



**BSI Standards Publication**

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

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

## National foreword

This British Standard is the UK implementation of ISO/IEC 18000-63:2021. It supersedes BS ISO/IEC 18000-63:2015, which is withdrawn.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 committee manager.

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ISBN 978 0 539 05885 7

ICS 35.040.50

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 November 2021.

### Amendments/corrigenda issued since publication

| Date | Text affected |
|------|---------------|
|------|---------------|

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

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

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

*Partie 63: Paramètres de communications d'une interface radio entre  
860 MHz et 960 MHz, Type C*



Reference number  
ISO/IEC 18000-63:2021(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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives) or [www.iec.ch/members\\_experts/refdocs](http://www.iec.ch/members_experts/refdocs)).

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

This third edition cancels and replaces the second edition (ISO/IEC 18000-63:2015), which has been technically revised.

The main changes are as follows:

- incorporation of the Technical Corrigendum;
- incorporation of a new sensor class for snapshot sensors.

A list of all parts in the ISO/IEC 18000 series can be found on the ISO and IEC websites.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html) and [www.iec.ch/national-committees](http://www.iec.ch/national-committees).

## Introduction

This document defines the physical and logical requirements for a passive-backscatter, Interrogator-talks-first (ITF), radio-frequency identification (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 or Transponders.

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. Tags are passive, meaning that they receive all of their operating energy from the Interrogator's RF signal.

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.

Interrogators and Tags are not required to talk simultaneously; rather, communications are half-duplex, i.e. Interrogators talk and Tags listen, or vice versa.

The described 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.

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 a patent.

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# Information technology — Radio frequency identification for item management —

## Part 63:

## Parameters for air interface communications at 860 MHz to 960 MHz Type C

### 1 Scope

This document 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 to develop RFID application standards. This document 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 document 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, i.e. a tag modulates its antenna reflection coefficient with an information signal only after being directed to do so by an Interrogator.

This document specifies

- physical interactions (the signalling layer of the communication link) between Interrogators and tags;
- logical operating procedures and commands between Interrogators and Tags;
- the collision arbitration scheme used to identify a specific tag in a multiple-tag environment;
- optional security commands that allow the use of crypto suites of ISO/IEC 29167.

### 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 15961 (all parts), *Information technology — Data protocol for radio frequency identification (RFID) for item management*

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

ISO/IEC 15963-1, *Information technology — Radio frequency identification for item management — Part 1: Unique identification for RF tags numbering systems*

ISO/IEC 18000-61, *Information technology — Radio frequency identification for item management — Part 61: Parameters for air interface communications at 860 MHz to 960 MHz Type A*

ISO/IEC 18000-62, *Information technology — Radio frequency identification for item management — Part 62: Parameters for air interface communications at 860 MHz to 960 MHz Type B*

ISO/IEC 18000-64, *Information technology — Radio frequency identification for item management — Part 64: Parameters for air interface communications at 860 MHz to 960 MHz Type D*

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

EPC Tag Data Standard available at <https://www.gs1.org/standards/epc-rfid/tds>

### 3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

#### 3.1 air interface

complete communication link between an Interrogator and a Tag including the physical layer, collision-arbitration algorithm, command and response structure, and data-coding methodology

#### 3.2 authenticated communication

communication in which message integrity is protected

#### 3.3 battery assisted mode

working mode of battery assisted tags with non-empty battery

#### 3.4 crypto superuser

key with an asserted CryptoSuperuser privilege

#### 3.5 data element

low-level, indivisible data construct

#### 3.6 XTID extended tag identifier

memory construct that defines a Tag's capabilities and which may include a Tag serial number

Note 1 to entry: Further specified in the EPC Tag Data Standard.

#### 3.7 extended temperature range

temperature range between  $-40\text{ }^{\circ}\text{C}$  to  $+65\text{ }^{\circ}\text{C}$

Note 1 to entry: See *nominal temperature range* (3.18).

**3.8****file type**

8-bit string that specifies a file's designated type

**3.9****file superuser**

access password or key with a 0011<sub>2</sub> **secured**-state file privilege value

**3.10****full-duplex communications**

communications channel that carries data in both directions at once

Note 1 to entry: See *half-duplex communications* ([3.11](#)).

**3.11****half-duplex communications**

communications channel that carries data in one direction at a time rather than in both directions at once

Note 1 to entry: See *full-duplex communications* ([3.10](#)).

**3.12****handle**

16-bit tag identifier

**3.13****hibernate**

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

**3.14****interrogator authentication**

means for a Tag to determine, via cryptographic means, that an Interrogator's identity is as claimed

**3.15****keyID**

numerical designator for a single key

**3.16****MAC****message authentication code**

code, computed over bits in a message, that an Interrogator or a Tag may use to verify the integrity of the message

**3.17****mutual authentication**

means for a Tag and an Interrogator to each determine, via cryptographic means, that the others' identity is as claimed

**3.18****nominal temperature range**

temperature range between -25 °C to +40 °C

Note 1 to entry: See *extended temperature range* ([3.7](#)).

**3.19****nonremovable Tag**

Tag that a consumer cannot physically detach from an item without special equipment or without compromising the item's intended functionality

Note 1 to entry: See *removable Tag* ([3.24](#)).

### 3.20

#### **password**

secret value sent by an Interrogator to a Tag to enable restricted Tag operations

Note 1 to entry: Passwords are not keys.

Note 2 to entry: The only passwords defined by this protocol are the kill and access passwords.

### 3.21

#### **private key**

undisclosed or non-distributed key in an asymmetric, or public-private key pair, cipher

Note 1 to entry: A private key is typically used for decryption or digital-signature generation.

Note 2 to entry: See *public key* ([3.22](#)).

### 3.22

#### **public key**

disclosed or distributed key in an asymmetric, or public-private key pair, cipher

Note 1 to entry: A public key is typically used for encryption or signature verification.

Note 2 to entry: See *private key* ([3.21](#)).

### 3.23

#### **Q**

parameter that an Interrogator uses to regulate the probability of Tag response

Note 1 to entry: An Interrogator instructs Tags in an inventory round to load a  $Q$ -bit random (or pseudo-random) number into their slot counter; the Interrogator may also command Tags to decrement their slot counter. Tags reply when the value in their slot counter, i.e. their slot ([3.30](#)), is zero.  $Q$  is an integer in the range (0,15); the corresponding Tag-response probabilities range from  $2^0 = 1$  to  $2^{-15} = 0,000031$ .

### 3.24

#### **removable Tag**

Tag that a consumer can physically detach from an item without special equipment and without compromising the item's intended functionality

Note 1 to entry: See nonremovable Tag ([3.19](#)).

### 3.25

#### **secure communication**

communication in which message confidentiality is protected

### 3.26

#### **security**

degree of protection against threats identified in a security policy

Note 1 to entry: A system is secure if it is protected to the degree specified in the *security policy* ([3.27](#)).

Note 2 to entry: See *security policy* ([3.27](#)).

### 3.27

#### **security policy**

definition, either explicit or implicit, of the threats a system is intended to address

Note 1 to entry: See *security* ([3.26](#)).

### 3.28

#### **session key**

temporary key generated by one or both of Tag and Interrogator and typically used for authenticated and/or secure communications

**3.29****simple sensor functionality**

functionality whereby a sensor provides a valid Simple Sensor data address and transmits Simple Sensor data subsequent to the UII as part of the reply to the *ACK* command

**3.30****slot**

point, in an inventory round, at which a Tag may respond

Note 1 to entry: Slot is the value output by a Tag's slot counter; Tags reply when their slot (i.e. the value in their slot counter) is zero.

Note 2 to entry: See *Q* ([3.23](#)).

**3.31****snapshot sensor**

sensor that makes a measurement during power-up or on demand from an Interrogator

**3.32****tag authentication**

means for an Interrogator to determine, via cryptographic means, that a Tag's identity is as claimed

**3.33****traceable**

not restricting the identifying information that a Tag exposes and/or the Tag's operating range

Note 1 to entry: See *untraceable* ([3.36](#)).

**3.34****untraceable privilege**

privilege given to the access password or to a key that grants an Interrogator using the access password or key the right to access untraceably hidden memory and/or to issue an *Untraceable* command

**3.35****untraceably hidden memory**

memory that an untraceable tag hides from Interrogators with a deasserted untraceable privilege

**3.36****untraceable**

restricting the identifying information that a Tag exposes and/or the Tag's operating range

Note 1 to entry: See *traceable* ([3.33](#)).

## 4 Symbols, abbreviated terms and notation

### 4.1 Symbols

|         |                                                                              |
|---------|------------------------------------------------------------------------------|
| C       | computed-response indicator                                                  |
| F       | file-services indicator (whether a Tag supports the <i>FileOpen</i> command) |
| FrT     | frequency tolerance                                                          |
| FS      | full function sensor indicator                                               |
| FT      | frequency tolerance                                                          |
| H       | hazmat indicator                                                             |
| INACT_T | inactivity threshold                                                         |

|                          |                                                                                                               |
|--------------------------|---------------------------------------------------------------------------------------------------------------|
| K                        | killable indicator                                                                                            |
| $M$                      | number of subcarrier cycles per symbol                                                                        |
| $M_h$                    | 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                                                                                      |
| NR                       | nonremovable Tag indicator                                                                                    |
| 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                                                        |
| S                        | security-services indicator (whether a Tag supports the <i>Challenge</i> and/or <i>Authenticate</i> commands) |
| SA                       | sensor alarm indicator                                                                                        |
| SLI                      | SL indicator                                                                                                  |
| SN                       | snapshot sensor indicator                                                                                     |
| SS                       | simple sensor indicator                                                                                       |
| T                        | numbering system identifier                                                                                   |
| T=>R                     | tag-to-Interrogator (tag-to-reader)                                                                           |
| $T_1$                    | time from Interrogator transmission to Tag response for an <i>immediate</i> Tag reply                         |
| $T_2$                    | 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                                                                    |
| $T_5$                    | time from Interrogator transmission to Tag response for a <i>delayed</i> Tag reply                            |
| $T_6$                    | time from Interrogator transmission to first Tag response for an <i>in-process</i> Tag reply                  |
| $T_7$                    | time between Tag responses for an <i>in-process</i> Tag reply                                                 |
| $T_f$ or $T_{f,10-90\%}$ | RF signal envelope fall time                                                                                  |
| $T_f$                    | 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                         |

|                                          |                                                                                                         |
|------------------------------------------|---------------------------------------------------------------------------------------------------------|
| TN                                       | tag-notification indicator                                                                              |
| $T_{\text{pri}}$                         | backscatter-link pulse-repetition interval ( $T_{\text{pri}} = 1/\text{BLF} = \text{TRcal}/\text{DR}$ ) |
| $T_{\text{r}}$ or $T_{\text{r},10-90\%}$ | RF signal envelope rise time                                                                            |
| $T_{\text{r}}$                           | rise time                                                                                               |
| $T_{\text{RTcal}}$                       | time duration of RTcal                                                                                  |
| $T_{\text{TRcal}}$                       | time duration of TRcal                                                                                  |
| TRcal                                    | tag-to-Interrogator (tag-to-reader) calibration symbol                                                  |
| $T_{\text{s}}$                           | time for an RF signal to settle to within a specified percentage of its final value                     |
| U                                        | untraceability indicator                                                                                |
| UMI                                      | user-memory indicator                                                                                   |
| X                                        | XTID indicator (whether a Tag implements an XTID)                                                       |
| XEB                                      | XPC_W2 indicator                                                                                        |
| $x_{\text{fp}}$                          | floating-point value                                                                                    |
| XI                                       | XPC_W1 indicator                                                                                        |
| $\text{xxxx}_2$                          | binary notation                                                                                         |
| $\text{xxxx}_h$                          | hexadecimal notation                                                                                    |

## 4.2 Abbreviated terms

|      |                                                                                         |
|------|-----------------------------------------------------------------------------------------|
| AC   | activation code                                                                         |
| AFI  | application family identifier                                                           |
| AM   | amplitude modulation                                                                    |
| AMSK | activation mask                                                                         |
| ASIC | application specific integrated circuit                                                 |
| BAM  | battery assisted mode                                                                   |
| BAP  | battery assisted passive                                                                |
| BAT  | battery assisted tag                                                                    |
| BLF  | backscatter-link frequency ( $\text{BLF} = 1/T_{\text{pri}} = \text{DR}/\text{TRcal}$ ) |
| CSI  | cryptographic suite identifier                                                          |
| CW   | continuous wave                                                                         |
| dBch | decibels referenced to the integrated power in the reference channel                    |
| DBR  | dead battery response                                                                   |
| DR   | divide ratio                                                                            |

|         |                                                                               |
|---------|-------------------------------------------------------------------------------|
| FDM     | frequency-Division Multiplexing                                               |
| MAC     | message authentication code                                                   |
| NoS     | number of sensors                                                             |
| NSI     | numbering system identifier                                                   |
| OTP     | one-time programmable                                                         |
| PC      | protocol control                                                              |
| PIE     | pulse interval encoding                                                       |
| pivot   | decision threshold differentiating an R=>T data-0 symbol from a data-1 symbol |
| PM      | passive mode                                                                  |
| ppm     | parts per million                                                             |
| R/W     | read/write                                                                    |
| RNG     | random or pseudo-random number generator                                      |
| RO      | read only                                                                     |
| RTC     | real time clock                                                               |
| SDS     | sensor directory system                                                       |
| SS      | simple sensor                                                                 |
| SSB-ASK | single-sideband amplitude-shift keying                                        |
| SSD     | simple sensor data                                                            |
| TEDS    | transducer electronic data sheet                                              |
| UMI     | user-memory indicator                                                         |
| UTC     | universal coordinated time                                                    |
| XPC_W1  | XPC word 1                                                                    |
| XPC_W2  | XPC word 2                                                                    |
| XTID    | extended tag identifier                                                       |

### 4.3 Notation

This document uses the following notational conventions.

- States and flags are denoted in bold. Some command parameters are also flags; a command parameter used as a flag will be bold. Example: **ready**.
- Command parameters are underlined. Some flags are also command parameters; a flag used as a command parameter will be underlined. Example: Pointer.
- Commands are denoted in italics. Variables are also denoted in italics. Where there might be confusion between commands and variables, this protocol will make an explicit statement. Example: *Query*.

- For logical negation, labels are preceded by ‘~’. Example: If **flag** is true, then **~flag** is false.
- The symbol, R=>T, refers to commands or signaling from an Interrogator to a Tag (Reader-to-Tag).
- The symbol, T=>R, refers to commands or signaling from a Tag to an Interrogator (Tag-to-Reader).
- The term “address” is used as a synonym for “bit address”. All addresses specified 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 Conformance

### 5.1 Claiming conformance

A device shall not claim conformance with this protocol unless the device complies with

- all clauses in this protocol (except those marked as optional), and
- the conformance document associated with this protocol.

It is presupposed that it is operated in accordance with local regulatory requirements.

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

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

### 5.2 General conformance requirements

#### 5.2.1 Interrogators

To conform to this document, an Interrogator shall:

- meet the requirements of this document;
- implement the mandatory commands defined in this document;
- modulate/transmit and receive/demodulate a sufficient set of the electrical signals defined in the signaling layer of this protocol to communicate with conformant Tags.

To conform to this document, an Interrogator may:

- implement any subset of the optional commands defined in this document;
- implement any proprietary and/or custom commands in conformance with this document.

To conform to this document, an Interrogator shall not:

- implement any command that conflicts with this document or any of the parts ISO/IEC 18000-61, ISO/IEC 18000-62 and ISO/IEC 18000-64;
- require using an optional, proprietary, or custom command to meet the requirements of this protocol.

