE symbols, decoding

Symbol	Mean duration	Limits
0	1 Tari	1/2 Tari < '0' ≤ 3/2 Tari
1	2 Tari	3/2 Tari < '1' ≤ 5/2 Tari
SOF	1 Tari followed by 3 Tari	Calibration sequence
EOF	4 Tari	≥ 4 Tari

The reference for the decoder is derived from the SOF and is = 3/2 Tari

The tag shall interpret an interval between received symbols of >4 Tari as an EOF and shall discard the preceding data.

If the tag does not receive data for a period greater than EOF, the tag shall wait for a SOF.

6.1.5.4 Frame format

The bits transmitted by the Interrogator to the tag are embedded in a frame as specified in Figure 10.

Before sending the frame, the Interrogator shall ensure that it has established an unmodulated carrier for a duration of at least Taq (Quiet time) of 300 µs.

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The frame consists of a Start Of Frame (SOF), immediately followed by the data bits and terminated by an End Of Frame (EOF). After having sent the EOF the Interrogator shall maintain a steady carrier for the time specified by the protocol so that the tags are powered for transmitting their response.

If the tag does not receive data for a period greater than EOF, then the command decoder shall revert to the ready state and await another SOF.

The tag shall interpret an interval between received symbols of >4 Tari as an error and shall discard the preceding data.

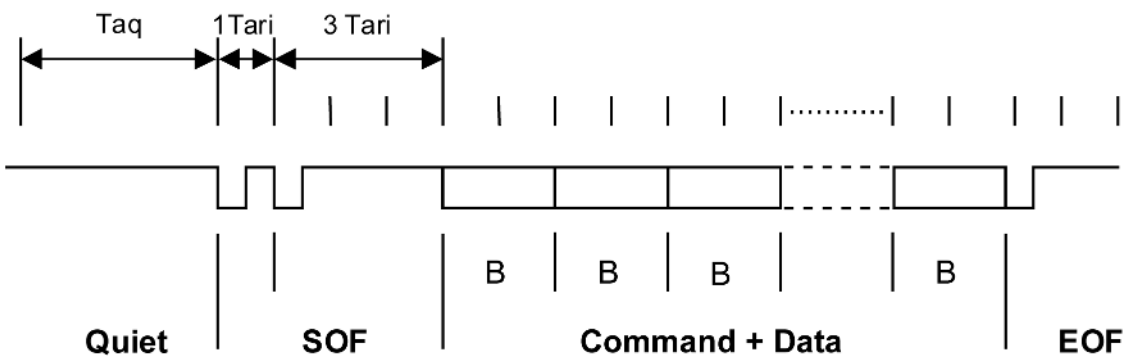

Figure 10 — Forward link frame format

6.1.5.5 Data decoding

The tag shall decode the symbols specified in Table 12.

The tag shall be able to decode an incoming signal having a modulation depth (as specified in 6.1.5.1, Figure 8 and Table 10) with respect to the Interrogator steady state carrier of 27 % or greater (i.e. 27 % to 100 %). In other words the modulation depth may be anywhere in the range of 0.27 to 1 times the steady state carrier amplitude.

If the tag detects an invalid code, it shall discard the frame and wait for an unmodulated carrier of 4 Tari duration.

6.1.5.6 Bits and byte ordering

Coding of data into symbols shall be MSB first. The coding for the 8 bits of hex byte 'B1' is shown in Figure 11.

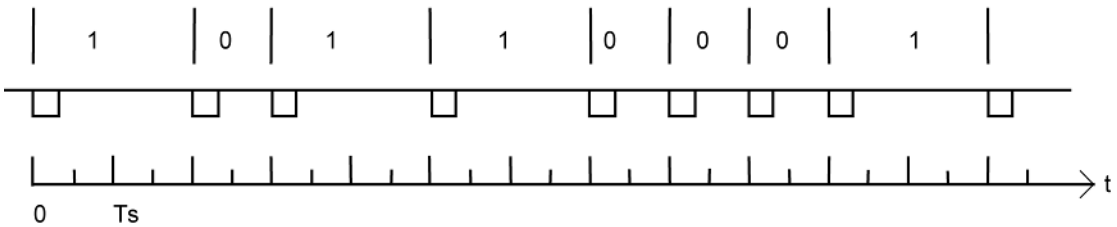

Figure 11 — Example of PIE byte encoding for 'B1'

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