## 5.2.2 Tags

To conform to this document, a Tag shall:

- meet the requirements of this document;
- implement the mandatory commands defined in this document;
- modulate a backscatter signal only after receiving the requisite command from an Interrogator.

To conform to this protocol, a Tag may:

- implement any of the optional Tag features in [Clause 7](#), [Clause 8](#), and [Annex L](#);
- implement any subset of the optional commands defined in this document;
- implement any proprietary and/or custom commands as defined in [5.3.4](#) and [5.3.5](#), respectively.

To conform to this document, a Tag shall not:

- implement any command that conflicts with this document or any of the parts ISO/IEC 18000-61, ISO/IEC 18000-62 and ISO/IEC 18000-64;
- require using an optional, proprietary, or custom command to meet the requirements of this protocol;
- modulate a backscatter signal unless commanded to do so by an Interrogator using the signaling layer defined in this document.

## 5.3 Command structure and extensibility

### 5.3.1 General

This document allows four command types: (1) mandatory, (2) optional, (3) proprietary, and (4) custom. Subclause [6.3.2.12](#) and [Table 6.28](#) define the structure of the command codes used by Interrogators and Tags for each of the four types, as well as the availability of future extensions. All commands defined by this protocol are either mandatory or optional. Proprietary or custom commands are manufacturer-defined.

### 5.3.2 Mandatory commands

Conforming Tags shall support all mandatory commands. Conforming Interrogators shall support all mandatory commands.

### 5.3.3 Optional commands

Conforming Tags may or may not support optional commands. Conforming Interrogators may or may not support optional commands. If a Tag or an Interrogator implements an optional command, then it shall implement it in the manner specified in this protocol.

### 5.3.4 Proprietary commands

Proprietary commands may be enabled in conformance with this protocol but are not specified herein. All proprietary commands shall be capable of being permanently disabled. Proprietary commands are intended for manufacturing purposes and shall not be used in field-deployed RFID systems.

### 5.3.5 Custom commands

Custom commands may be enabled in conformance with this protocol but are not specified herein. An Interrogator shall issue a custom command only after first singulating a Tag, and then reading (or having

prior knowledge of) the Tag manufacturer's identification in the Tag's TID memory. An Interrogator shall use a custom command only in accordance with the specifications of the Tag manufacturer identified in the TID. A custom command shall not solely duplicate the functionality of any mandatory or optional command defined in this protocol by a different method.

## 5.4 Reserved for Future Use (RFU)

This document denotes some Tag memory addresses, Interrogator command codes, and bit fields within Interrogator commands as RFU.

RFU values are reserved for future extensibility. Third parties, including but not limited to solution providers and end users, shall not use these RFU values for proprietary purposes.

## 5.5 Cryptographic Suite Indicators

A Tag may support one or more cryptographic suites. The *Challenge* and *Authenticate* commands include a CSI field that specifies a single cryptographic suite. CSI is an 8-bit field with bit values defined below.

- Four most-significant bits: Cryptographic suite assigning authority, as follows:
  - $0000_2$  to  $0011_2$ : ISO/IEC 29167
  - $0100_2$  to  $1100_2$ : RFU
  - $1101_2$ : Tag manufacturer
  - $1110_2$ : GS1
  - $1111_2$ : RFU
- Four least-significant bits: One of 16 cryptographic suites that the assigning authority may assign.

EXAMPLE     CSI=00000000<sub>2</sub> is the first and CSI=00000001<sub>2</sub> is the second suite that ISO/IEC 29167 may assign.

# 6 Protocol requirements

## 6.1 Protocol overview

### 6.1.1 Physical layer

An Interrogator sends information to one or more Tags by modulating an RF carrier using double-sideband amplitude shift keying (DSB-ASK), single-sideband amplitude shift keying (SSB-ASK), or phase-reversal amplitude shift keying (PR-ASK) using a pulse-interval encoding (PIE) format. Tags receive their operating energy from this same modulated RF carrier.

An Interrogator receives information from a Tag by transmitting an unmodulated RF carrier and listening for a backscattered reply. Tags communicate information by backscatter modulating the amplitude and/or phase of the RF carrier. The encoding format, selected in response to Interrogator commands, is either FM0 or Miller-modulated subcarrier. The communications link between Interrogators and Tags is half-duplex communications, meaning that Tags shall not be required to demodulate Interrogator commands while backscattering. A Tag shall not respond to a mandatory or optional command using full-duplex communications.

### 6.1.2 Tag-identification layer

An Interrogator manages Tag populations using three basic operations:

- a) **Select.** Choosing a Tag population. An Interrogator may use a *Select* command to select one or more Tags based on a value or values in Tag memory and may use a *Challenge* command to challenge one

or more Tags based on Tag support for the desired cryptographic suite and authentication type. An Interrogator may subsequently inventory and access the chosen Tag(s).

- b) **Inventory.** Identifying individual Tags. An Interrogator begins an inventory round by transmitting a *Query* command in one of four sessions. One or more Tags may reply. The Interrogator detects a single Tag reply and requests the Tag's UII. Inventory comprises multiple commands. An inventory round operates in one and only one session at a time.
- c) **Access.** Communicating with an identified Tag. The Interrogator may perform a core operation such as reading, writing, locking, or killing the Tag; a security-related operation such as authenticating the Tag; or a file-related operation such as opening a particular file in the Tag's User memory. Access comprises multiple commands. An Interrogator may only access a uniquely identified Tag.

## 6.2 Protocol parameters

### 6.2.1 Signaling — Physical and media access control parameters

Table 6.1 and Table 6.2 provide an overview of parameters for R=>T and T=>R communications according to this protocol. For those parameters that do not apply to or are not used in this protocol the notation "N/A" indicates that the parameter is "Not Applicable".

**Table 6.1 — Interrogator-to-Tag (R=>T) communications**

| Ref.   | Parameter Name                                                              | Description                                                                                                                     |
|--------|-----------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|
| Int:1  | Operating Frequency Range                                                   | 860 MHz to 960 MHz, as required by local regulations                                                                            |
| Int:1a | Default Operating Frequency                                                 | Determined by local radio regulations and by the radio-frequency environment at the time of the communication                   |
| Int:1b | Operating Channels<br>(spread-spectrum systems)                             | In accordance with local regulations; if the channelization is unregulated, then as specified                                   |
| Int:1c | Operating Frequency Accuracy                                                | As specified                                                                                                                    |
| Int:1d | Frequency Hop Rate<br>(frequency-hopping [FHSS] systems)                    | In accordance with local regulations                                                                                            |
| Int:1e | Frequency Hop Sequence<br>(frequency-hopping [FHSS] systems)                | In accordance with local regulations                                                                                            |
| Int:2  | Occupied Channel Bandwidth                                                  | In accordance with local regulations                                                                                            |
| Int:2a | Minimum Receiver Bandwidth                                                  | In accordance with local regulations                                                                                            |
| Int:3  | Interrogator Transmit Maximum EIRP                                          | In accordance with local regulations                                                                                            |
| Int:4  | Interrogator Transmit Spurious Emissions                                    | As specified; local regulation may impose tighter emission limits                                                               |
| Int:4a | Interrogator Transmit Spurious Emissions, In-Band (spread-spectrum systems) | As specified; local regulation may impose tighter emission limits                                                               |
| Int:4b | Interrogator Transmit Spurious Emissions, Out-of-Band                       | As specified; local regulation may impose tighter emission limits                                                               |
| Int:5  | Interrogator Transmitter Spectrum Mask                                      | As specified; local regulation may impose tighter emission limits                                                               |
| Int:6  | Timing                                                                      | As specified                                                                                                                    |
| Int:6a | Transmit-to-Receive Turn-Around Time                                        | MAX(RT <sub>cal</sub> , 10T <sub>pri</sub> ) nominal                                                                            |
| Int:6b | Receive-to-Transmit Turn-Around Time                                        | 3T <sub>pri</sub> minimum; 20T <sub>pri</sub> maximum when Tag is in <b>reply &amp; acknowledged</b> states; no limit otherwise |
| Int:6c | Dwell Time or Interrogator Transmit Power-On Ramp                           | 1500 µs, maximum settling time                                                                                                  |

Table 6.1 (continued)

| Ref.    | Parameter Name                                         | Description                                        |
|---------|--------------------------------------------------------|----------------------------------------------------|
| Int:6d  | Decay Time or Interrogator Transmit Power-Down Ramp    | 500 $\mu$ s, maximum                               |
| Int:7   | Modulation                                             | DSB-ASK, SSB-ASK, or PR-ASK                        |
| Int:7a  | Spreading Sequence<br>(direct-sequence [DSSS] systems) | N/A                                                |
| Int:7b  | Chip Rate<br>(spread-spectrum systems)                 | N/A                                                |
| Int:7c  | Chip Rate Accuracy<br>(spread-spectrum systems)        | N/A                                                |
| Int:7d  | Modulation Depth                                       | 90 % nominal                                       |
| Int:7e  | Duty Cycle                                             | 48 % to 82.3 % (time the waveform is high)         |
| Int:7f  | FM Deviation                                           | N/A                                                |
| Int:8   | Data Coding                                            | PIE                                                |
| Int:9   | Bit Rate                                               | 26,7 kbps to 128 kbps (assuming equiprobable data) |
| Int:9a  | Bit Rate Accuracy                                      | $\pm 1$ %, minimum                                 |
| Int:10  | Interrogator Transmit Modulation Accuracy              | As specified                                       |
| Int:11  | Preamble                                               | Required                                           |
| Int:11a | Preamble Length                                        | As specified                                       |
| Int:11b | Preamble Waveform(s)                                   | As specified                                       |
| Int:11c | Bit Sync Sequence                                      | None                                               |
| Int:11d | Frame Sync Sequence                                    | Required                                           |
| Int:12  | Scrambling (spread-spectrum systems)                   | N/A                                                |
| Int:13  | Bit Transmission Order                                 | MSB is transmitted first                           |
| Int:14  | Wake-up Process                                        | As specified                                       |
| Int:15  | Polarization                                           | Not specified                                      |

Table 6.2 — Tag-to-Interrogator (T=&gt;R) communications

| Ref.   | Parameter Name                                                    | Description                                              |
|--------|-------------------------------------------------------------------|----------------------------------------------------------|
| Tag:1  | Operating Frequency Range                                         | 860 MHz to 960 MHz, inclusive                            |
| Tag:1a | Default Operating Frequency                                       | Tags respond to Interrogator signals that satisfy Int:1a |
| Tag:1b | Operating Channels<br>(spread-spectrum systems)                   | Tags respond to Interrogator signals that satisfy Int:1b |
| Tag:1c | Operating Frequency Accuracy                                      | As specified                                             |
| Tag:1d | Frequency Hop Rate<br>(frequency-hopping [FHSS] systems)          | Tags respond to Interrogator signals that satisfy Int:1d |
| Tag:1e | Frequency Hop Sequence<br>(frequency-hopping [FHSS] systems)      | Tags respond to Interrogator signals that satisfy Int:1e |
| Tag:2  | Occupied Channel Bandwidth                                        | In accordance with local regulations                     |
| Tag:3  | Transmit Maximum EIRP                                             | In accordance with local regulations                     |
| Tag:4  | Transmit Spurious Emissions                                       | In accordance with local regulations                     |
| Tag:4a | Transmit Spurious Emissions, In-Band<br>(spread-spectrum systems) | In accordance with local regulations                     |

Table 6.2 (continued)

| Ref.    | Parameter Name                                                         | Description                                                                                           |
|---------|------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|
| Tag:4b  | Transmit Spurious Emissions, Out-of-Band                               | In accordance with local regulations                                                                  |
| Tag:5   | Transmit Spectrum Mask                                                 | In accordance with local regulations                                                                  |
| Tag:6a  | Transmit-to-Receive Turn-Around Time                                   | $3T_{pri}$ minimum, $32T_{pri}$ maximum in <b>reply &amp; acknowledged</b> states; no limit otherwise |
| Tag:6b  | Receive-to-Transmit Turn-Around Time                                   | $MAX(RT_{cal}, 10T_{pri})$ nominal                                                                    |
| Tag:6c  | Dwell Time or Transmit Power-On Ramp                                   | Receive commands 1500 $\mu$ s after power-up                                                          |
| Tag:6d  | Decay Time or Transmit Power-Down Ramp                                 | N/A                                                                                                   |
| Tag:7   | Modulation                                                             | ASK and/or PSK modulation (selected by Tag)                                                           |
| Tag:7a  | Spreading Sequence<br>(direct sequence [DSSS] systems)                 | N/A                                                                                                   |
| Tag:7b  | Chip Rate<br>(spread-spectrum systems)                                 | N/A                                                                                                   |
| Tag:7c  | Chip Rate Accuracy<br>(spread-spectrum systems)                        | N/A                                                                                                   |
| Tag:7d  | On-Off Ratio                                                           | Not specified                                                                                         |
| Tag:7e  | Subcarrier Frequency                                                   | 40 kHz to 640 kHz                                                                                     |
| Tag:7f  | Subcarrier Frequency Accuracy                                          | As specified                                                                                          |
| Tag:7g  | Subcarrier Modulation                                                  | Miller, at the data rate                                                                              |
| Tag:7h  | Duty Cycle                                                             | FM0: 50 %, nominal<br>Subcarrier: 50 %, nominal                                                       |
| Tag:7i  | FM Deviation                                                           | N/A                                                                                                   |
| Tag:8   | Data Coding                                                            | Baseband FM0 or Miller-modulated subcarrier (selected by the Interrogator)                            |
| Tag:9   | Bit Rate                                                               | FM0: 40 kbps to 640 kbps<br>Subcarrier modulated: 5 kbps to 320 kbps                                  |
| Tag:9a  | Bit Rate Accuracy                                                      | Same as Subcarrier Frequency Accuracy; see Tag:7f                                                     |
| Tag:10  | Tag Transmit Modulation Accuracy<br>(frequency-hopping [FHSS] systems) | N/A                                                                                                   |
| Tag:11  | Preamble                                                               | Required                                                                                              |
| Tag:11a | Preamble Length                                                        | As specified                                                                                          |
| Tag:11b | Preamble Waveform                                                      | As specified                                                                                          |
| Tag:11c | Bit-Sync Sequence                                                      | None                                                                                                  |
| Tag:11d | Frame-Sync Sequence                                                    | None                                                                                                  |
| Tag:12  | Scrambling<br>(spread-spectrum systems)                                | N/A                                                                                                   |
| Tag:13  | Bit Transmission Order                                                 | MSB is transmitted first                                                                              |
| Tag:14  | Reserved                                                               | Deliberately left blank                                                                               |
| Tag:15  | Polarization                                                           | Tag dependent; not specified by this protocol                                                         |
| Tag:16  | Minimum Tag Receiver Bandwidth                                         | Tag dependent; not specified by this protocol.                                                        |

## 6.2.2 Logical — Operating procedure parameters

Table 6.3 and Table 6.4 identify and describe parameters used by an Interrogator during the selection, inventory, and access of Tags according to this protocol. For those parameters that do not apply to or are not used in this protocol the notation “N/A” indicates that the parameter is “Not Applicable”.

**Table 6.3 — Tag inventory and access parameters**

| Ref. | Parameter name                      | Description                                                                                                                                                                                                                                                                                                                                             |
|------|-------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| P:1  | Who Talks First                     | Interrogator                                                                                                                                                                                                                                                                                                                                            |
| P:2  | Tag Addressing Capability           | As specified                                                                                                                                                                                                                                                                                                                                            |
| P:3  | Tag UII                             | Contained in Tag memory                                                                                                                                                                                                                                                                                                                                 |
| P:3a | UII Length                          | As specified                                                                                                                                                                                                                                                                                                                                            |
| P:3b | UII Format                          | T=0 <sub>2</sub> : As specified in the EPC Tag Data Standard,<br>T=1 <sub>2</sub> : As specified in the ISO/IEC 15961 series                                                                                                                                                                                                                            |
| P:4  | Read size                           | Multiples of 16 bits                                                                                                                                                                                                                                                                                                                                    |
| P:5  | Write Size                          | Multiples of 16 bits                                                                                                                                                                                                                                                                                                                                    |
| P:6  | Read Transaction Time               | Varied with R=>T & T=>R link rate and number of bits being read                                                                                                                                                                                                                                                                                         |
| P:7  | Write Transaction Time              | 20 ms (maximum) after end of <i>Write</i> command                                                                                                                                                                                                                                                                                                       |
| P:8  | Error Detection                     | Interrogator-to-Tag:<br><i>Select</i> and <i>Challenge</i> commands: 16-bit CRC<br><i>Query</i> command: 5-bit CRC<br>Other Inventory commands: Command length<br>Access commands: 16-bit CRC<br>Tag-to-Interrogator:<br>PC/XPC, UII: 16-bit CRC<br>RN16: None or 16-bit CRC (varies by command)<br><i>handle</i> : 16-bit CRC<br>All other: 16-bit CRC |
| P:9  | Error Correction                    | None                                                                                                                                                                                                                                                                                                                                                    |
| P:10 | Memory Size                         | Tag dependent, extensible (size is neither limited nor specified by this protocol)                                                                                                                                                                                                                                                                      |
| P:11 | Command Structure and Extensibility | As specified                                                                                                                                                                                                                                                                                                                                            |

**Table 6.4 — Collision management parameters**

| Ref. | Parameter name                        | Description                                                                                                          |
|------|---------------------------------------|----------------------------------------------------------------------------------------------------------------------|
| A:1  | Type (Probabilistic or Deterministic) | Probabilistic                                                                                                        |
| A:2  | Linearity                             | Linear up to 2 <sup>15</sup> Tags in the Interrogator's RF field; above that number, NlogN for Tags with unique UIIs |
| A:3  | Tag Inventory Capacity                | Unlimited for Tags with unique UIIs                                                                                  |

## 6.3 Description of operating procedure

The operating procedure defines the physical and logical requirements for an Interrogator-talks-first, random-slotted collision arbitration, RFID system operating in the 860 MHz to 960 MHz frequency range.

### 6.3.1 Physical interface

The physical interface between an Interrogator and a Tag may be viewed as the signaling layer in a layered network communication system. The signaling interface defines frequencies, modulation, data coding, RF envelope, data rates, and other parameters required for RF communications.

#### 6.3.1.1 Operational frequencies

Tags shall receive power from and communicate with Interrogators within the frequency range from 860 MHz to 960 MHz, inclusive. An Interrogator's choice of operational frequency will be determined by local radio regulations and by the local radio-frequency environment. Interrogators certified for operation in dense-Interrogator environments shall support, but are not required to always use, the optional dense-Interrogator mode described in [Annex G](#).

#### 6.3.1.2 Interrogator-to-Tag (R=>T) communications

An Interrogator communicates with one or more Tags by modulating an RF carrier using DSB-ASK, SSB-ASK, or PR-ASK with PIE encoding. Interrogators shall use a fixed modulation format and data rate for the duration of an inventory round, where "inventory round" is defined in ISO/IEC 19762. The Interrogator sets the data rate by means of the preamble that initiates the inventory round.

The high values in [Figure 6.1](#), [Figure 6.2](#), [Figure 6.3](#), [Figure 6.4](#), and [Figure 6.5](#) correspond to emitted CW (i.e. an Interrogator delivering power to the Tag or Tags) whereas the low values correspond to attenuated CW.

##### 6.3.1.2.1 Interrogator frequency accuracy

Interrogators certified for operation in single- or multiple-Interrogator environments shall have a frequency accuracy that meets local regulations.

Interrogators certified for operation in dense-Interrogator environments shall have a frequency accuracy of  $\pm 10$  ppm over the nominal temperature range ( $-25$  °C to  $+40$  °C) and  $\pm 20$  ppm over the extended temperature range ( $-40$  °C to  $+65$  °C). Interrogators rated by the manufacturer to have a temperature range wider than nominal but different from extended shall have a frequency accuracy of  $\pm 10$  ppm over the nominal temperature range and  $\pm 20$  ppm to the extent of their rated range. If local regulations specify tighter frequency accuracy then the Interrogator shall meet the local regulations.

##### 6.3.1.2.2 Modulation

Interrogators shall communicate using DSB-ASK, SSB-ASK, or PR-ASK modulation, detailed in [Annex H](#). Tags shall demodulate all three modulation types.

##### 6.3.1.2.3 Data encoding

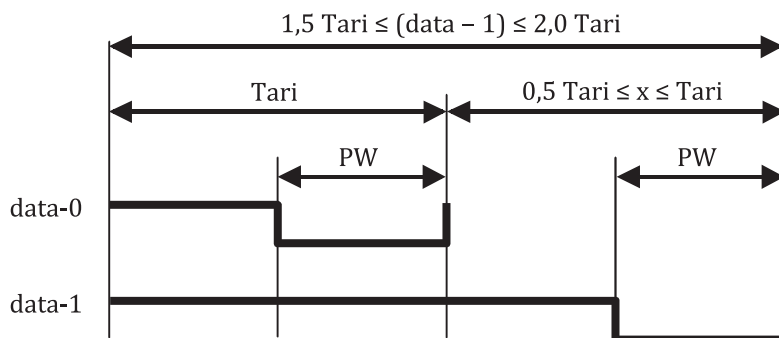


Figure 6.1 — PIE symbols

The R=>T link shall use PIE, shown in [Figure 6.1](#). Tari is the reference time interval for Interrogator-to-Tag signaling and is the duration of a data-0. High values represent transmitted CW; low values represent attenuated CW. Pulse modulation depth, rise time, fall time, and PW shall be as specified in [Table 6.5](#), and shall be the same for a data-0 and a data-1. Interrogators shall use a fixed modulation depth, rise time, fall time, PW, Tari, data-0 length, and data-1 length for the duration of an inventory round. The RF envelope shall be as specified in [Figure 6.2](#).

#### 6.3.1.2.4 Tari values

Interrogators shall communicate using Tari values in the range of 6,25  $\mu\text{s}$  to 25  $\mu\text{s}$ . Interrogator compliance shall be evaluated using at least one Tari value between 6,25  $\mu\text{s}$  and 25  $\mu\text{s}$  with at least one value of the parameter x. The tolerance on all parameters specified in units of Tari shall be  $\pm 1\%$ . The choice of Tari value and x shall be in accordance with local radio regulations.

#### 6.3.1.2.5 R=>T RF envelope

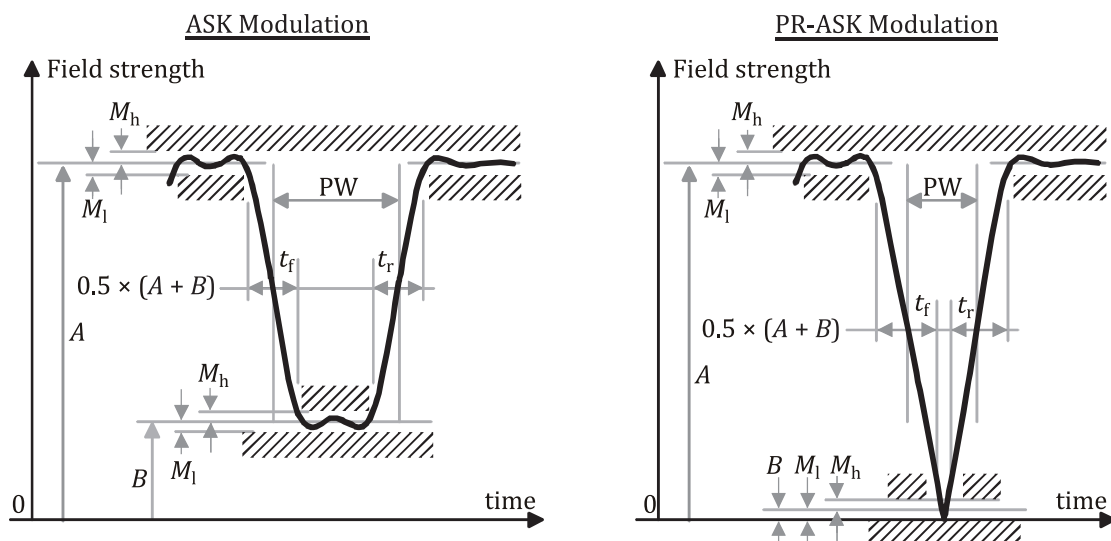


Figure 6.2 — Interrogator-to-Tag RF envelope

Table 6.5 — RF envelope parameters

| Tari                                         | Parameter             | Symbol          | Minimum                           | Nominal | Maximum              | Units         |
|----------------------------------------------|-----------------------|-----------------|-----------------------------------|---------|----------------------|---------------|
| 6,25 $\mu\text{s}$<br>to<br>25 $\mu\text{s}$ | Modulation Depth      | $(A-B)/A$       | 80                                | 90      | 100                  | %             |
|                                              | RF Envelope Ripple    | $M_h = M_l$     | 0                                 |         | $0,05(A-B)$          | V/m or A/m    |
|                                              | RF Envelope Rise Time | $T_{r,10-90\%}$ | 0                                 |         | $0,33 \text{ Tari}$  | $\mu\text{s}$ |
|                                              | RF Envelope Fall Time | $T_{f,10-90\%}$ | 0                                 |         | $0,33 \text{ Tari}$  | $\mu\text{s}$ |
|                                              | RF Pulsewidth         | PW              | $\text{MAX}(0,265\text{Tari}, 2)$ |         | $0,525 \text{ Tari}$ | $\mu\text{s}$ |

The R=>T RF envelope shall comply with [Figure 6.2](#) and [Table 6.5](#). The electric or magnetic field strength A (as appropriate) is the maximum amplitude of the RF envelope, measured in units of V/m or A/m, respectively. Tari is defined in [Figure 6.1](#). The pulsewidth is measured at the 50 % point on the pulse. An Interrogator shall not change the R=>T modulation type (i.e. shall not switch between DSB-ASK, SSB-ASK, or PR-ASK) without first powering down its RF waveform (see [6.3.1.2.7](#)).

#### 6.3.1.2.6 Interrogator power-up waveform

The Interrogator power-up RF envelope shall comply with [Figure 6.3](#) and [Table 6.6](#). Once the carrier level has risen above the 10 % level, the power-up envelope shall rise monotonically until at least

the ripple limit  $M_l$ . The RF envelope shall not fall below the 90 % point in Figure 6.3 during interval  $T_s$ . Interrogators shall not issue commands before the end of the maximum settling-time interval in Table 6.6 (i.e. before the end of  $T_s$ ). Interrogators shall meet the frequency-accuracy requirement specified in 6.3.1.2.1 by the end of interval  $T_s$  in Figure 6.3.

#### 6.3.1.2.7 Interrogator power-down waveform

The Interrogator power-down RF envelope shall comply with Figure 6.3 and Table 6.7. Once the carrier level has fallen below the 90 % level, the power-down envelope shall fall monotonically until the power-off limit  $M_s$ . Once powered off, an Interrogator shall remain powered off for a least 1 ms before powering up again.

#### 6.3.1.2.8 R=>T preamble and frame-sync

An Interrogator shall begin all R=>T signaling with either a preamble or a frame-sync, both of which are shown in Figure 6.4. A preamble shall precede a *Query* command (see 6.3.2.12.2.1) and denotes the start of an inventory round. All other signaling shall begin with a frame-sync. The tolerance on all parameters specified in units of Tari shall be  $\pm 1$  %. PW shall be as specified in Table 6.5. The RF envelope shall be as specified in Figure 6.2.

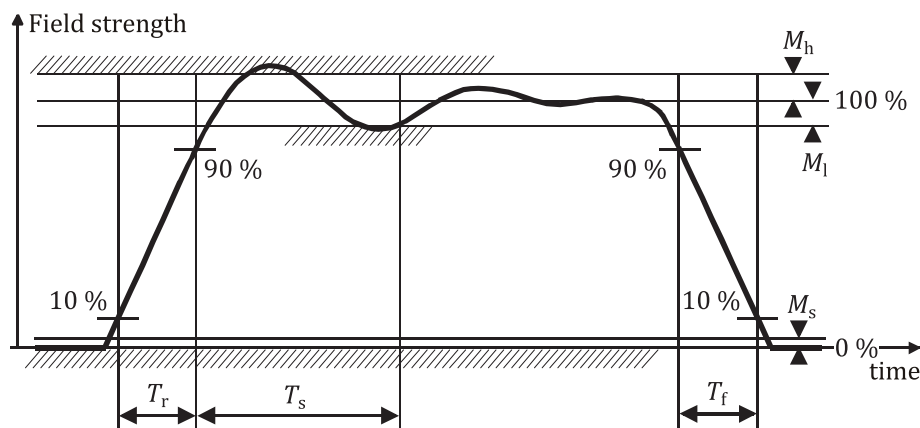


Figure 6.3 — Interrogator power-up and power-down RF envelope

Table 6.6 — Interrogator power-up waveform parameters

| Parameter | Definition            | Minimum | Nominal | Maximum | Units         |
|-----------|-----------------------|---------|---------|---------|---------------|
| $T_r$     | Rise time             | 1       |         | 500     | $\mu\text{s}$ |
| $T_s$     | Settling time         |         |         | 1500    | $\mu\text{s}$ |
| $M_s$     | Signal level when OFF |         |         | 1       | % full scale  |
| $M_l$     | Undershoot            |         |         | 5       | % full scale  |
| $M_h$     | Overshoot             |         |         | 5       | % full scale  |

Table 6.7 — Interrogator power-down waveform parameters

| Parameter | Definition            | Minimum | Nominal | Maximum | Units         |
|-----------|-----------------------|---------|---------|---------|---------------|
| $T_f$     | Fall time             | 1       |         | 500     | $\mu\text{s}$ |
| $M_s$     | Signal level when OFF |         |         | 1       | % full scale  |
| $M_l$     | Undershoot            |         |         | 5       | % full scale  |
| $M_h$     | Overshoot             |         |         | 5       | % full scale  |

A preamble shall comprise a fixed-length start delimiter, a data-0 symbol, an R=>T calibration (RTcal) symbol, and a T=>R calibration (TRcal) symbol.

- **RTcal:** An Interrogator shall set RTcal equal to the length of a data-0 symbol plus the length of a data-1 symbol ( $RTcal = 0_{length} + 1_{length}$ ). A Tag shall measure the length of RTcal and compute *pivot* = RTcal / 2. A Tag shall interpret subsequent Interrogator symbols shorter than *pivot* to be data-0s, and subsequent Interrogator symbols longer than *pivot* to be data-1s. A Tag shall interpret symbols longer than 4 RTcal to be invalid. Prior to changing RTcal, an Interrogator shall transmit CW for a minimum of 8 RTcal.
- **TRcal:** An Interrogator shall specify a Tag's backscatter-link frequency (its FM0 datarate or the frequency of its Miller subcarrier) using the TRcal and divide ratio (DR) in the preamble and payload, respectively, of a *Query* command that initiates an inventory round. [Formula \(1\)](#) specifies the relationship between the backscatter-link frequency (BLF), TRcal, and DR. A Tag shall measure the length of TRcal, compute BLF, and adjust its T=>R link rate to be equal to BLF ([Table 6.9](#) shows BLF values and tolerances). The TRcal and RTcal that an Interrogator uses in any inventory round shall meet the constraints in [Formula \(2\)](#):

$$f_{BLF} = n_{DR} / T_{TRcal} \quad (1)$$

where

$f_{BLF}$  is the backscatter-link frequency;

$n_{DR}$  is the divide ratio;

$T_{TRcal}$  is the time duration of TRcal.

$$1,1 \times T_{RTcal} \leq T_{TRcal} \leq 3 \times T_{RTcal} \quad (2)$$

where

$T_{RTcal}$  is the time duration of RTcal;

$T_{TRcal}$  is the time duration of TRcal.

A frame-sync is identical to a preamble, minus the TRcal symbol. An Interrogator, for the duration of an inventory round, shall use the same length RTcal in a frame-sync as it used in the preamble that initiated the round.

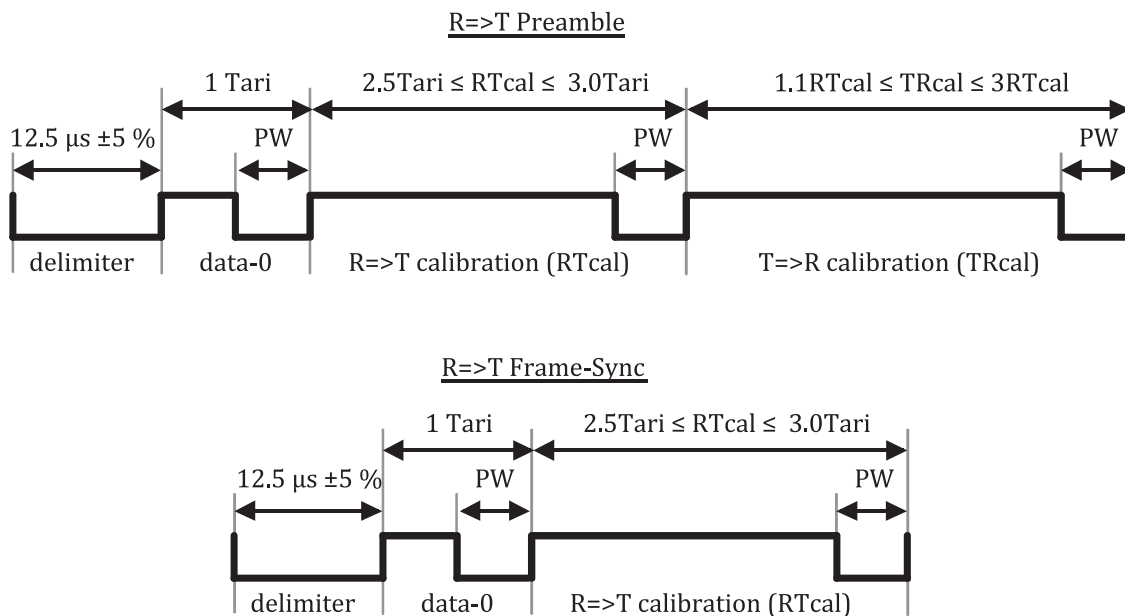


Figure 6.4 — R=>T preamble and frame-sync

#### 6.3.1.2.9 Frequency-hopping spread-spectrum waveform

When an Interrogator uses frequency-hopping spread spectrum (FHSS) signaling, the Interrogator's RF envelope shall comply with [Figure 6.5](#) and [Table 6.8](#). The RF envelope shall not fall below the 90 % point in [Figure 6.5](#) during interval  $T_{hs}$ . Interrogators shall not issue commands before the end of the maximum settling-time interval in [Table 6.8](#) (i.e. before the end of  $T_{hs}$ ). The maximum time between frequency hops and the minimum RF-off time during a hop shall meet local regulatory requirements. Interrogators shall meet the frequency-accuracy requirement specified in [6.3.1.2.1](#) by the end of interval  $T_{hs}$  in [Figure 6.5](#).

#### 6.3.1.2.10 Frequency-hopping spread-spectrum channelization

Interrogators certified for operation in single-Interrogator environments shall meet local regulations for spread-spectrum channelization. Interrogators certified for operation in multiple- or dense-Interrogator environments shall meet local regulations for spread-spectrum channelization, unless the channelization is unregulated. In which case Interrogators should adopt a channel plan that fits for the chosen regulatory region (see also [Annex G](#), which describes multiple- and dense-Interrogator channelized signaling).

#### 6.3.1.2.11 Transmit mask

Interrogators certified for operation according to this protocol shall meet local regulations for out-of-channel and out-of-band spurious radio-frequency emissions.

Interrogators certified for operation in multiple-Interrogator environments shall meet both local regulations and the Multiple-Interrogator Transmit Mask described below and shown in [Figure 6.6](#).

**Multiple-Interrogator Transmit Mask:** For an Interrogator transmitting random data in channel  $R$ , and any other channel  $S \neq R$ , the ratio of the integrated power  $P()$  in channel  $S$  to that in channel  $R$  shall not exceed the specified values:

- $|R - S| = 1$ :  $10\log_{10}(P(S) / P(R)) < -20$  dB
- $|R - S| = 2$ :  $10\log_{10}(P(S) / P(R)) < -50$  dB
- $|R - S| = 3$ :  $10\log_{10}(P(S) / P(R)) < -60$  dB

—  $|R - S| > 3$ :  $10\log_{10}(P(S) / P(R)) < -65$  dB

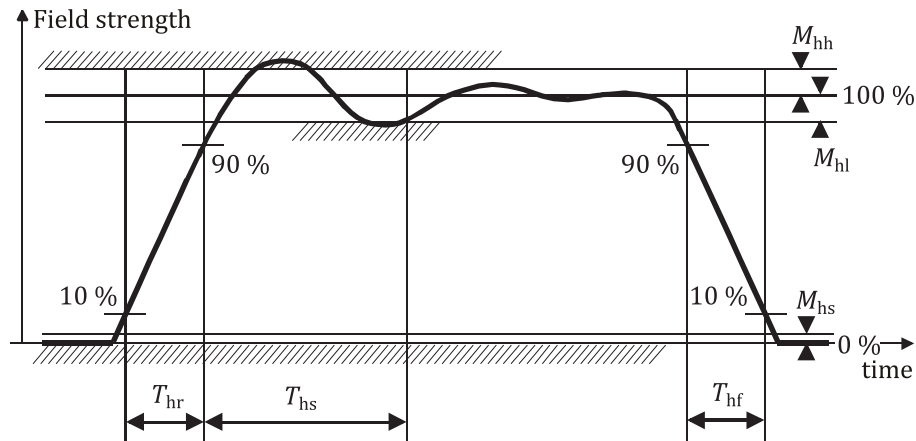


Figure 6.5 — FHSS Interrogator RF envelope

Table 6.8 — FHSS waveform parameters

| Parameter | Definition              | Minimum | Nominal | Maximum | Units        |
|-----------|-------------------------|---------|---------|---------|--------------|
| $T_{hr}$  | Rise time               |         |         | 500     | $\mu$ s      |
| $T_{hs}$  | Settling time           |         |         | 1 500   | $\mu$ s      |
| $T_{hf}$  | Fall time               |         |         | 500     | $\mu$ s      |
| $M_{hs}$  | Signal level during hop |         |         | 1       | % full scale |
| $M_{hl}$  | Undershoot              |         |         | 5       | % full scale |
| $M_{hh}$  | Overshoot               |         |         | 5       | % full scale |

Where  $P()$  denotes the total integrated power in the specified channel. This mask is shown graphically in [Figure 6.6](#), with dBch defined as dB referenced to the integrated power in the reference channel. The channel width shall be as specified by local regulations, unless the width is unregulated, in which case Interrogators should adopt a suitable width for the chosen regulatory region. The channel spacing shall be set equal to the channel width (measured channel center to channel center). For any transmit channel  $R$ , two exceptions to the mask are permitted, provided that

- neither exception exceeds -50 dBch;
- neither exception exceeds local regulatory requirements.

An exception occurs when the integrated power in a channel  $S$  exceeds the mask. Each channel that exceeds the mask shall be counted as an exception.

Interrogators certified for operation in dense-Interrogator environments shall meet both local regulations and the Dense-Interrogator Transmit Mask described below and shown in [Figure 6.7](#). Interrogators may meet the Dense-Interrogator Transmit Mask during non-dense-Interrogator operation. Regardless of the mask used, Interrogators certified for operation in dense-Interrogator environments shall not be permitted the two exceptions to the transmit mask that are allowed for Interrogators certified for operation in multiple-Interrogator environments.

**Dense-Interrogator Transmit Mask:** For Interrogator transmissions centered at a frequency  $f_c$ , a  $2,5/T_{ari}$  bandwidth  $R_{BW}$  also centered at  $f_c$ , an offset frequency  $f_o = 2,5/T_{ari}$ , and a  $2,5/T_{ari}$  bandwidth  $S_{BW}$  centered at  $(n \times f_o) + f_c$  (integer  $n$ ), the ratio of the integrated power  $P()$  in  $S_{BW}$  to that in  $R_{BW}$  with the Interrogator transmitting random data shall not exceed the specified values:

- $|n| = 1$ :  $10\log_{10}(P(S_{BW}) / P(R_{BW})) < -30$  dB
- $|n| = 2$ :  $10\log_{10}(P(S_{BW}) / P(R_{BW})) < -60$  dB

—  $|n| > 2$ :  $10\log_{10}(P(S_{BW}) / P(R_{BW})) < -65$  dB

Where  $P()$  denotes the total integrated power in the  $2,5/T_{ari}$  reference bandwidth. This mask is shown graphically in [Figure 6.7](#), with dBch defined as dB referenced to the integrated power in the reference channel.

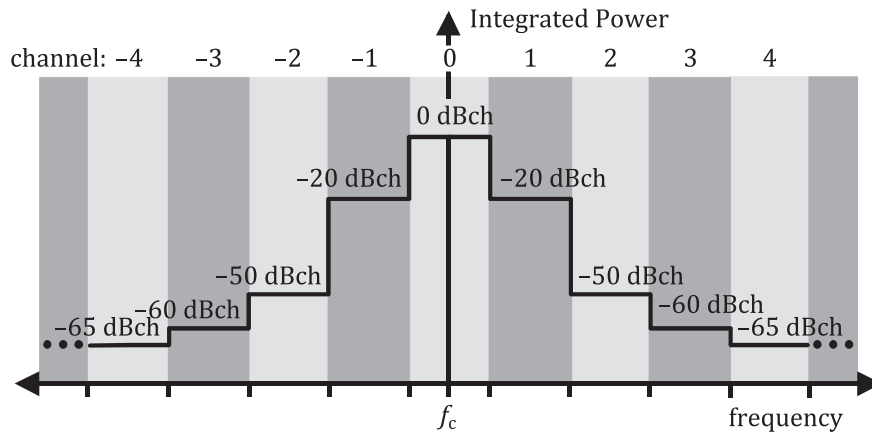


Figure 6.6 — Transmit mask for multiple-Interrogator environments

### 6.3.1.3 Tag-to-Interrogator (T=>R) communications

A Tag communicates with an Interrogator using backscatter modulation, in which the Tag switches the reflection coefficient of its antenna between two states in accordance with the data being sent.

A Tag shall backscatter using a fixed modulation format, data encoding, and data rate for the duration of an inventory round, where “inventory round” is defined in ISO/IEC 19762. The Tag selects the modulation format; the Interrogator selects the data encoding and data rate by means of the *Query* command that initiates the round. The low values in [Figure 6.9](#), [Figure 6.10](#), [Figure 6.11](#), [Figure 6.13](#), [Figure 6.14](#), and [Figure 6.15](#) correspond to the antenna-reflectivity state the Tag exhibits during the CW period prior to a T=>R preamble (e.g. ASK Tag absorbing power), whereas the high values correspond to the antenna-reflectivity state the Tag exhibits during the first high pulse of a T=>R preamble (e.g. ASK Tag reflecting power).

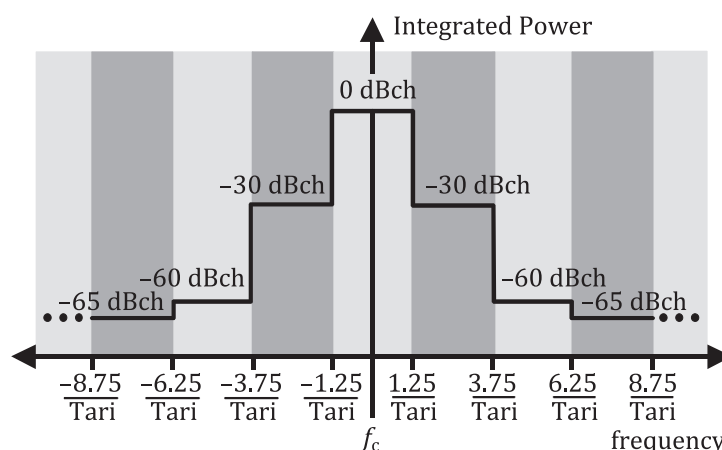


Figure 6.7 — Transmit mask for dense-Interrogator environments

#### 6.3.1.3.1 Modulation

Tag backscatter shall use ASK and/or PSK modulation. The Tag manufacturer selects the modulation format. Interrogators shall demodulate both modulation types.

### 6.3.1.3.2 Data encoding

Tags shall encode the backscattered data as either FM0 baseband or Miller modulation of a subcarrier at the data rate. The Interrogator specifies the encoding type.

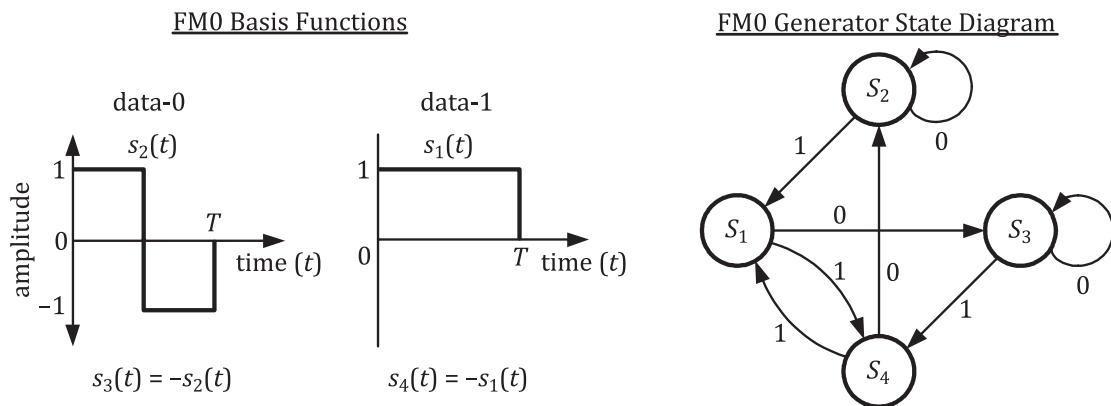


Figure 6.8 — FM0 basis functions and generator state diagram

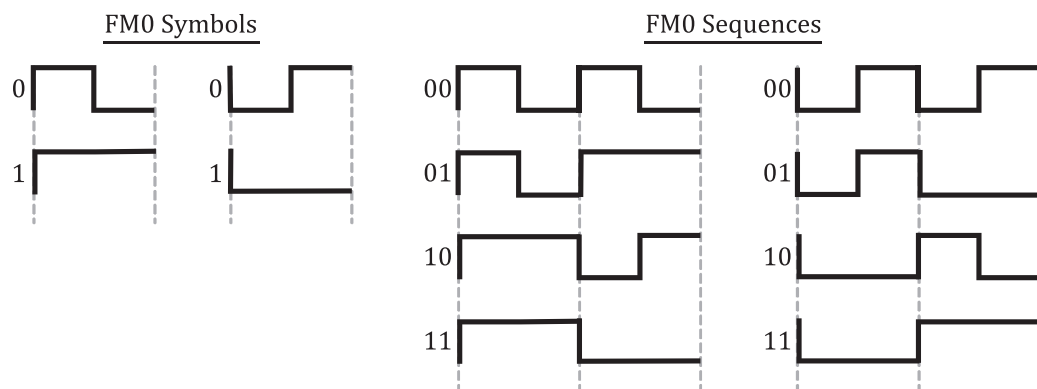


Figure 6.9 — FM0 symbols and sequences

#### 6.3.1.3.2.1 FM0 baseband

Figure 6.8 shows basis functions and a state diagram for generating FM0 (bi-phase space) encoding. FM0 inverts the baseband phase at every symbol boundary; a data-0 has an additional mid-symbol phase inversion. The state diagram in Figure 6.8 maps a logical data sequence to the FM0 basis functions that are transmitted. The state labels,  $S_1$  to  $S_4$ , indicate four possible FM0-encoded symbols, represented by the two phases of each of the FM0 basis functions. The state labels also represent the FM0 waveform that is transmitted upon entering the state. The labels on the state transitions indicate the logical values of the data sequence to be encoded. For example, a transition from state  $S_2$  to  $S_3$  is disallowed because the resulting transmission would not have a phase inversion on a symbol boundary.

Figure 6.9 shows generated baseband FM0 symbols and sequences. The duty cycle of a 00 or 11 sequence, measured at the modulator output, shall be a minimum of 45 % and a maximum of 55 %, with a nominal value of 50 %. FM0 encoding has memory; consequently, the choice of FM0 sequences in Figure 6.9 depends on prior transmissions. FM0 signaling shall always end with a “dummy” data-1 bit at the end of a transmission, as shown in Figure 6.10.

#### 6.3.1.3.2.2 FM0 preamble

T=>R FM0 signaling shall begin with one of the two preambles shown in Figure 6.11. The choice depends on the *TRExt* value specified in the *Query* that initiated the inventory round, unless a Tag is replying to a command that uses a *delayed* or *in-process* reply (see 6.3.1.6), in which case a Tag shall use the extended

preamble regardless of  $T_{\text{Rext}}$  (i.e. a Tag replies as if  $T_{\text{Rext}}=1$  regardless of the  $T_{\text{Rext}}$  value specified in the *Query*—see 6.3.2.12.2.1). The “v” shown in Figure 6.11 indicates an FM0 violation (i.e. a phase inversion should have occurred but did not).

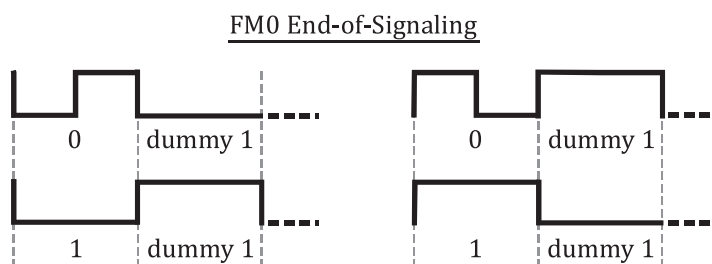


Figure 6.10 — Terminating FM0 transmissions

### 6.3.1.3.2.3 Miller-modulated subcarrier

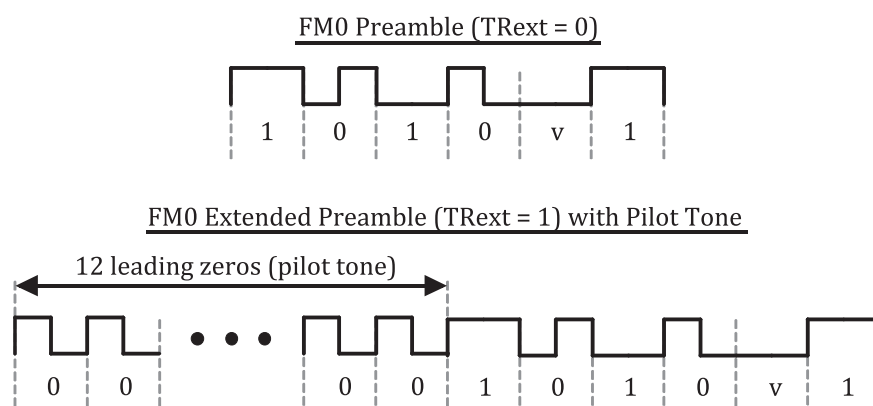


Figure 6.11 — FM0 T=>R preamble

Figure 6.12 shows basis functions and a state diagram for generating Miller encoding. Baseband Miller inverts its phase between two data-0s in sequence. Baseband Miller also places a phase inversion in the middle of a data-1 symbol. The state diagram in Figure 6.12 maps a logical data sequence to baseband Miller basis functions. The state labels,  $S_1$  to  $S_4$ , indicate four possible Miller-encoded symbols, represented by the two phases of each of the Miller basis functions. The state labels also represent the baseband Miller waveform that is generated upon entering the state. The transmitted waveform is the baseband waveform multiplied by a square-wave at  $M$  times the symbol rate. The labels on the state transitions indicate the logical values of the data sequence to be encoded. For example, a transition from state  $S_1$  to  $S_3$  is disallowed because the resulting transmission would have a phase inversion on a symbol boundary between a data-0 and a data-1.

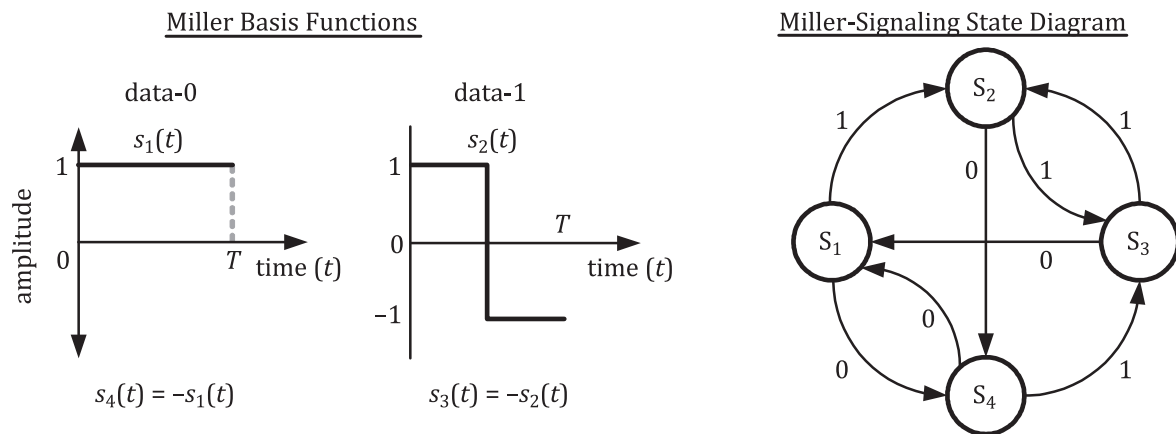


Figure 6.12 — Miller basis functions and generator state diagram

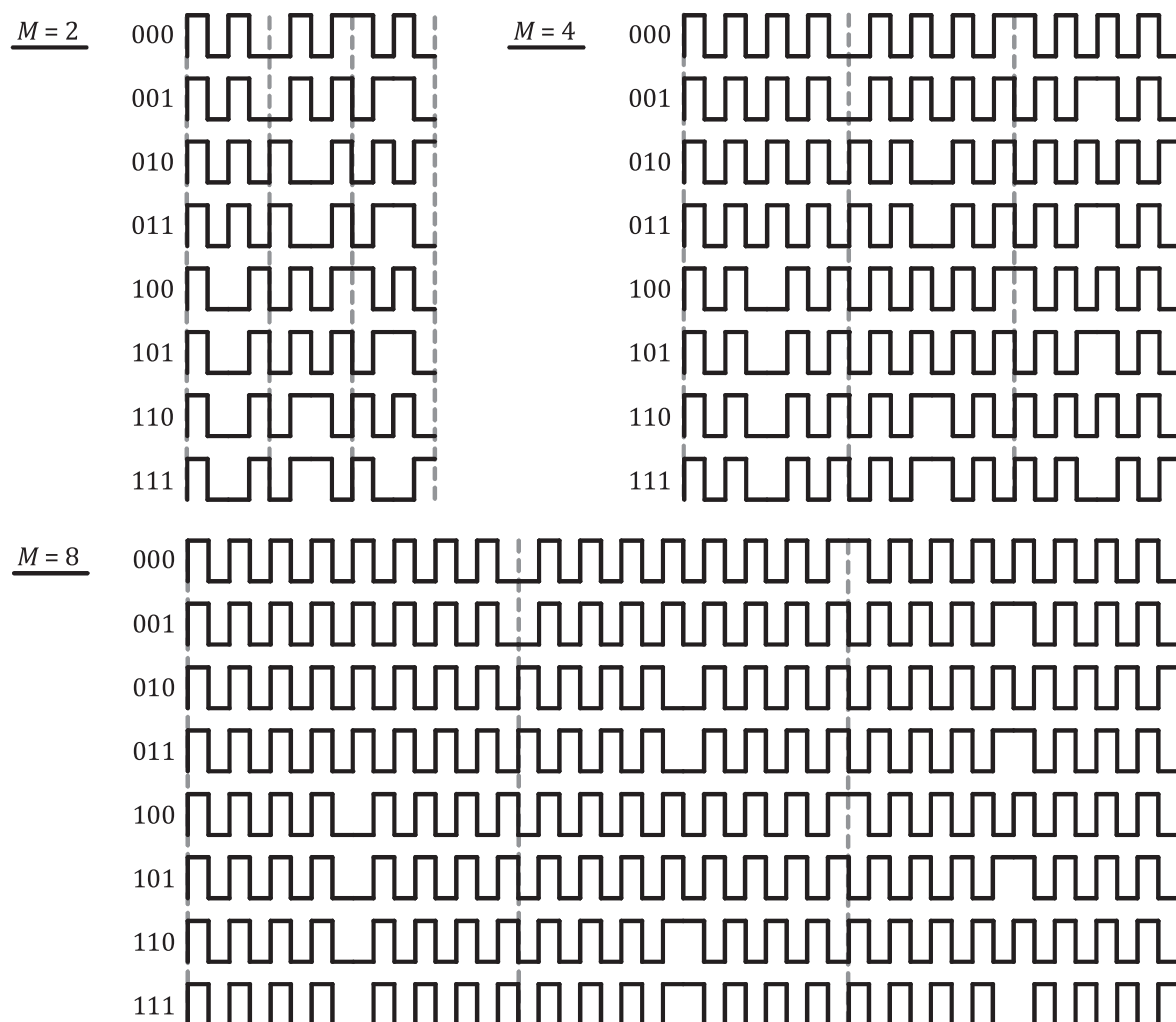


Figure 6.13 — Miller subcarrier sequences

Figure 6.13 shows Miller-modulated subcarrier sequences; the Miller sequence shall contain exactly two, four, or eight subcarrier cycles per bit, depending on the  $M$  value specified in the *Query* command that initiated the inventory round (see Table 6.10). The duty cycle of a 0 or 1 symbol, measured at the modulator output, shall be a minimum of 45 % and a maximum of 55 %, with a nominal value of 50 %. Miller encoding has memory; consequently, the choice of Miller sequences in Figure 6.13 depends

on prior transmissions. Miller signaling shall always end with a “dummy” data-1 bit at the end of a transmission, as shown in [Figure 6.13](#).

#### 6.3.1.3.2.4 Miller subcarrier preamble

T=>R subcarrier signaling shall begin with one of the two preambles shown in [Figure 6.15](#). The choice depends on the **TRext** value specified in the *Query* that initiated the inventory round, unless a Tag is replying to a command that uses a *delayed* or *in-process* reply (see [6.3.1.6](#)), in which case a Tag shall use the extended preamble regardless of **TRext** (i.e. a Tag replies as if **TRext**=1 regardless of the **TRext** value specified in the *Query*, see [6.3.2.12.2.1](#)).

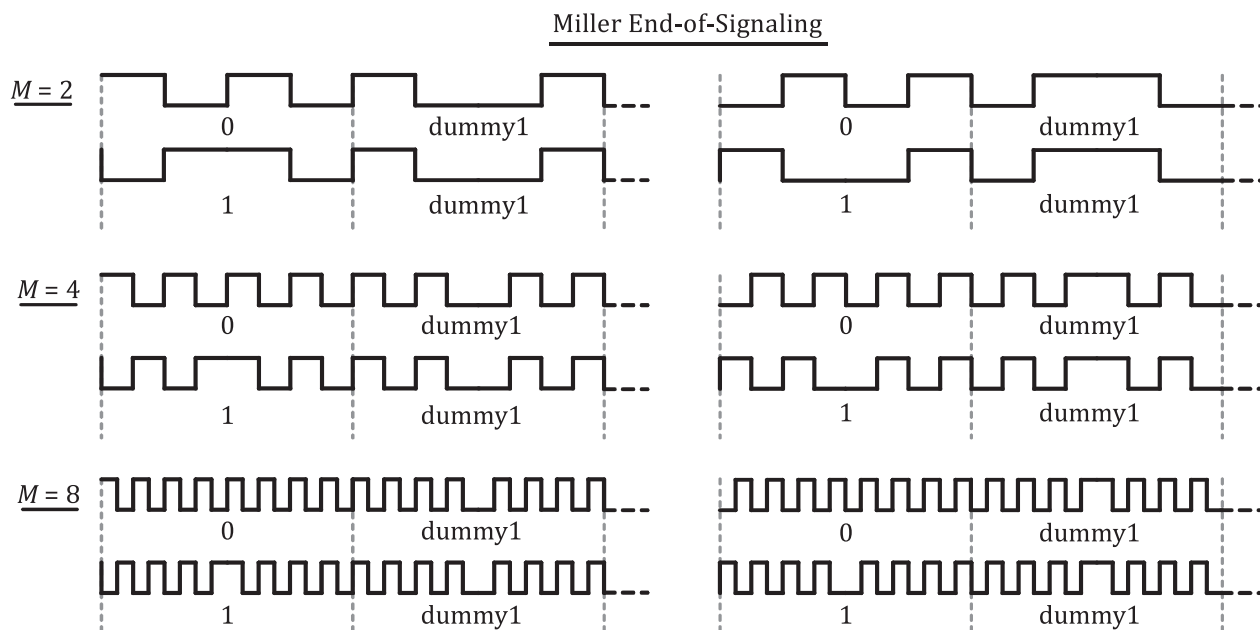


Figure 6.14 — Terminating subcarrier transmissions

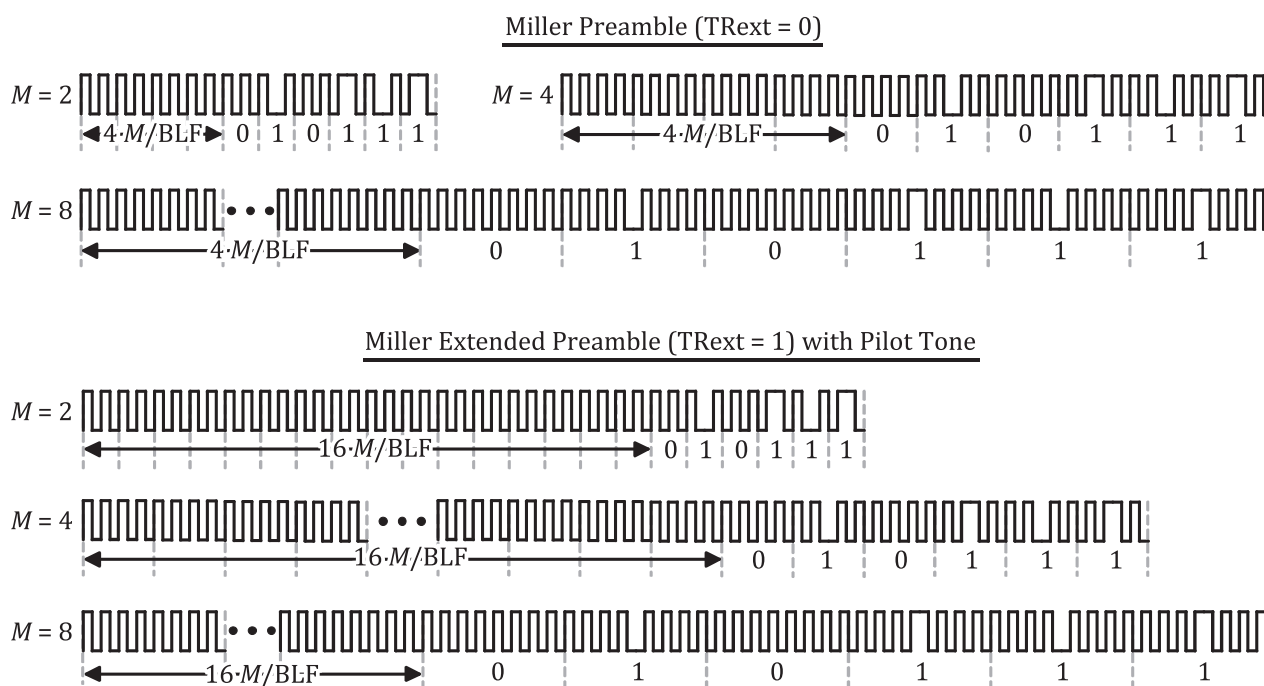


Figure 6.15 — Subcarrier T=>R preamble

### 6.3.1.3.3 Tag supported Tari values and backscatter-link rates

Tags shall support all  $R \Rightarrow T$  Tari values in the range of 6,25  $\mu\text{s}$  to 25  $\mu\text{s}$ , over all parameters allowed by 6.3.1.2.3.

Tags shall support the  $T \Rightarrow R$  link frequencies and tolerances specified in Table 6.9 and the  $T \Rightarrow R$  data rates specified in Table 6.10. The frequency-variation requirement in Table 6.9 includes both frequency drift and short-term frequency variation during Tag response to an Interrogator command. The *Query* command that initiates an inventory round specifies  $\underline{DR}$  in Table 6.9 and  $\underline{M}$  in Table 6.10; the preamble that precedes the *Query* specifies TRcal. BLF is computed using Formula (1). These four parameters together define the backscatter-link frequency, modulation type (FM0 or Miller), and  $T \Rightarrow R$  data rate for the round (see also 6.3.1.2.8).

**Table 6.9 — Tag-to-Interrogator link frequencies**

| DR: Di-<br>vide ratio | TRcal <sup>1</sup><br>( $\mu\text{s} \pm 1\%$ ) | BLF: Link<br>frequency (kHz) | Frequency<br>tolerance FrT<br>(nominal temp) | Frequency toler-<br>ance FrT (extend-<br>ed temp) | Frequency vari-<br>ation during<br>backscatter |
|-----------------------|-------------------------------------------------|------------------------------|----------------------------------------------|---------------------------------------------------|------------------------------------------------|
| 64/3                  | 33,3                                            | 640                          | $\pm 15\%$                                   | $\pm 15\%$                                        | $\pm 2,5\%$                                    |
|                       | $33,3 < \text{TRcal} < 66,7$                    | $320 < \text{BLF} < 640$     | $\pm 22\%$                                   | $\pm 22\%$                                        | $\pm 2,5\%$                                    |
|                       | 66,7                                            | 320                          | $\pm 10\%$                                   | $\pm 15\%$                                        | $\pm 2,5\%$                                    |
|                       | $66,7 < \text{TRcal} < 83,3$                    | $256 < \text{BLF} < 320$     | $\pm 12\%$                                   | $\pm 15\%$                                        | $\pm 2,5\%$                                    |
|                       | 83,3                                            | 256                          | $\pm 10\%$                                   | $\pm 10\%$                                        | $\pm 2,5\%$                                    |
|                       | $83,3 < \text{TRcal} \leq 133,3$                | $160 \leq \text{BLF} < 256$  | $\pm 10\%$                                   | $\pm 12\%$                                        | $\pm 2,5\%$                                    |
|                       | $133,3 < \text{TRcal} \leq 200$                 | $107 \leq \text{BLF} < 160$  | $\pm 7\%$                                    | $\pm 7\%$                                         | $\pm 2,5\%$                                    |
|                       | $200 < \text{TRcal} \leq 225$                   | $95 \leq \text{BLF} < 107$   | $\pm 5\%$                                    | $\pm 5\%$                                         | $\pm 2,5\%$                                    |
| 8                     | $17,2 \leq \text{TRcal} < 25$                   | $320 < \text{BLF} \leq 465$  | $\pm 19\%$                                   | $\pm 19\%$                                        | $\pm 2,5\%$                                    |
|                       | 25                                              | 320                          | $\pm 10\%$                                   | $\pm 15\%$                                        | $\pm 2,5\%$                                    |
|                       | $25 < \text{TRcal} < 31,25$                     | $256 < \text{BLF} < 320$     | $\pm 12\%$                                   | $\pm 15\%$                                        | $\pm 2,5\%$                                    |
|                       | 31,25                                           | 256                          | $\pm 10\%$                                   | $\pm 10\%$                                        | $\pm 2,5\%$                                    |
|                       | $31,25 < \text{TRcal} < 50$                     | $160 < \text{BLF} < 256$     | $\pm 10\%$                                   | $\pm 10\%$                                        | $\pm 2,5\%$                                    |
|                       | 50                                              | 160                          | $\pm 7\%$                                    | $\pm 7\%$                                         | $\pm 2,5\%$                                    |
|                       | $50 < \text{TRcal} \leq 75$                     | $107 \leq \text{BLF} < 160$  | $\pm 7\%$                                    | $\pm 7\%$                                         | $\pm 2,5\%$                                    |
|                       | $75 < \text{TRcal} \leq 200$                    | $40 \leq \text{BLF} < 107$   | $\pm 4\%$                                    | $\pm 4\%$                                         | $\pm 2,5\%$                                    |

<sup>1</sup> Allowing two different TRcal values (with two different  $\underline{DR}$  values) to specify the same BLF offers flexibility in specifying Tari and RTcal.

**Table 6.10 — Tag-to-Interrogator data rates**

| M: Number of subcarrier cycles<br>per symbol | Modulation type   | Data rate (kbps) |
|----------------------------------------------|-------------------|------------------|
| 1                                            | FM0 baseband      | BLF              |
| 2                                            | Miller subcarrier | BLF/2            |
| 4                                            | Miller subcarrier | BLF/4            |
| 8                                            | Miller subcarrier | BLF/8            |

### 6.3.1.3.4 Tag power-up timing

Tags energized by an Interrogator shall be capable of receiving and acting on Interrogator commands within a period not exceeding the maximum settling-time interval specified in Table 6.6 or Table 6.8, as appropriate (i.e. by the end of  $T_s$  or  $T_{hs}$ , respectively).

### 6.3.1.3.5 Minimum operating RF field strength and backscatter strength

For a Tag certified to this protocol, the Tag manufacturer shall specify:

- free-space sensitivity;
- minimum backscattered modulated power (ASK modulation) or change in radar cross-section or equivalent (phase modulation);
- the manufacturer's normal operating conditions;

for the Tag mounted on one or more manufacturer-selected materials.

### 6.3.1.4 Transmission order

The transmission order for all R=>T and T=>R communications shall be most-significant bit (MSB) first.

Within each message, the most-significant word shall be transmitted first.

Within each word, the MSB shall be transmitted first.

### 6.3.1.5 Cyclic-redundancy check (CRC)

A CRC is a cyclic-redundancy check that a Tag uses to ensure the validity of certain R=>T commands, and an Interrogator uses to ensure the validity of certain backscattered T=>R replies. This protocol uses two CRC types: (i) a CRC-16, and (ii) a CRC-5. [Annex F](#) describes both CRC types.

To generate a CRC-16 a Tag or Interrogator shall first generate the CRC-16 precursor shown in [Table 6.11](#), and then take the ones-complement of the generated precursor to form the CRC-16.

**Table 6.11 — CRC-16 precursor**

| CRC-16 precursor (See also <a href="#">Annex F</a> ) |         |                             |                   |                   |
|------------------------------------------------------|---------|-----------------------------|-------------------|-------------------|
| CRC Type                                             | Length  | Polynomial                  | Preset            | Residue           |
| ISO/IEC 13239                                        | 16 bits | $x^{16} + x^{12} + x^5 + 1$ | FFFF <sub>h</sub> | 1D0F <sub>h</sub> |

A Tag or Interrogator shall verify the integrity of a received message that uses a CRC-16. The Tag or Interrogator may use one of the methods described in [Annex F](#) to verify the CRC-16.

A Tag calculates and saves into memory a 16-bit StoredCRC. See [6.3.2.1.2.1](#).

During inventory a Tag backscatters a 16-bit PacketCRC that the Tag calculates dynamically.

Tags shall append a CRC-16 to those replies that use a CRC-16. See [6.3.2.12](#) for command-specific replies.

**Table 6.12 — CRC-5 definition**

| CRC-5 definition (See also <a href="#">Annex F</a> ) |        |                 |                    |                    |
|------------------------------------------------------|--------|-----------------|--------------------|--------------------|
| CRC Type                                             | Length | Polynomial      | Preset             | Residue            |
| —                                                    | 5 bits | $x^5 + x^3 + 1$ | 01001 <sub>2</sub> | 00000 <sub>2</sub> |

To generate a CRC-5 an Interrogator shall use the definition in [Table 6.12](#).

A Tag shall verify the integrity of a received message that uses a CRC-5. The Tag may use the method described in [Annex F](#) to verify a CRC-5.

Interrogators shall append the appropriate CRC to R=>T transmissions as specified in [Table 6.28](#).

### 6.3.1.6 Link timing

Figure 6.18 illustrates R=>T and T=>R link timing. The figure (not drawn to scale) defines Interrogator interactions with a Tag population. Table 6.16 shows the timing requirements for Figure 6.18, while 6.3.2.12 describes the commands. Tags and Interrogators shall meet all timing requirements shown in Table 6.16. RTcal is defined in 6.3.1.2.8;  $T_{pri}$  is the T=>R link period ( $T_{pri} = 1 / BLF$ ). As described in 6.3.1.2.8, an Interrogator shall use a fixed R=>T link rate for the duration of an inventory round; prior to changing the R=>T link rate an Interrogator shall transmit CW for a minimum of 8 RTcal. Figure 6.18 illustrates three types of Tag reply timing denoted *immediate*, *delayed*, and *in-process*. These reply timings are defined in 6.3.1.6.1, 6.3.1.6.2, and 6.3.1.6.3, respectively. Table 6.28 specifies the reply type that a Tag uses for each Interrogator command.

#### 6.3.1.6.1 Immediate Tag reply

An *immediate* Tag reply is a reply that meets  $T_1$  specified in Table 6.16.

#### 6.3.1.6.2 Delayed Tag reply

A *delayed* Tag reply is a reply that meets  $T_5$  specified in Table 6.16. After issuing a command that uses *delayed* reply timing an Interrogator shall transmit CW for at least the lesser of  $T_{REPLY}$  or  $T_{5(max)}$ , where  $T_{REPLY}$  is the time between the Interrogator's command and the Tag's backscattered reply. An Interrogator may observe several possible outcomes from a command that uses *delayed* reply timing, depending on the success or failure of the Tag's internal operations:

- (a) **The Tag successfully executes the command:** After executing the command the Tag shall backscatter the reply shown in Table 6.13 and Figure 6.16, comprising a header (a 0-bit), the Tag's handle, and a CRC-16 calculated over the 0-bit and handle. The reply shall meet the  $T_5$  limits in Table 6.16. If the Interrogator observes this reply within  $T_{5(max)}$  then the command completed successfully.
- (b) **The Tag encounters an error:** The Tag shall backscatter an error code (see Annex I) during the CW period rather than the reply shown in Table 6.13. The error code shall meet the  $T_5$  limits in Table 6.16. An error-code reply uses header=1 (see Annex I) to differentiate it from a successful reply.
- (c) **The Tag fails to execute the command:** If the Interrogator does not observe a Tag reply within  $T_{5(max)}$  then the Tag did not execute the command successfully. The Interrogator typically issues a subsequent *Req\_RN* (containing the Tag's handle) to verify that the Tag is still in the Interrogator's energizing RF field and may then issue another command or commands.

A Tag shall ignore Interrogator commands while processing a prior command that specified a *delayed* reply. If an Interrogator transmits a command while the Tag is processing then the Tag may continue with its processing or, in environments with limited power availability, may undergo a power-on reset.

**Table 6.13 — Tag reply after successfully executing a delayed-reply command**

|                | Header | RN            | CRC    |
|----------------|--------|---------------|--------|
| number of bits | 1      | 16            | 16     |
| description    | 0      | <u>handle</u> | CRC-16 |

A *delayed* Tag reply shall use the extended preamble shown in Figure 6.11 or Figure 6.15, as appropriate (i.e. the Tag shall reply as if  $T_{Rext}=1$  regardless of the  $T_{Rext}$  value in the *Query* that initiated the inventory round).

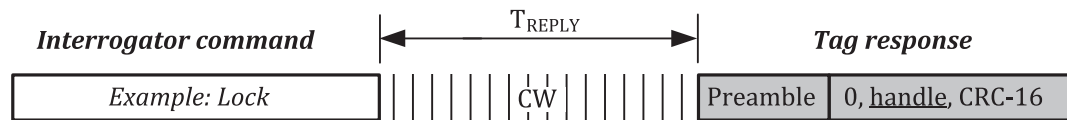


Figure 6.16 — Successful delayed-reply sequence

### 6.3.1.6.3 In-process Tag reply

An *in-process* reply allows a Tag to spend longer than  $T_{5(\max)}$  executing a command, and to notify the Interrogator on a periodic basis that it is still processing the command. An *in-process* reply may include multiple backscatter transmissions from Tag to Interrogator. The first transmission shall meet the  $T_6$  limits specified in Table 6.16; subsequent transmissions (if any) shall meet  $T_7$ . A Tag shall backscatter a transmission at least once every  $T_{7(\max)}$  while processing the command. A Tag may backscatter a “processing” notification more frequently than  $T_{7(\max)}$  and may backscatter an intermediate “processing” notification even if it can complete its processing within  $T_{6(\max)}$ . An Interrogator specifies, in every access command that uses an *in-process* reply (except *AuthComm* – see 6.3.2.12.3.11), whether a Tag, when done processing, backscatters its final response or stores it in the Tag’s ResponseBuffer. A Tag always backscatters (and never stores) the response to an *AuthComm*.

A Tag’s *in-process* reply or replies shall be as shown in Table 6.14. The reply includes a 7-bit Barker code, done, header, optional length (length of the response regardless of whether the Tag backscatters or stores it), response (null if a Tag stores its response), the Tag’s handle, and a CRC-16 calculated from Barker code to handle, inclusive. The Tag replies shall be consistent for first and subsequent Tag transmissions – i.e. if the final reply includes length then all intermediate replies shall include length, and vice versa.

An Interrogator may observe several possible outcomes from a command that uses *in-process* reply timing, depending on the success or failure of the Tag’s internal operations:

- The Tag successfully executes the command:** While processing the command the Tag backscatters a transmission as shown in Table 6.14 at least once every  $T_{7(\max)}$ . Done and header for these intermediate replies shall be zero, response shall be null, and if the replies include length then length=0000<sub>h</sub>. When the Tag has finished processing it sends a final reply, also as shown in Table 6.14, including done=1, header=0, response, and optional length. All replies shall meet the  $T_6$  and  $T_7$  limits specified in Table 6.16. If the Interrogator observes a final reply with header=0 then the command completed successfully.
- The Tag encounters an error:** While processing the command the Tag backscatters a transmission as shown in Table 6.14 at least once every  $T_{7(\max)}$ . Done and header for these intermediate replies shall be zero, response shall be null, and if the replies include length then length=0000<sub>h</sub>. When a Tag encounters an error it sends a final reply, also as shown in Table 6.14, including done=1, header=1, response, and optional length. All replies shall meet the  $T_6$  and  $T_7$  limits specified in Table 6.16. If the Interrogator observes a final reply with header=1 then the Tag encountered an error (see Annex I).
- The Tag fails to execute the command:** If the Interrogator does not observe a Tag reply within  $T_{6(\max)}$  for the first reply or  $T_{7(\max)}$  for subsequent replies then the Tag did not execute the command successfully. The Interrogator typically issues a subsequent *Req\_RN* (containing the Tag’s handle) to verify that the Tag is still in the Interrogator’s energizing RF field and may then issue another command or commands.

Done indicates whether the Tag is still processing a command. Done=0 means the Tag is still processing; done=1 means the Tag has finished processing. Header indicates whether response is an error code. Header=0 means the computation was successful and response includes a result; header=1 means response is an error code.

The optional length field specifies the length of a Tag’s computed response (in bits), regardless of whether a Tag backscatters or stores this response. Length shall comprise a 15-bit value field followed

by an even parity bit (the number of 1's in the 16-bit length field shall be an even number, with length=0000<sub>h</sub> an allowed value). An Interrogator specifies, in every command that uses an *in-process* reply, whether the Tag omits or includes length in its reply. If the Interrogator does not request length, then the Tag omits length from its reply; if the Interrogator requests length then the Tag includes length in its reply. For the latter case, in the event of a stored response, length specifies the length of the stored response (and is therefore typically nonzero) but the response that the Tag actually backscatters will be null.

Response contains the Tag's computed result or an error code if the Interrogator instructed the Tag to backscatter its response, or null if the Interrogator instructed the Tag to store its response in the ResponseBuffer.

Table 6.15 shows values for the fields in an *in-process* reply depending on (a) whether a Tag sends its response or stores it in its ResponseBuffer, (b) how quickly the Tag executes the command, (c) whether the reply includes length, and (d) whether the Tag was able to successfully execute the command.

A Tag shall ignore Interrogator commands while processing a prior command that specified an *in-process* reply. If an Interrogator transmits a command while the Tag is processing then the Tag may continue with its processing or, in environments with limited power availability, may undergo a power-on reset.

After issuing a command that uses an *in-process* reply an Interrogator shall transmit CW until the Interrogator either (a) observes a reply with done=1 indicating the Tag has finished executing the command, or (b) fails to observe a reply for at least  $T_{6(max)}$  or  $T_{7(max)}$  (as appropriate) indicating that the Tag failed to execute the command.

An *in-process* Tag reply shall use the extended preamble shown in Figure 6.11 or Figure 6.15, as appropriate (i.e. the Tag shall reply as if TRExt=1 regardless of the TRExt value in the *Query* that initiated the inventory round).

#### 6.3.1.6.4 ResponseBuffer

A Tag that implements a *Challenge* command, or any access command (other than *AuthComm*) that employs an *in-process* reply, shall implement a **C** flag and a ResponseBuffer with the following properties:

- The **C** flag, located in the Tag's XPC\_W1 (see Table 6.18), indicates whether the Tag has a stored response (result or error code) in its ResponseBuffer. If **C**=1 then the ResponseBuffer contains data; if **C**=0 then the ResponseBuffer is empty.
- A Tag shall set **C**=0 upon (1) receiving an access command containing SenRep (c.f. 6.3.2.12.3.10), (2) receiving a *Challenge* command, or (3) when specified by a cryptographic suite, and shall set **C**=1 after storing a response (result or error code) in its ResponseBuffer.
- The **C** flag shall be selectable using a *Select* command.
- If an access command with SenRep=0 or a *Challenge* command specifies IncRepLen=0 then a Tag shall not include a length field with its stored response, so the first word of the stored response shall be at ResponseBuffer location 00<sub>h</sub>. If the command specifies IncRepLen=1 then ResponseBuffer bits 00<sub>h</sub> – 0E<sub>h</sub> shall contain the length of the stored response in bits, ResponseBuffer bit 0F<sub>h</sub> shall contain an even parity bit that the Tag computes over bits 00<sub>h</sub> – 0E<sub>h</sub>, and the first word of the stored response shall be at ResponseBuffer location 10<sub>h</sub>. See Figure 6.17.
- The maximum size of a stored response shall be 32 kbits.

Table 6.14 — In-process Tag reply omitting and including length field

|                | Barker Code | Done | Header | Response | RN | CRC |
|----------------|-------------|------|--------|----------|----|-----|
| number of bits | 7           | 1    | 1      | variable | 16 | 16  |

Table 6.14 (continued)

|             | Barker Code | Done                      | Header                      | Response                | RN     | CRC    |
|-------------|-------------|---------------------------|-----------------------------|-------------------------|--------|--------|
| description | 1110010     | 0: Working<br>1: Finished | 0: Success<br>1: Error code | result or<br>error code | handle | CRC-16 |

|                | Barker code | Done                      | Header                      | Length                                                                                            | Re-<br>sponse              | RN     | CRC    |
|----------------|-------------|---------------------------|-----------------------------|---------------------------------------------------------------------------------------------------|----------------------------|--------|--------|
| number of bits | 7           | 1                         | 1                           | 16                                                                                                | variable                   | 16     | 16     |
| description    | 1110010     | 0: Working<br>1: Finished | 0: Success<br>1: Error code | 15 bits encoding <u>length</u> of<br><u>result</u> or error code fol-<br>lowed by even parity bit | result<br>or error<br>code | handle | CRC-16 |

- The maximum ResponseBuffer size shall be 32,784 bits (15 length bits, 1 parity bit, 32k response bits). A Tag manufacturer may limit the ResponseBuffer to a size less than this maximum. A Tag shall dynamically adjust its ResponseBuffer, on a command-by-command basis, to the required size.
- An Interrogator may read the ResponseBuffer using a *ReadBuffer* command. See [6.3.2.12.3.15](#).
- The ResponseBuffer shall be read-only to an Interrogator.
- A Tag shall abort command processing and instead store an error code in its ResponseBuffer if and when it determines that response will overflow the ResponseBuffer (see [Annex I](#)).
- A Tag shall retain data in its ResponseBuffer with the persistence of its C flag (see [Table 6.20](#)). When C is 1 then a Tag shall maintain the data in its ResponseBuffer. When C is or becomes 0 then a Tag shall deallocate its ResponseBuffer.

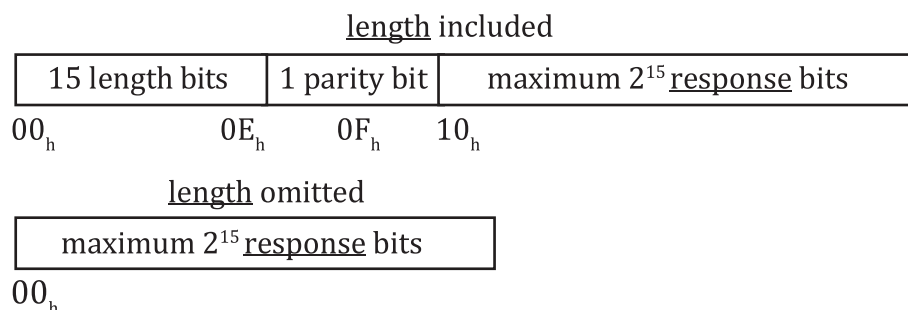


Figure 6.17 — ResponseBuffer data storage

This protocol does not specify a Tag memory location for the ResponseBuffer. Also, because a ResponseBuffer is not writeable by an Interrogator, this protocol does not specify a mechanism for an Interrogator to write to it.

Table 6.15 — Possible in-process Tag replies

| Sent or stored reply | Time for Tag to execute command? | Omit or include length? | Reply                                                                                                                                                                                                                 |                                                                                                                                                                                                                 |
|----------------------|----------------------------------|-------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                      |                                  |                         | Tag executed command                                                                                                                                                                                                  | Tag failed to execute command                                                                                                                                                                                   |
| Sent                 | $\leq T_{6(\max)}$               | Omit                    | Done: 1<br>Header: 0<br>Response: <u>result</u>                                                                                                                                                                       | Done: 1<br>Header: 1<br>Response: error code                                                                                                                                                                    |
|                      |                                  | Include                 | Done: 1<br>Header: 0<br>Length: <u>length</u> of sent <u>result</u><br>Response: <u>result</u>                                                                                                                        | Done: 1<br>Header: 1<br>Length: <u>length</u> of sent error code<br>Response: error code                                                                                                                        |
|                      | Any                              | Omit                    | Intermediate reply or replies<br>Done: 0<br>Header: 0<br>Response: null<br>Final reply<br>Done: 1<br>Header: 0<br>Response: <u>result</u>                                                                             | Intermediate reply or replies<br>Done: 0<br>Header: 0<br>Response: null<br>Final reply<br>Done: 1<br>Header: 1<br>Response: error code                                                                          |
|                      |                                  | Include                 | Intermediate reply or replies<br>Done: 0<br>Header: 0<br>Length: 0000 <sub>h</sub><br>Response: null<br>Final reply<br>Done: 1<br>Header: 0<br>Length: <u>length</u> of sent <u>result</u><br>Response: <u>result</u> | Intermediate reply or replies<br>Done: 0<br>Header: 0<br>Length: 0000 <sub>h</sub><br>Response: null<br>Final reply<br>Done: 1<br>Header: 1<br>Length: <u>length</u> of sent error code<br>Response: error code |

Table 6.15 (continued)

| Sent or stored reply | Time for Tag to execute command? | Omit or include length? | Reply                                                                                                                                                                                                          |                                                                                                                                                                                                             |
|----------------------|----------------------------------|-------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                      |                                  |                         | Tag executed command                                                                                                                                                                                           | Tag failed to execute command                                                                                                                                                                               |
| Stored               | $\leq T_{6(\max)}$               | Omit                    | Done: 1<br>Header: 0<br>Response: null                                                                                                                                                                         | Done: 1<br>Header: 1<br>Response: null                                                                                                                                                                      |
|                      |                                  | Include                 | Done: 1<br>Header: 0<br>Length: <u>length</u> of stored <u>result</u><br>Response: null                                                                                                                        | Done: 1<br>Header: 1<br>Length: <u>length</u> of stored error code<br>Response: null                                                                                                                        |
|                      | Any                              | Omit                    | Intermediate reply or replies<br>Done: 0<br>Header: 0<br>Response: null<br>Final reply<br>Done: 1<br>Header: 0<br>Response: null                                                                               | Intermediate reply or replies<br>Done: 0<br>Header: 0<br>Response: null<br>Final reply<br>Done: 1<br>Header: 1<br>Response: null                                                                            |
|                      |                                  | Include                 | Intermediate reply or replies<br>Done: 0<br>Header: 0<br>Length: 0000 <sub>h</sub><br>Response: null<br>Final reply<br>Done: 1<br>Header: 0<br>Length: <u>length</u> of stored <u>result</u><br>Response: null | Intermediate reply or replies<br>Done: 0<br>Header: 0<br>Length: 0000 <sub>h</sub><br>Response: null<br>Final reply<br>Done: 1<br>Header: 1<br>Length: <u>length</u> of stored error code<br>Response: null |

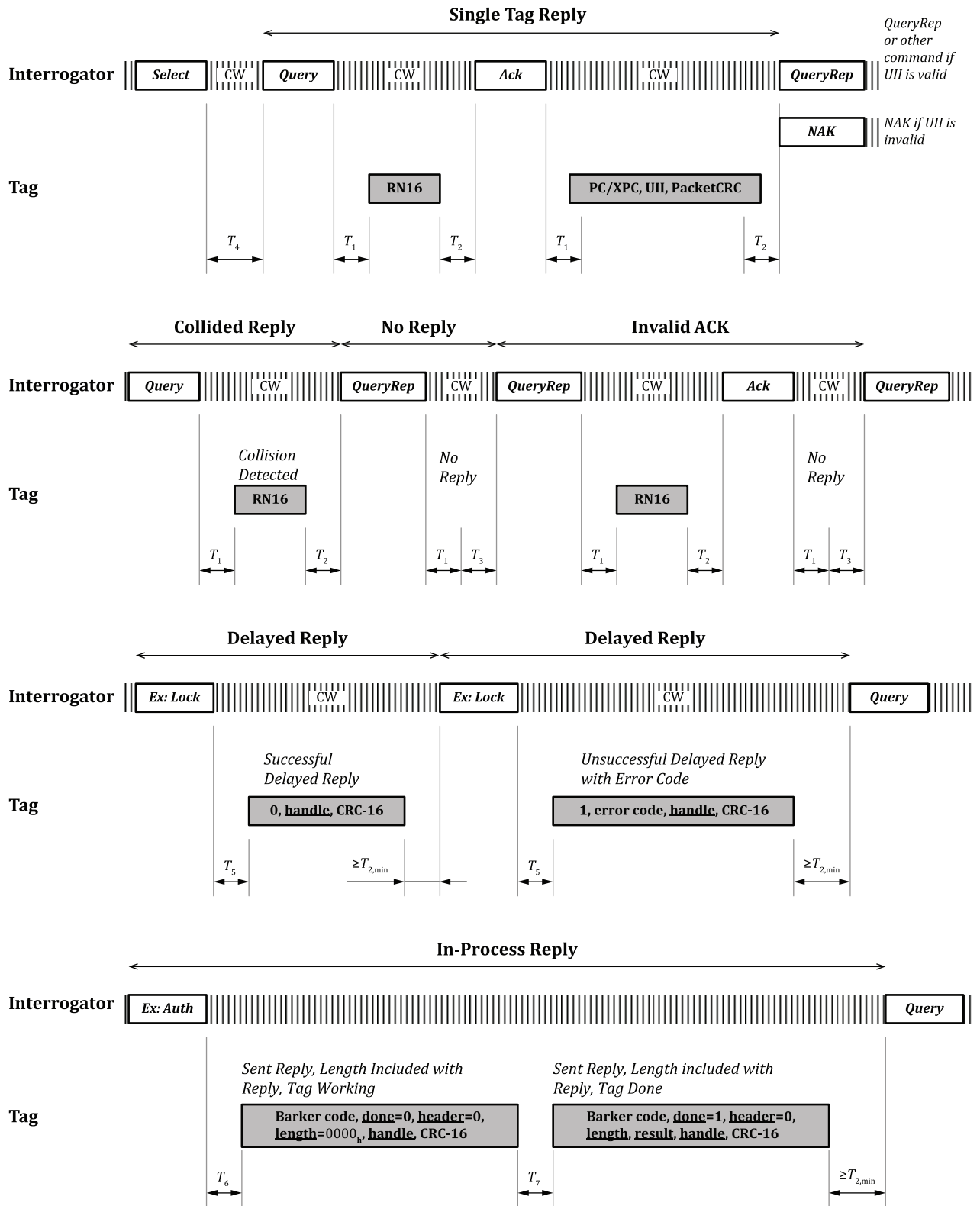


Figure 6.18 — Link timing

Table 6.16 — Link timing parameters

| Parameter | Minimum                                                                                | Nominal                                      | Maximum                                                                                | Description                                                                                                                                                                                                                                                                                                                                           |
|-----------|----------------------------------------------------------------------------------------|----------------------------------------------|----------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $T_1$     | $\text{MAX}(\text{RTcal}, 10T_{\text{pri}}) \times (1 -  \text{FrT} ) - 2 \mu\text{s}$ | $\text{MAX}(\text{RTcal}, 10T_{\text{pri}})$ | $\text{MAX}(\text{RTcal}, 10T_{\text{pri}}) \times (1 +  \text{FrT} ) + 2 \mu\text{s}$ | <i>Immediate</i> reply time from Interrogator transmission to Tag reply. Specifically, the time from the last rising edge of the last bit of the Interrogator transmission to the first rising edge of the Tag reply for an <i>immediate</i> Tag reply, measured at the Tag's antenna terminals.                                                      |
| $T_2$     | $3.0T_{\text{pri}}$                                                                    |                                              | $20.0T_{\text{pri}}$                                                                   | Interrogator reply time if a Tag is to demodulate the Interrogator signal, measured from the end of the last (dummy) bit of the Tag reply to the first falling edge of the Interrogator transmission                                                                                                                                                  |
| $T_3$     | $0.0T_{\text{pri}}$                                                                    |                                              |                                                                                        | Time an Interrogator waits, after $T_1$ , before it issues another command                                                                                                                                                                                                                                                                            |
| $T_4$     | $2.0 \text{ RTcal}$                                                                    |                                              |                                                                                        | Minimum time between Interrogator commands                                                                                                                                                                                                                                                                                                            |
| $T_5$     | $\text{MAX}(\text{RTcal}, 10T_{\text{pri}}) \times (1 -  \text{FrT} ) - 2 \mu\text{s}$ |                                              | 20 ms                                                                                  | <i>Delayed</i> reply time from Interrogator transmission to Tag reply. Specifically, the time from the last rising edge of the last bit of the Interrogator transmission to the first rising edge of the Tag reply for a <i>delayed</i> Tag reply, measured at the Tag's antenna terminals.                                                           |
| $T_6$     | $\text{MAX}(\text{RTcal}, 10T_{\text{pri}}) \times (1 -  \text{FrT} ) - 2 \mu\text{s}$ |                                              | 20 ms                                                                                  | <i>In-process</i> reply time from Interrogator transmission to the first Tag reply. Specifically, the time from the last rising edge of the last bit of the Interrogator transmission to the first rising edge of the first Tag reply indicating that the Tag is either (a) still working, or (b) is done, measured at the Tag's antenna terminals    |
| $T_7$     | $\text{MAX}(250 \mu\text{s}, T_{2(\text{max})})$                                       |                                              | 20 ms                                                                                  | <i>In-process</i> reply time between Tag replies. Specifically, the time from the end of the last (dummy) bit of the Tag's prior transmission indicating that the Tag is still working to the first rising edge of the current Tag reply indicating that the Tag is either (a) still working, or (b) is done, measured at the Tag's antenna terminals |

The following items apply to the requirements specified in [Table 6.16](#):

- $T_{\text{pri}}$  denotes either the commanded period of an FM0 symbol or the commanded period of a single subcarrier cycle, as appropriate.
- The maximum value for  $T_2$  shall apply only to Tags in the **reply** or **acknowledged** states (see [6.3.2.6.3](#) and [6.3.2.6.4](#)). For a Tag in the **reply** or **acknowledged** states, if  $T_2$  expires (i.e. reaches its maximum value):
  - Without the Tag receiving a valid command, the Tag shall transition to the **arbitrate** state (see [6.3.2.6.2](#)),
  - During the reception of a valid command, the Tag shall execute the command,
  - During the reception of an invalid command, the Tag shall transition to **arbitrate** upon determining that the command is invalid.

In all other states the maximum value for  $T_2$  shall be unrestricted. A Tag shall be allowed a tolerance of  $20.0T_{\text{pri}} \leq T_{2(\text{max})} \leq 32T_{\text{pri}}$  in determining whether  $T_2$  has expired. “Invalid command” is defined in [6.3.2.12](#).

3. An Interrogator may transmit a new command prior to interval  $T_2$  (i.e. during a Tag response). In this case the responding Tag may ignore the new command and, in environments with limited power availability, and may undergo a power-on reset.
4. FrT is the frequency tolerance specified in [Table 6.9](#).
5.  $T_1 + T_3$  shall not be less than  $T_4$ .

### 6.3.2 Logical interface

The logical interface between an Interrogator and a Tag may be viewed as the lowest level in the data link layer of a layered network communication system. The logical interface defines Tag memory, flags, states, selection, inventory, and access.

#### 6.3.2.1 Tag memory

Tag memory shall be logically separated into the four distinct memory banks shown in [Figure 6.19](#), each of which may comprise zero or more memory words. The memory banks are:

**Reserved memory** shall contain the kill and and/or access passwords, if passwords are implemented on the Tag. The kill password shall be stored at memory addresses  $00_h$  to  $1F_h$ ; the access password shall be stored at memory addresses  $20_h$  to  $3F_h$ . See [6.3.2.1.1](#).

**UII memory** shall contain a StoredCRC at memory addresses  $00_h$  to  $0F_h$ , a StoredPC at addresses  $10_h$  to  $1F_h$ , a code (such as a UII, and hereafter referred to as a UII) that identifies the object to which the Tag is or will be attached beginning at address  $20_h$ , and if the Tag implements Extended Protocol Control (XPC) then either one or two XPC word(s) beginning at address  $210_h$ . See [6.3.2.1.2](#).

**TID memory** shall contain an 8-bit ISO/IEC 15963-1 allocation class identifier at memory locations  $00_h$  to  $07_h$ . TID memory shall contain sufficient identifying information above  $07_h$  for an Interrogator to uniquely identify the custom commands and/or optional features that a Tag supports. See [6.3.2.1.3](#).

**User memory** is optional. If a Tag implements User memory, then it may partition the User memory into one or more files. If the Tag implements a single file, then that file is File\_0. See [6.3.2.1.4](#) and [6.3.2.11.3](#).

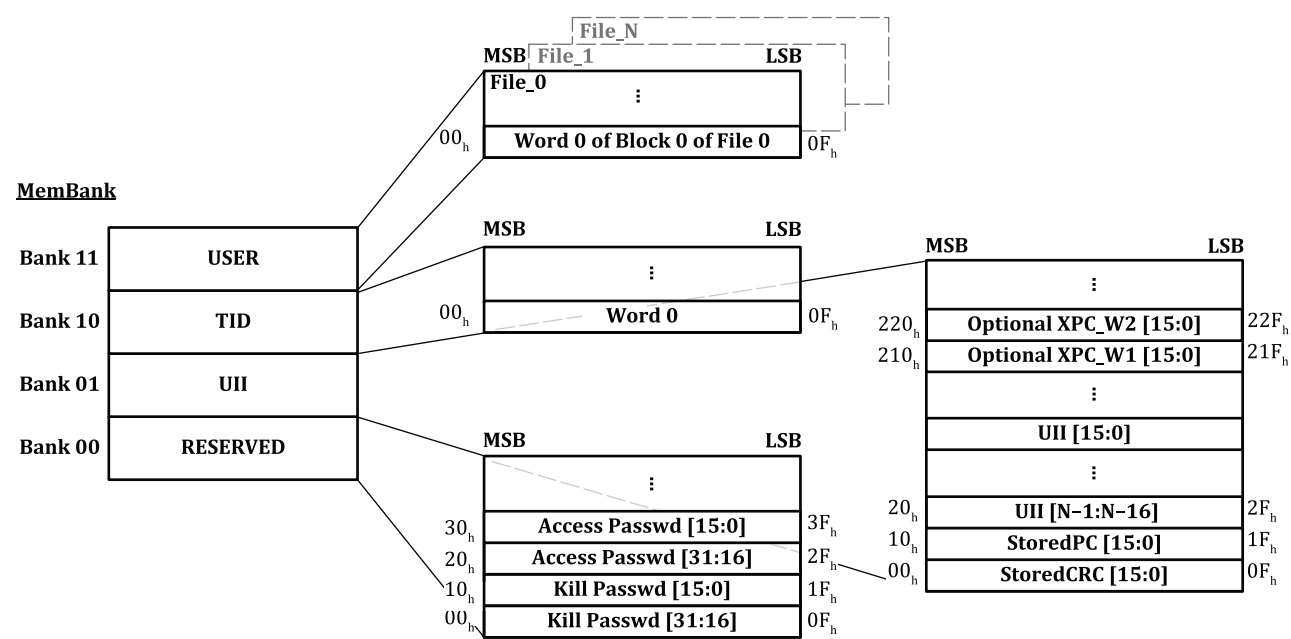


Figure 6.19 — Logical memory map

The logical addressing of all memory banks and User-memory files shall begin at 00<sub>h</sub>. The physical memory map is Tag-manufacturer defined. When a Tag backscatters data from memory the order is left-to-right and bottom-to-top in [Figure 6.19](#). The backscatter shall fall on word boundaries (except for a truncated reply – see [6.3.2.12.1.1](#)).

MemBank shall be defined as follows:

|                 |          |                 |      |
|-----------------|----------|-----------------|------|
| 00 <sub>2</sub> | Reserved | 01 <sub>2</sub> | UII  |
| 10 <sub>2</sub> | TID      | 11 <sub>2</sub> | User |

Operations in one logical memory bank shall not access memory locations in another bank.

Memory writes involve the transfer of one or more 16-bit words from Interrogator to Tag. A *Write* command writes 16 bits (i.e. one word) at a time, using link cover-coding to obscure the data during R=>T transmission. The optional *BlockWrite* command writes one or more 16-bit words at a time, without link cover-coding. The optional *BlockErase* command erases one or more 16-bit words at a time. A *Write*, *BlockWrite*, or *BlockErase* shall not alter a Tag’s killed status regardless of the memory address (whether valid or invalid) specified in the command.

An Interrogator may issue a *Lock* command (see [6.3.2.12.3.5](#)) to lock, permanently lock, unlock, or permanently unlock the kill password, access password, UII memory bank, TID memory bank, or File\_0 of User memory, thereby preventing or allowing subsequent changes (as appropriate). If the passwords are locked or permanently locked, then they are unwriteable and unreadable by any command and usable only by a *Kill* or *Access* command. If UII memory, TID memory, or File\_0 are locked or permanently locked then they are unwriteable but readable, except for the **L** and **U** bits in UII memory; an Interrogator with an asserted Untraceable privilege may alter the **L** and **U** bits regardless of the lock or permalock status of UII memory (see [6.3.2.12.3.16](#)).

If a Tag implements User memory then it partitions each File\_N, N≥0 of User memory into one or more equal-size blocks. A Tag shall use the same block size for file allocation (see [6.3.2.11.3](#)) as it does for the *BlockPermalock* command (see [6.3.2.12.3.9](#)). A Tag may use different block sizes for the *BlockWrite* and *BlockErase* commands. If a Tag supports the *BlockPermalock* command, then an Interrogator may issue a *BlockPermalock* to permanently lock one or more memory blocks. If blocks within File\_0 are permalocked then these blocks are permanently unwriteable but readable. If blocks within File\_N, N>0

are permalocked then these blocks are permanently unwriteable but readable by an Interrogator with appropriate read privileges (see [Table 6.24](#) and [Table 6.25](#)).

#### 6.3.2.1.1 Reserved memory

Reserved memory contains the kill (see [6.3.2.1.1.1](#)) and/or access (see [6.3.2.1.1.2](#)) passwords, if passwords are implemented on a Tag. If a Tag does not implement the kill and/or access password(s) then the Tag shall logically operate as though it has zero-valued password(s) that are permanently read/write locked (see [6.3.2.12.3.5](#)), and the corresponding physical memory locations in Reserved memory need not exist.

##### 6.3.2.1.1.1 Kill password

The kill password is a 32-bit value stored in Reserved memory 00<sub>h</sub> to 1F<sub>h</sub>, MSB first. The default (unprogrammed) value shall be zero. A Tag that does not implement a kill password shall behave as though it has a zero-valued kill password that is permanently read/write locked. A Tag shall not execute a password-based kill if its kill password is zero (see [6.3.2.12.3.4](#)). An Interrogator may use a nonzero kill password in a password-based *Kill*-command sequence to kill a Tag and render it nonresponsive thereafter.

##### 6.3.2.1.1.2 Access password

The access password is a 32-bit value stored in Reserved memory 20<sub>h</sub> to 3F<sub>h</sub>, MSB first. The default (unprogrammed) value shall be zero. A Tag that does not implement an access password shall behave as though it has a zero-valued access password that is permanently read/write locked. A Tag with a zero-valued access password transitions from the **acknowledged** state to the **secured** state upon commencing access, without first entering the **open** state. A Tag with a nonzero-valued access password transitions from the **acknowledged** state to the **open** state upon commencing access; an Interrogator may then use the access password in an *Access* command sequence to transition the Tag from the **open** to the **secured** state.

#### 6.3.2.1.2 UII memory

UII memory contains a StoredCRC at addresses 00<sub>h</sub> to 0F<sub>h</sub>, a StoredPC at 10<sub>h</sub> to 1F<sub>h</sub>, a UII beginning at 20<sub>h</sub>, and optional first and second XPC words at 210<sub>h</sub> to 21F<sub>h</sub> (XPC\_W1) and 220<sub>h</sub> to 22F<sub>h</sub> (XPC\_W2), respectively. The StoredCRC, StoredPC, UII, and XPC word(s) shall be stored MSB first (i.e. the UII's MSB is at location 20<sub>h</sub>).

The StoredCRC and StoredPC are described in [6.3.2.1.2.1](#) and [6.3.2.1.2.2](#), respectively.

The UII identifies the object to which the Tag is affixed. The UII for GS1 Applications is described in [6.3.2.1.2.3](#); the UII for ISO Applications is described in [6.3.2.1.2.4](#). An Interrogator may issue a *Select* that includes all or part of the UII in its *Mask*. An Interrogator may issue an *ACK* to cause a Tag to backscatter its UII. Under certain circumstances a Tag may truncate its backscattered UII (see [6.3.2.12.3.16](#) and [6.3.2.12.1.1](#)). An Interrogator may issue a *Read* to read all or part of the UII.

The XPC\_W1 and XPC\_W2 are described in [6.3.2.1.2.5](#).

##### 6.3.2.1.2.1 CRC-16 (StoredCRC and PacketCRC)

A Tag shall implement both a StoredCRC and a PacketCRC. The StoredCRC is stored in UII memory, is selectable by an Interrogator using a *Select* command, and is readable by an Interrogator using a *Read* command. The PacketCRC is computed and sent by a Tag during backscatter, protects the transmitted PC/XPC and UII, and is neither selectable nor directly readable by an Interrogator.

A Tag shall compute and store its StoredCRC either (i) when an Interrogator writes or overwrites bits in the UII (including in the StoredPC), or (ii) every time the Tag powers up. The Tag manufacturer shall choose whether the Tag implements (i) or (ii). A Tag shall perform its computing and storing for these two cases as follows: