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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/ Figure/Table/Note	Type of comment	Comment (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	



DRAFT International Standard

ISO/IEC DIS 18000-63

Information technology — Radio frequency identification for item management —

Part 63: Parameters for air interface communications at 860 MHz to 930 MHz Type C

ICS: 35.040.50

ISO/IEC JTC 1/SC 31

Secretariat: **ANSI**

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2025-09-29

This document is circulated as received from the committee secretariat.

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Contents

Page

Foreword	v
Introduction	vi
1 Scope	1
2 Normative references	1
3 Terms and definitions	2
4 Symbols, abbreviated terms and notation	6
4.1 Symbols	6
4.2 Abbreviated terms	8
4.3 Notation	9
5 Conformance	10
5.1 Claiming conformance	10
5.2 General conformance requirements	11
5.2.1 Interrogators	11
5.2.2 Tags	11
5.3 Command structure and extensibility	11
5.3.1 General	11
5.3.2 Mandatory commands	12
5.3.3 Optional commands	12
5.3.4 Proprietary commands	12
5.3.5 Custom commands	12
5.4 Reserved for Future Use (RFU)	12
5.5 Cryptographic Suite Indicators	12
6 Protocol requirements	13
6.1 Protocol overview	13
6.1.1 Physical layer	13
6.1.2 Tag-identification layer	13
6.2 Protocol parameters	13
6.2.1 Signaling — Physical and media access control parameters	13
6.2.2 Logical — Operating procedure parameters	16
6.3 Description of operating procedure	17
6.3.1 Physical interface	17
6.3.2 Logical interface	43
7 Battery Assisted Passive (BAP) Interrogator Talks First systems (optional)	131
7.1 Applicability	131
7.2 General overview, definitions, and requirements of BAP	131
7.3 BAP inventoried flag and state machine behaviour modifications	133
7.3.1 Modification to ready state and power-down support for BAP Tags	133
7.3.2 Signal loss tolerance via timer (mandatory)	133
7.3.3 Modified persistence of BAP PIE inventory flags (optional)	136
7.4 BAP PIE (optional)	138
7.4.1 Flex_Query command (optional)	138
7.4.2 BAP PIE detailed operation including optional Battery Saver Mode	139
7.5 Manchester mode Battery Assisted operation protocol extensions	145
7.5.1 General	145
7.5.2 Physical layer	145
7.5.3 Manchester activation	151
7.5.4 Commands summary	165
8 Sensor support (optional)	179
8.1 Applicability	179
8.2 Overview	179
8.3 Real Time Clock (RTC)	180
8.3.1 General	180

8.3.2	Setting the RTC	180
8.3.3	BroadcastSync command (optional)	181
8.3.4	Time synchronisation	181
8.4	HandleSensor command (optional)	182
8.5	Simple Sensors	183
8.5.1	Simple Sensor implementation	183
8.6	Full Function Sensors and Sensor Directory System	185
8.6.1	General	185
8.6.2	Sensor Access — General approach	186
8.7	Snapshot Sensors	191
8.7.1	General	191
8.7.2	Initiating Snapshot Sensor measurements	194
8.7.3	Reporting Snapshot Sensor Information	195
Annex A (normative) Extensible bit vectors (EBV)		197
Annex B (normative) State-transition tables		200
Annex C (normative) Command-response tables		267
Annex D (informative) Example slot-count (<i>Q</i>) selection algorithm		298
Annex E (informative) Example Tag inventory and access		299
Annex F (informative) Calculation of 5-bit and 16-bit cyclic redundancy checks		300
Annex G (normative) Multiple- and dense-Interrogator channelized signaling		303
Annex H (informative) Interrogator-to-Tag link modulation		305
Annex I (normative) Error codes		307
Annex J (normative) Slot counter		309
Annex K (informative) Example data-flow exchange		310
Annex L (informative) Optional Tag features		313
Annex M (informative) Cryptographic-Suite checklist		316
Annex N (informative) Battery Assisted Tag to Interrogator synchronization		317
Annex O (normative) Simple Sensors Data Block		320
Annex P (normative) Record structures and commands for Ported Simple Sensors		332
Annex Q (informative) Battery Assisted Passive (BAP) PIE and Manchester mode tutorial guide		346
Annex R (informative) Manchester mode RF power control		356
Bibliography		361

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 or www.iec.ch/members_experts/refdocs).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html. In the IEC, see www.iec.ch/understanding-standards.

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

This fourth edition cancels and replaces the third edition (ISO/IEC 18000-63:2021), which has been technically revised.

The main changes are as follows:

- Improved tag selection of process.
- Added method to ensuring tags are sufficiently energized before selection and communication.
- Providing a method for tag data reading;
- Added QueryX and QueryY make the selection process more topics useful and robust.
- ReadVar and the Read-User-Memory-bit (RUM) automate the access of be added item attributes and the Tag Identifier (TID).
- ResponseBuffer made optional

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 and 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 930 MHz frequency range. The system comprises Interrogators, also known as Readers, and Tags, also known as Labels or Transponders. This document is also referred as RAIN Air Interface.

An Interrogator transmits information to a Tag by modulating an RF signal in the 860 MHz to 930 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 930 MHz Type C

1 Scope

This document defines the air interface for radio frequency identification (RFID) devices operating in the 860 MHz to 930 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 [\[1\]](#).

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

ISO/IEC 18000-63:2021, *Information technology — Radio frequency identification for item management — Part 63: Parameters for air interface communications at 860 MHz to 960 MHz Type C*

ISO/IEC 18047-63:2023, *Information technology — Radio frequency identification device conformance test methods — Part 63: Test methods for air interface communications at 860 MHz to 960 MHz*

ISO/IEC 29143:2011, *Information technology — Automatic identification and data capture techniques — Air interface specification for Mobile RFID interrogators*

ETSI EN 302 208, *Radio Frequency Identification Equipment operating in the band 865 MHz to 868 MHz with power levels up to 2 W and in the band 915 MHz to 921 MHz with power levels up to 4 W; Harmonised Standard for access to radio spectrum*

GS1 EPC Tag Data Standard (TDS) available at <https://www.gs1.org/standards/epc-rfid/tds>

IEEE1588-2002, *Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems*

IETF RFC 1769, *Simple Network Time Protocol (SNTP)*

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*

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

backscatter link frequency

frequency at which at Tag modulates the backscattered signal.

3.4

battery assisted mode

working mode of battery assisted tags with non-empty battery

3.5**crypto superuser**

key with an asserted CryptoSuperuser privilege

3.6**cover coding**

method by which an Interrogator obscures information that it is transmitting to a Tag. To cover-code data or a password, an Interrogator first requests a random number from the Tag. The Interrogator then performs a bitwise XOR (exclusive OR) of the data or password with this random number, and transmits the cover-coded string to the Tag. The Tag uncovers the data or password by performing a bitwise XOR of the received cover-coded string with the original random number

3.7**data element**

low-level, indivisible data construct

3.8**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 GS1 EPC Tag Data Standard.

3.9**extended temperature range**

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

3.10**file type**

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

3.11**file superuser**

access password or key with a 0011_2 **secured**-state file privilege value

3.12**full-duplex communications**

communications channel that carries data in both directions at once

Note 1 to entry: See *half-duplex communications* ([3.14](#)).

3.13**GS1 EPCglobal® Application**

application whose usage denotes an acceptance of GS1 EPCglobal standards and policies (see ISO Application).

Note 1 to entry: [\[2\]](#) contains details on this.

3.14**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* ([3.12](#)).

3.15**handle**

16-bit tag identifier

3.16**hibernate**

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

3.17

interrogator authentication

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

3.18

Inventory round

the period initiated by a Query command or a QueryX command and terminated by either a subsequent Query command, a subsequent QueryX command, a Select command, or a Challenge command

3.19

ISO Application

an application whose usage denotes an acceptance of ISO standards and policies (see GS1 EPCglobal Application)

3.20

keyID

numerical designator for a single key

3.21

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

3.22

mutual authentication

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

3.23

nominal temperature range

temperature range between $-25\text{ }^{\circ}\text{C}$ to $+40\text{ }^{\circ}\text{C}$

Note 1 to entry: See *extended temperature range* ([3.9](#)).

3.24

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* ([3.30](#)).

3.25

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.

3.26

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* ([3.27](#)).

3.27

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* (3.26).

3.28

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* (3.36), is zero. *Q* is an integer in the range (0,15); the corresponding Tag-response probabilities range from $2^0 = 1$ to $2^{-15} = 0,000031$.

3.29

RAIN

an acronym derived from RAdio Identification

3.30

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* (3.24).

3.31

secure communication

communication in which message confidentiality is protected

3.32

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* (3.33).

3.33

security policy

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

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

3.34

session key

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

3.35

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

3.36

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* (3.28).

3.37

snapshot sensor

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

3.38**tag authentication**

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

3.39**traceable**

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

Note 1 to entry: See *untraceable* (3.42).

3.40**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

3.41**untraceably hidden memory**

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

3.42**untraceable**

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

Note 1 to entry: See *traceable* (3.39).

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
H	hazmat indicator
INACT_T	inactivity threshold
K	killable indicator
M	number of subcarrier cycles per symbol
M_{adjd}	RF field adjust down
M_{adju}	RF field adjust up
M_{adjh}	RF envelope ripple adjusted (overshoot)
M_{adjl}	RF envelope ripple adjusted (undershoot)
M_{h}	RF signal envelope ripple (overshoot)
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_8	Time from end of <i>QueryX</i> or <i>QueryY</i> command to beginning of a subsequent <i>QueryY</i>
T_{cp}	Time before command, power-up
$t_{f,10-90\%}$	RF signal envelope fall time
T_{fp}	Fall time, power-down
t_{lag}	RF adjust lag time
t_{lead}	RF adjust lead time
TN	tag-notification indicator
T_{pri}	backscatter link pulse-repetition interval ($T_{pri} = 1/BLF = TRcal/DR$)
T_r or $T_{r,10-90\%}$	RF signal envelope rise time
T_{REPLY}	Time between Interrogator command and Tag backscattered
T_{rp}	Rise time, power-up
T_{sp}	Settling time, power-up
T_{RTcal}	time duration of RTcal
T_{TRcal}	time duration of TRcal

TRcal	tag-to-Interrogator (tag-to-reader) calibration symbol
U	untraceability indicator
RUM	Read user memory indicator
X	XTID indicator (whether a Tag implements an XTID)
XEB	XPC_W2 indicator
x_{fp}	floating-point value
XI	XPC_W1 indicator
$xxxx_2$	binary notation
$xxxx_h$	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 ($BLF = 1/T_{pri} = DR/TRcal$)
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
MDID	Mask Designer Identifier
MSB	Most significant bit
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
PW	Pulse width
pwd	Password
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
RUM	Read user memory indicator
UTC	universal coordinated time
UWC	User word count
XOR	Exclusive OR
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 and Tag reply parameters are underlined. Some flags are also command parameters; a flag used as a command parameter will be underlined. Example: Pointer.
- Command parameters are upper-case and Tag reply parameters are lower-case, even when at the [EDITOR: check against comment]. Example: Pointer and handle.
- 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, $\otimes$, refers to XOR.
- The symbol, $||$, refers to concatenation.
- The symbol, $\neq$, refers to not equal.
- The symbol, $R \Rightarrow T$, refers to commands or signaling from an Interrogator to a Tag (Reader-to-Tag).
- The symbol, $T \Rightarrow R$, refers to commands or signaling from a Tag to an Interrogator (Tag-to-Reader).
- The numbering base is denoted with a subscript. Binary numbers are denoted with a subscript 2 ($xxxx_2$) and hexadecimal numbers are denoted with a subscript h ($xxxx_h$); the absence of a subscript denotes decimal numbering system.
- The symbol, $\&$, refers to bitwise Boolean and operation.
- The capitalized AND refers to logical (true/false) and operation.
- The capitalized OR refers to logical (true/false) or operation.
- When used in conditions, three or more logical conditions separated the symbol, $;$, share the same logical operation. For example, a condition represented as “condition1; condition2; AND condition3” is true if “condition1 AND condition2 AND condition3” is true. The symbol, $;$, also represents three or more separate actions. For example, “action1; action2; and action3” represent invoking of action1, action2, and action3.
- The symbols, (and), are used to clarify the order of evaluation for more complex conditions or actions. For example, a condition represented as “(condition1 OR condition 2) AND condition3” is true if either “condition1 AND condition3” or “condition2 AND condition3” is true.
- 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^[3] and ISO/IEC 18047-63:2023.

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

Optional performance test methods are provided in ISO/IEC 18046-1:2011^[4], ISO/IEC 18046-3:2020^[5] and ISO/IEC 18046-2:2020^[6].

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 demodulate/receive 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 6-29](#) 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.

NOTE Due to the wide use of this standard the use of RFU values is recommended to be communicated to GS1 in a timely manner, of its use or potential use of these RFU values.

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 : [\[1\]](#)
 - 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=00000000₂ is the first and CSI=00000001₂ is the second suite that ISO/IEC 29167-1:2014[\[1\]](#) 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, 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). An Interrogator may also use *QueryX* command followed by zero or more *QueryY* commands to select a population of Tags based on a value or values in Tag memory.
- b) **Inventory.** Identifying individual Tags. An Interrogator begins an inventory round by transmitting a *Query* command or a *QueryX* command followed by zero or more *QueryY* commands using one of four sessions to initialize an inventory round. One or more Tags may reply. The Interrogator detects a single Tag reply and requests the Tag's UII or TID. 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 930 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 (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 (frequency-hopping [FHSS] systems)	In accordance with local regulations
Int:1e	Frequency Hop Sequence (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	$\text{MAX}(\text{RT}_{\text{cal}}, 10\text{T}_{\text{pri}})$ nominal
Int:6b	Receive-to-Transmit Turn-Around Time	3T_{pri} minimum; 20T_{pri} maximum when Tag is in reply and acknowledged states; no limit otherwise
Int:6c	Dwell Time or Interrogator Transmit Power-On Ramp	2500 μs , minimum time
Int:6d	Decay Time or Interrogator Transmit Power-Down Ramp	500 μs , maximum time
Int:7	Modulation	DSB-ASK, SSB-ASK, or PR-ASK
Int:7a	Spreading Sequence (direct-sequence [DSSS] systems)	N/A
Int:7b	Chip Rate (spread-spectrum systems)	N/A
Int:7c	Chip Rate Accuracy (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	± 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

Table 6-1 (continued)

Ref.	Parameter Name	Description
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=>R) communications

Ref.	Parameter Name	Description
Tag:1	Operating Frequency Range	860 MHz to 930 MHz, inclusive
Tag:1a	Default Operating Frequency	Tags respond to Interrogator signals that satisfy Int:1a
Tag:1b	Operating Channels (spread-spectrum systems)	Tags respond to Interrogator signals that satisfy Int:1b
Tag:1c	Operating Frequency Accuracy	As specified
Tag:1d	Frequency Hop Rate (frequency-hopping [FHSS] systems)	Tags respond to Interrogator signals that satisfy Int:1d
Tag:1e	Frequency Hop Sequence (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 (spread-spectrum systems)	In accordance with local regulations
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 reply and acknowledged 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 2500 μ 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 (direct sequence [DSSS] systems)	N/A
Tag:7b	Chip Rate (spread-spectrum systems)	N/A
Tag:7c	Chip Rate Accuracy (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 Subcarrier: 50 %, nominal
Tag:7i	FM Deviation	N/A

Table 6-2 (continued)

Ref.	Parameter Name	Description
Tag:8	Data Coding	Baseband FM0 or Miller-modulated subcarrier (selected by the Interrogator)
Tag:9	Bit Rate	FM0: 40 kbps to 640 kbps 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 (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 (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 ₂ : As specified in the GS1 EPC Tag Data Standard , T=1 ₂ : 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	Varies with R=>T and 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: <i>Select</i> , <i>QueryX</i> , <i>QueryY</i> and <i>Challenge</i> commands: 16-bit CRC <i>Query</i> command: 5-bit CRC Other Inventory commands: Command length Access commands: 16-bit CRC Tag-to-Interrogator: PC/XPC, UII: 16-bit CRC RN16: None, 5-bit CRC, or 16-bit CRC (varies by command) <u>handle</u> : 16-bit CRC All other: 16-bit CRC

Table 6-3 (continued)

Ref.	Parameter name	Description
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^{15} Tags in the Interrogator's RF field; above that number, $N \log N$ for Tags with unique UIIs, where N = number of tags
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 930 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 930 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 ± 10 ppm over the nominal temperature range (-25 °C to $+40$ °C) and ± 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 ± 10 ppm over the nominal temperature range and ± 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

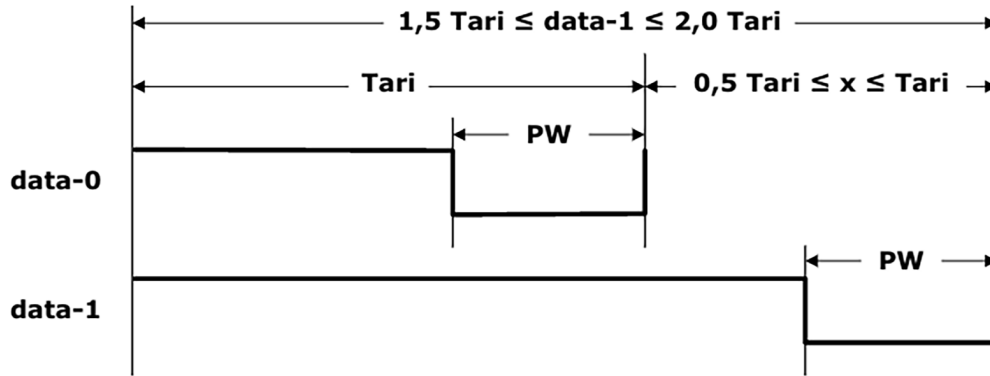


Figure 6-1 — PIE symbols

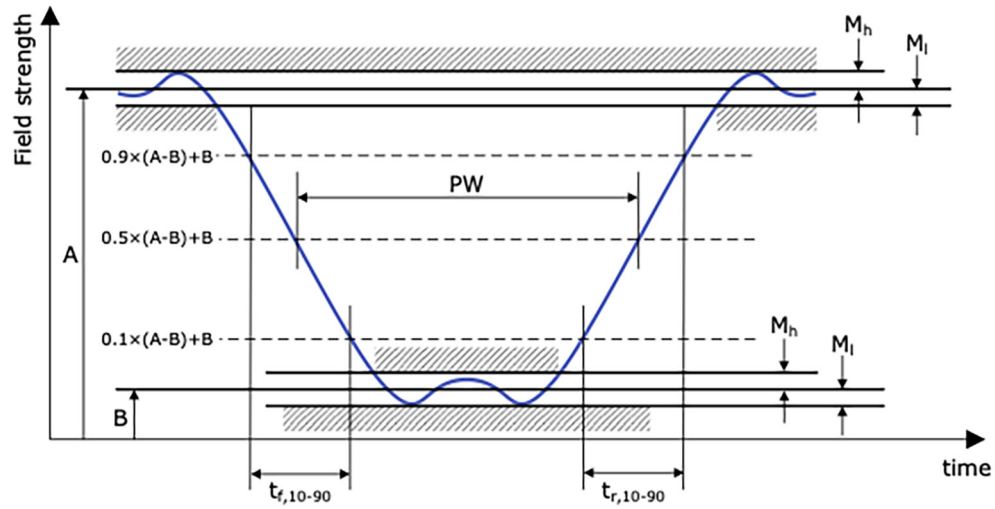
The R=>T link shall use PIE, shown in [Figure 6-1](#). Tari is the reference time interval for Interrogator-to-Tag signaling and is the duration of a data-0. High values represent transmitted CW; low values represent attenuated CW. Pulse modulation depth, rise time, fall time, and PW shall be as specified 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 μs to 25 μs . Interrogator compliance shall be evaluated using at least one Tari value between 6,25 μs and 25 μs 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

a) ASK Modulation



b) PR-ASK Modulation

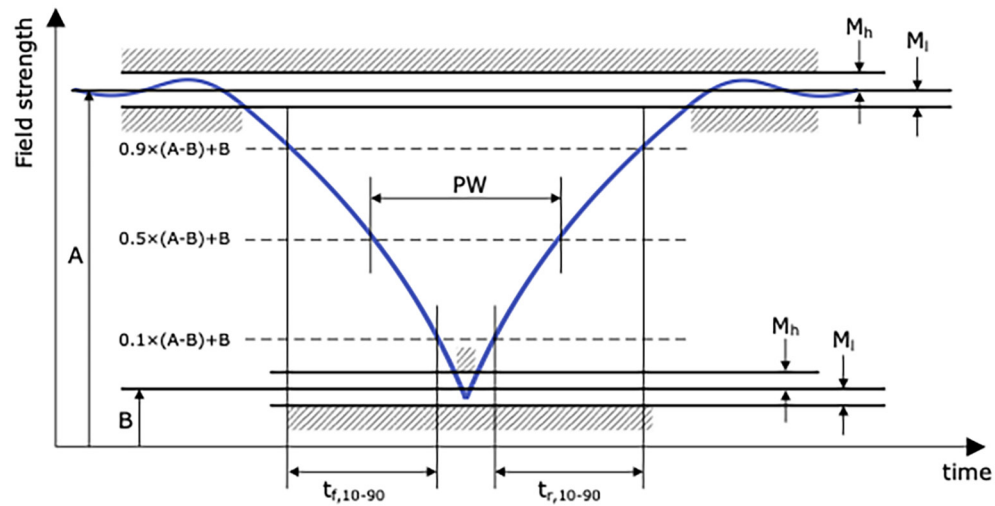


Figure 6-2 — Interrogator-to-Tag RF envelope

Table 6-5 — RF envelope parameters

Tari	Parameter	Symbol	Minimum	Nominal	Maximum	Units
6,25 μ s to 25 μ s	Modulation Depth	$(A-B)/A$	80	90	100	%
	Modulation Depth, Adjusted	$(A_{adj} - B_{adj})/A_{adj}$				
	RF Envelope Ripple	$M_h = M_l$	0		0,05(A-B)	V/m or A/m
	RF Envelope Ripple, Adjusted	$M_{adjh} = M_{adjl}$	0		0,05(A _{adj} - B _{adj})	V/m or A/m
	RF Field Adjust Down	M_{adjd}	0		0,20A	V/m or A/m
	RF Field Adjust Up	M_{adju}	0		0,25A _{adj}	V/m or A/m
	RF Adjust Lead Time	t_{lead}	500			μ s
	RF Adjust Lag Time	t_{lag}	0		0,67RTCal	μ s
	RF Envelope Rise Time	$T_{r,10-90\%}$	0		0,33 Tari	μ s
	RF Envelope Fall Time	$T_{f,10-90\%}$	0		0,33 Tari	μ s
	RF Pulsewidth	PW	MAX(0,265Tari, 2)		0,525 Tari	μ s

The R=>T RF envelope shall comply with [Figure 6-2](#) and [Table 6-5](#). The amplitude of the RF envelope is an electric or magnetic field strength, and the field strength A is the nominal field strength of the RF envelope, measured in units of V/m or A/m. Tari is defined in [Figure 6-1](#). The pulsewidth is measured at the 50 % point on the pulse. Unless permitted by field strength adjustment ([6.3.1.2.9](#)), an Interrogator shall implement the R=>T RF envelope between modulating pulses in an inventory round with a single nominal field strength (A) and a magnitude between A-M_l and A+M_h (see [Figure 6-2](#)). An Interrogator with an R=>T RF envelope using PR-ASK modulation shall comply with the ASK modulation mask with B+M_h ≤ 0.1A when modulating the delimiter shown in [Figure 6-2](#).

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 M_s, the power-up envelope shall monotonically increase to 0.1A.
- During the T_{rp} interval the power-up envelope shall increase from 0.1A to 0.9A, and the increasing envelope may momentarily decrease at a rate ≤ 1%/10 μ sec with a maximum decrease of 2.5%.
- During the T_{sp} interval the power-up envelope shall not fall below 0.9A as in [Figure 6-3a](#). Within the constraints of [Figure 6-3a](#) and [Table 6-6](#) this protocol recommends the Interrogator maximizes the time duration and maximizes the field strength to a constant value during the T_{sp} interval. An Interrogator shall meet the frequency-accuracy requirement specified in [6.3.1.2.1](#) by the end of the T_{sp} interval.
- An Interrogator shall not issue commands before the minimum time of the T_{cp} interval in [Table 6-6](#). An interrogator compliant to prior versions of this protocol may issue a command prior to the minimum T_{cp} interval; if so, a Tag compliant to this protocol may not participate in an inventory round.

Interrogators shall not begin field strength adjust (see [6.3.1.2.9](#)) before the minimum time of the T_{cp} interval in [Table 6-6](#). Interrogators may begin field strength adjust after the minimum time of the T_{cp} interval by decreasing the field strength (adjust down), dwelling on the adjusted field strength, and issuing a *Select*, *Challenge*, *Query*, or *QueryX* command.

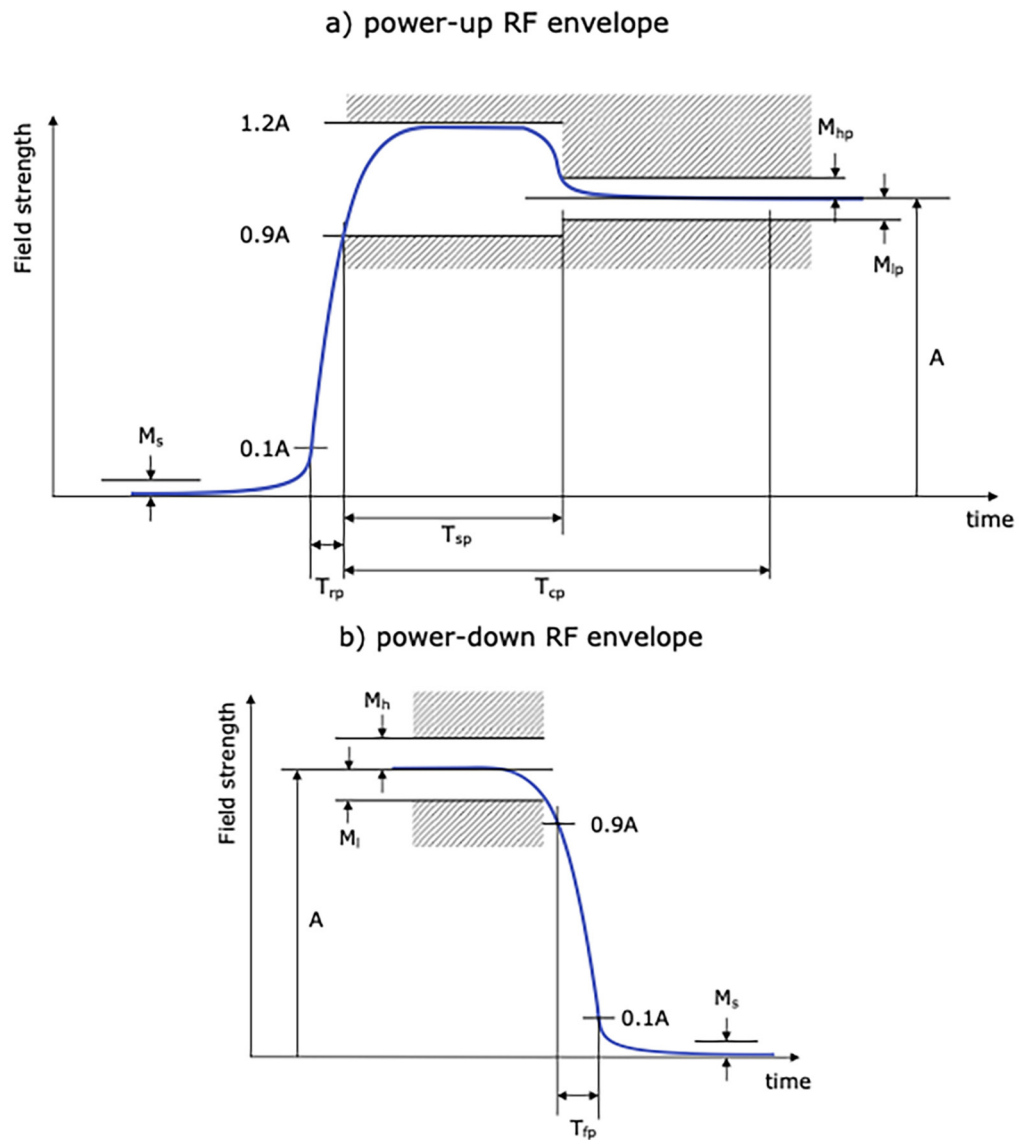


Figure 6-3 — Interrogator power-up and power-down RF envelope

Table 6-6 — Interrogator power-up waveform parameters

Parameter	Definition	Minimum	Nominal	Maximum	Units
M_s	RF signal level when OFF			0.01A	V/m or A/m
T_{rp}	Rise time, power-up	1		250	μs
T_{sp}	Settling time, power-up			1000	μs
T_{cp}	Time before command, power-up	2500			μs
M_{lp}	RF undershoot, power-up			0.05A	V/m or A/m
M_{hp}	RF overshoot, power-up			0.05A	V/m or A/m

6.3.1.2.7 Interrogator power-down waveform

The Interrogator power-down RF envelope shall comply with [Figure 6-3 b\)](#) and [Table 6-7](#). Except as permitted by modulation and by field-strength adjust transmitted by an Interrogator, once the carrier level has fallen below the A-M_l level, the Interrogator shall decrease the RF envelope monotonically from 0.9A until the power-off limit M_s. Once powered off, an Interrogator shall remain powered off for a least 1ms before powering up again.

Table 6-7 — Interrogator power-down waveform parameters

Parameter	Definition	Minimum	Nominal	Maximum	Units
T _{fp}	Fall time, power-down			500	μs
M _s	see Table 6-6				
M _l	see Table 6-5				
M _h	see Table 6-5				

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](#). An Interrogator shall precede a *Query* command (see [6.3.2.12.2.1](#)) and a *QueryX* command (see [6.3.2.12.2.2](#)) with a preamble. A preamble-*Query* or preamble-*QueryX* begins 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 ±1 %. PW shall be as specified in [Table 6-5](#). The RF envelope shall be as specified in [Figure 6-2](#). 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. The rise time, fall time, and 12.5 μs pulse width delimiter shall comply with the R=>T RF envelope using the Tari defined after the delimiter.

- **RTcal:** An Interrogator shall set RTcal equal to the length of a data-0 symbol plus the length of a data-1 symbol. 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 data rate or the frequency of its Miller subcarrier) using the TRcal and divide ratio (DR) in the preamble and payload, respectively, of a *Query* or *QueryX* command that begins an inventory round. [Formula 6-1](#) 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 6-2](#):

$$f_{BLF} = n_{DR} / T_{TRcal} \quad \text{Formula 6-1}$$

where

- f_{BLF} is the backscatter link frequency;
- n_{DR} is the divide ratio;
- T_{TRcal} is the time duration of TRcal.

$$1,1 \times T_{RTcal} \leq T_{TRcal} \leq 3 \times T_{RTcal}$$

Formula 6-2

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.

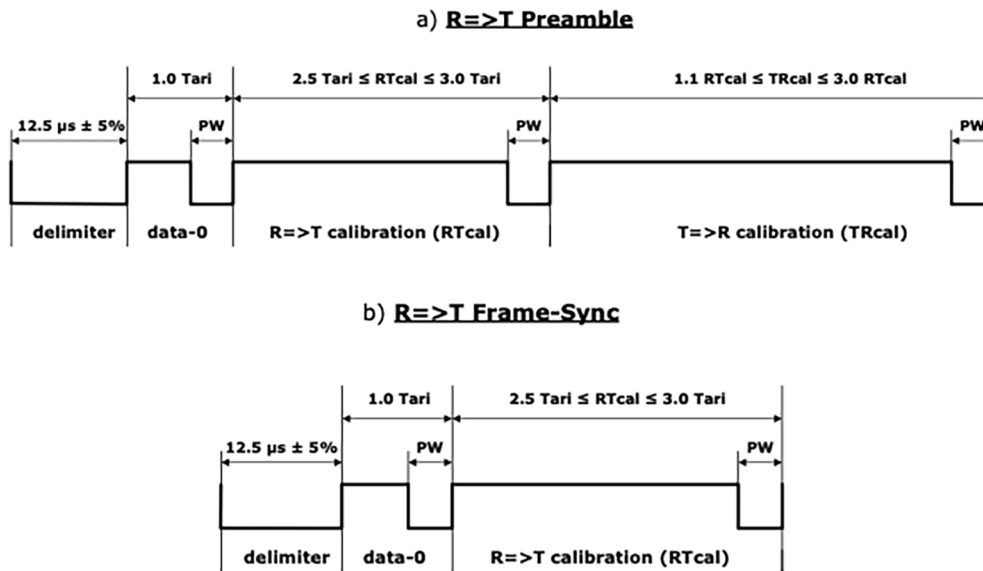


Figure 6-4 — R=>T preamble and frame-sync

6.3.1.2.9 R=>T Field strength adjust

Interrogators may reduce (adjust down) the nominal field strength by M_{adjd} before the start delimiter of a *Select*, *Challenge*, *Query*, or *QueryX* command as in [Figure 6-5 a\)](#) and [Table 6-5](#). If an Interrogator adjusts the nominal field strength down, the Interrogator shall monotonically decrease the field strength from A_{M1} to $A_{adj} + M_{adjh}$, and then the field strength shall remain within $A_{adj} - M_{adjl}$ to $A_{adj} + M_{adjh}$ for the minimum t_{lead} time before modulating the delimiter. If an Interrogator adjusts the nominal field strength down, the Interrogator shall use the adjusted nominal field strength (A_{adj}) and other adjusted envelope parameters (B_{adj} , M_{adjh} , M_{adjl}) in [Table 6-5](#) to modulate the command and modulate the frame-sync or preamble that precedes the command.

Interrogators may increase (adjust up) the field strength by M_{adju} after the last transmitted bit of a *Query*, *QueryX* with $Init=1_2$, or *QueryY* with $Init=1_2$ command as in [Figure 6-5 b\)](#) and [Table 6-5](#). If an Interrogator adjusts the field strength up after the last transmitted bit, the Interrogator shall monotonically increase the field strength from the end of the pulsewidth to A_{M1} within maximum t_{lag} time. An Interrogator may adjust up, adjust down, or use different values for M_{adjd} and M_{adju} .

Tags shall communicate with Interrogators that adjust the field strength of the R=>T envelope. Using the parameters in [Table 6-8](#) and an RF envelope sequence of power-up, field strength adjust down, a *QueryX* command, field strength adjust up, and then *ACK* command, then the minimum nominal field strength for a Tag to complete a reply to an *ACK* shall be less than 1.25 times the maximum nominal field strength with no reply to a *QueryX*.

The minimum nominal field strength for a complete reply from a command includes all backscatter data to complete a valid reply. The maximum nominal field strength from a command with no reply is the absence of any (partial or complete) backscatter data after the command.

An Interrogator may be unable to inventory all Tags when using field strength adjust for a *Query* command. Tags that are compliant to prior versions of this protocol may not tolerate the field strength adjustment and consequently will not be inventoried.

Table 6-8 — Conformance test parameters for Tag's field strength adjust for *QueryX* command^a

Parameter or memory	Value	Additional details
Modulation	DSB-ASK	
Modulation Depth	90%	
Tari	6.25 μ s	
PIE ratio	1.5	
TRcal	33 μ s	TRcal=33 μ s for BLF=640kHz
<u>Session</u>	00 ₂	Session S0
<u>Action</u>	000 ₂	S0 inventoried → A
<u>SelType</u>	011 ₂	always matching
<u>Flx</u>	0 ₂	no flexible filter
<u>ReplyCRC</u>	0 ₂	reply with RN16
<u>AckData</u>	01 ₂	reply with UII to ACK
<u>DBLF</u>	001 ₂	BLF=640kHz
<u>DR</u>	1 ₂	DR=64/3 for BLF=640kHz
<u>M</u>	01 ₂	Miller = 2 encoding
<u>TRext</u>	0 ₂	No extended preamble
<u>Sel</u>	00 ₂	All tags
<u>Target</u>	0 ₂	Target A
<u>Q</u>	000 ₂	Q=0
UII value	00...00 _h	All zeros, 96-bit length (6 words)

^a These are conformance test parameters. Interrogator may use other parameters with field strength adjust.

6.3.1.2.10 Frequency-hopping spread-spectrum waveform and channelization

When an Interrogator uses frequency-hopping spread spectrum (FHSS) signaling, the Interrogator's RF envelope shall comply with the power-up and power-down waveforms in a, b, [Table 6-6](#) and [Table 6-7](#). The maximum time between frequency hops and the minimum RF-off time during a hop shall meet local regulatory requirements. 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 (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 modulating an R=>T inventory command sequence 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

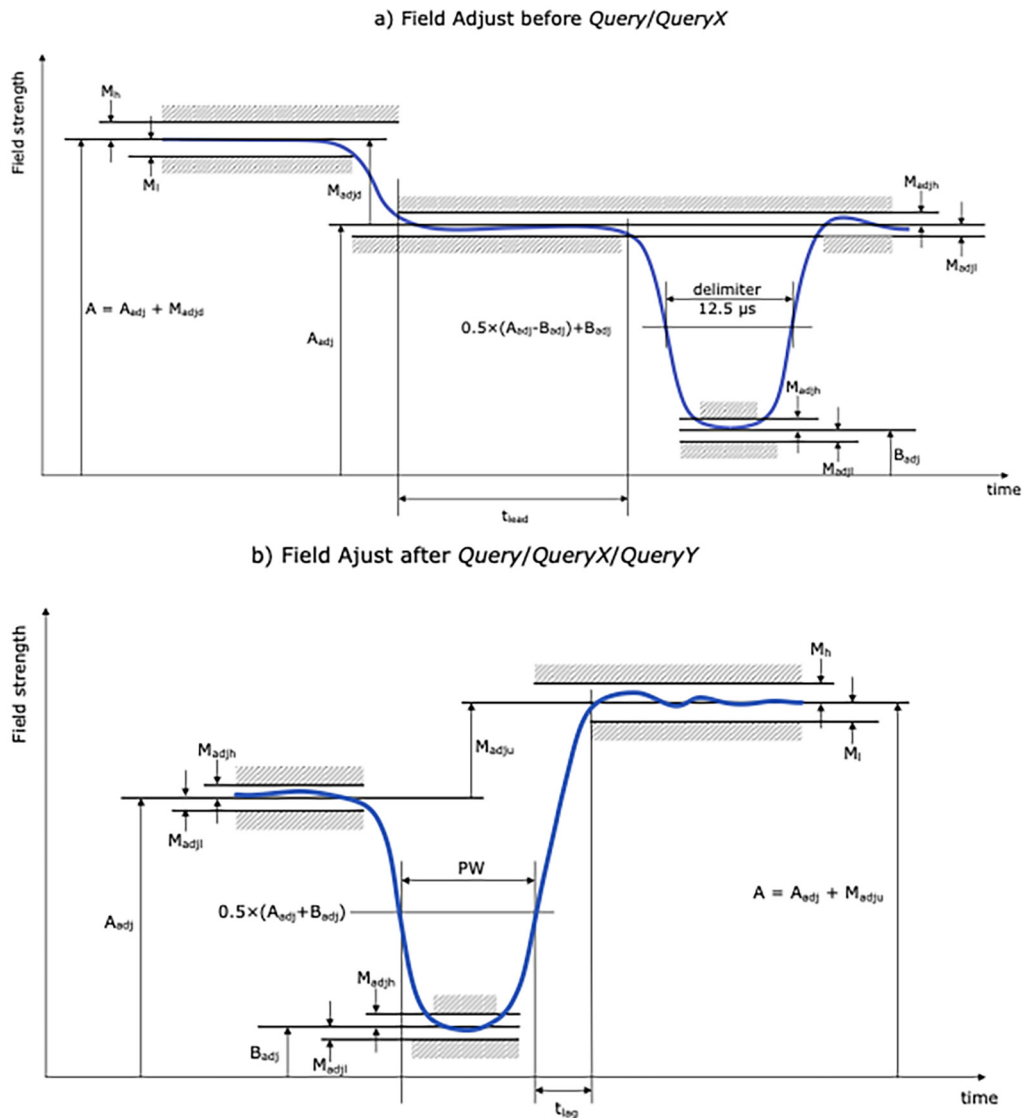


Figure 6-5 — RF envelope for field strength adjust

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. 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 $2,5/\text{Tari}$ bandwidth R_{BW} also centered at f_c , an offset frequency $f_o = 2,5/\text{Tari}$, and a $2,5/\text{Tari}$ 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 modulating an R=>T inventory command sequence shall not exceed the specified values:

- $|n| = 1$: $10\log_{10}(P(S_{BW}) / P(R_{BW})) < -30 \text{ dB}$
- $|n| = 2$: $10\log_{10}(P(S_{BW}) / P(R_{BW})) < -60 \text{ dB}$
- $|n| > 2$: $10\log_{10}(P(S_{BW}) / P(R_{BW})) < -65 \text{ dB}$

Where $P()$ denotes the total integrated power in the $2,5/\text{Tari}$ 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.

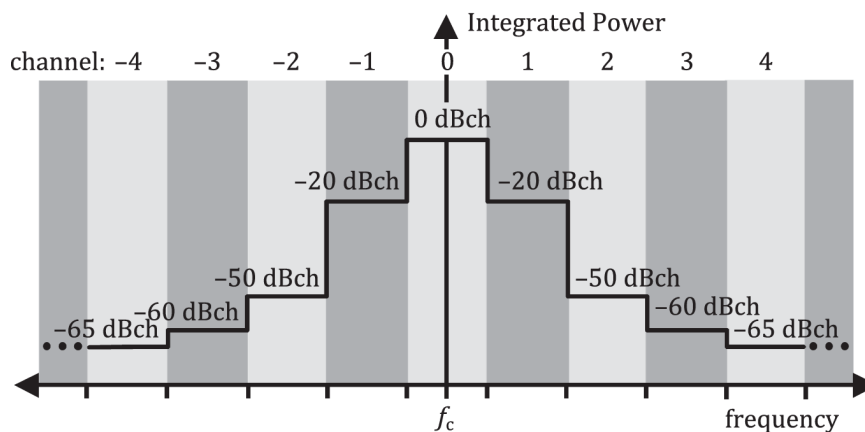


Figure 6-6 — Transmit mask for multiple-Interrogator environments

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* or *QueryX* command that begins 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).

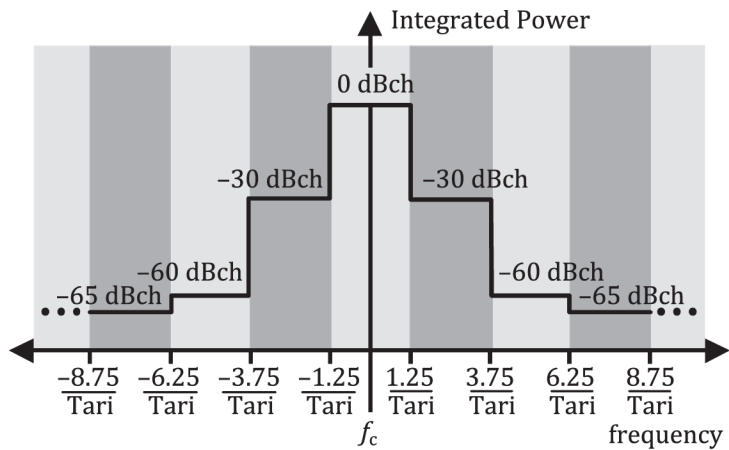


Figure 6-7 — Transmit mask for dense-Interrogator environments

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.

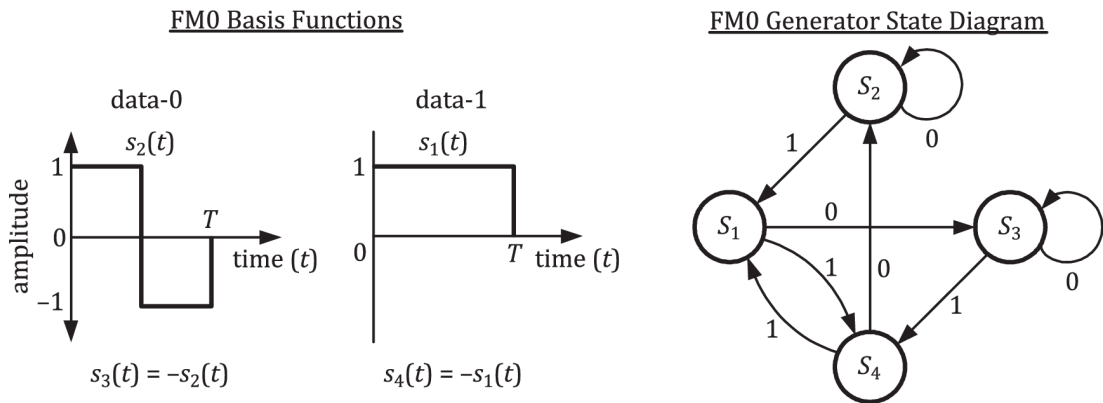


Figure 6-8 — FM0 basis functions and generator state diagram

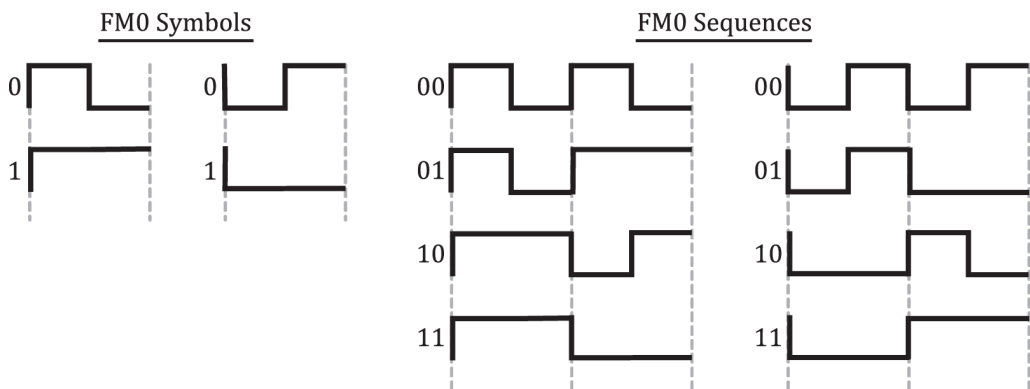


Figure 6-9 — FM0 symbols and sequences

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 an extra data-1 bit, known as a “dummy” 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 **T_{Rext}** value specified in the *Query* or *QueryX* that begins 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_{Rext}** (i.e. a Tag replies as if **T_{Rext}**=1₂ regardless of the **T_{Rext}** value specified in the *Query* (see [6.3.2.12.2.1](#)) or in the *QueryX* (see [6.3.2.12.2.2](#)). An FM0 violation (i.e. a phase inversion should have occurred but did not) is indicated by “v” in [Figure 6-11](#).

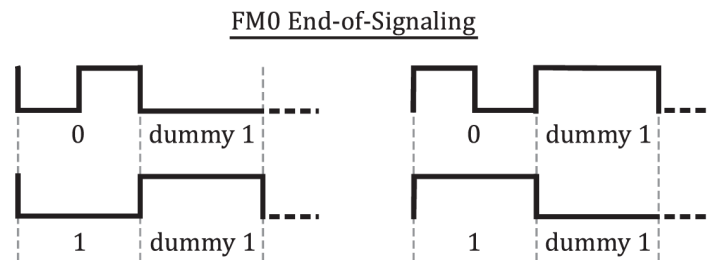


Figure 6-10 — Terminating FM0 transmissions

6.3.1.3.2.3 Miller-modulated subcarrier

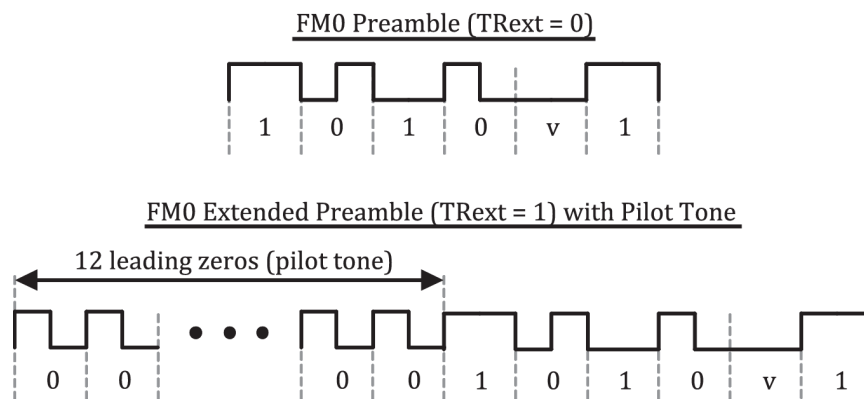


Figure 6-11 — FM0 T=>R preamble

[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.

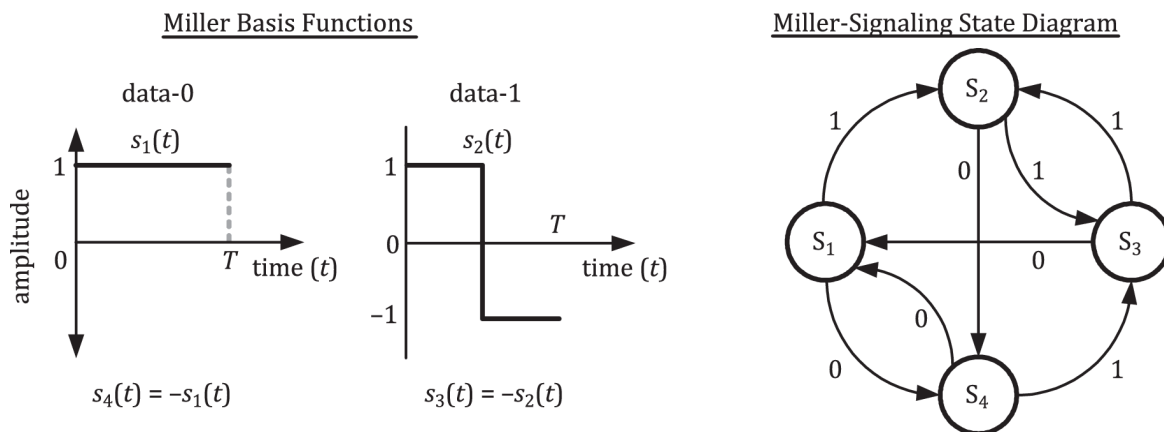


Figure 6-12 — Miller basis functions and generator state diagram

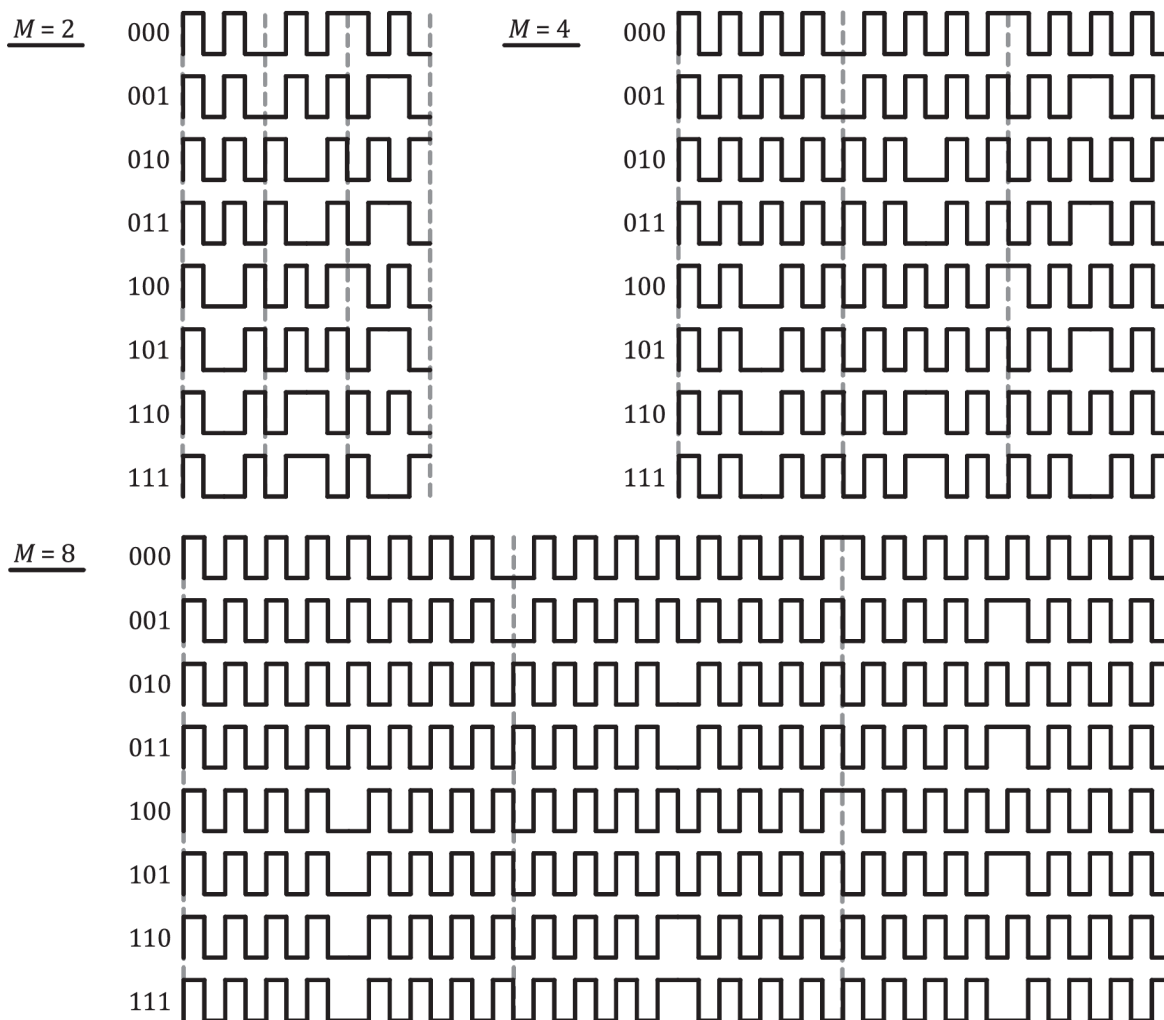


Figure 6-13 — Miller subcarrier sequences

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* or *QueryX* command that began the inventory round (see Table 6-10). The duty cycle of a data-0 or data-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 an extra data-1 bit, known as a “dummy” bit at the end of a transmission, as shown in Figure 6-14.

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 TR_{ext} value specified in the *Query* or *QueryX* that began 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 TR_{ext} (i.e. a Tag replies as if $TR_{ext}=1_2$ regardless of the TR_{ext} value specified in the *Query*, see 6.3.2.12.2.1) or in the *QueryX* (see 6.3.2.12.2.2).

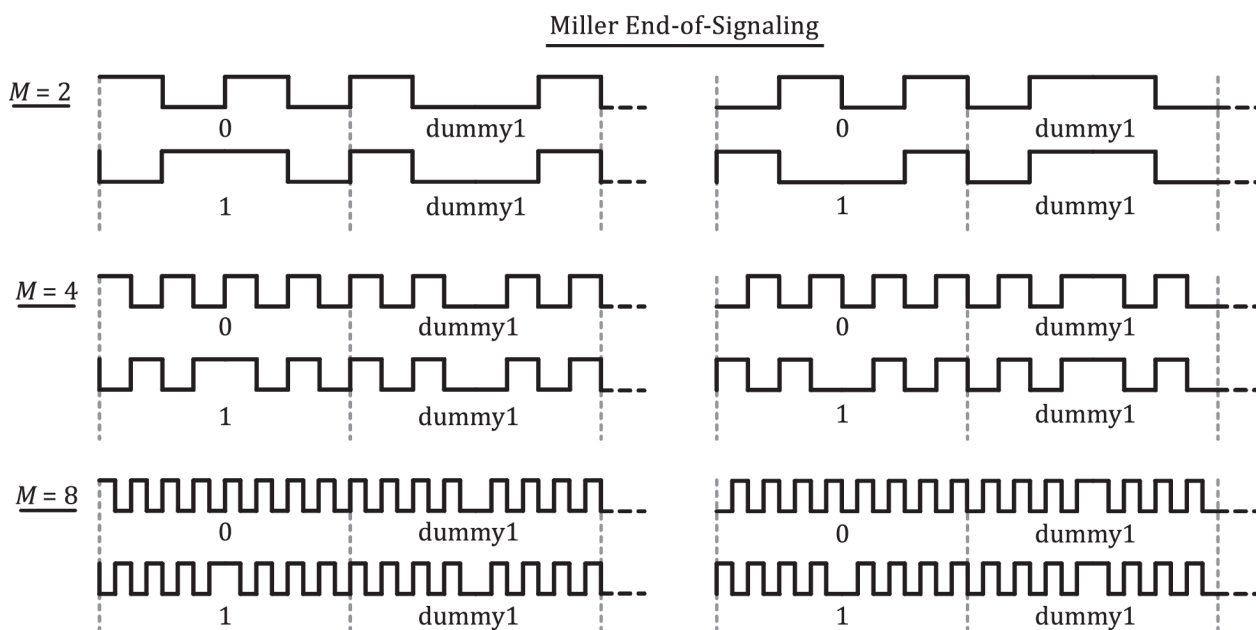


Figure 6-14 — Terminating subcarrier transmissions

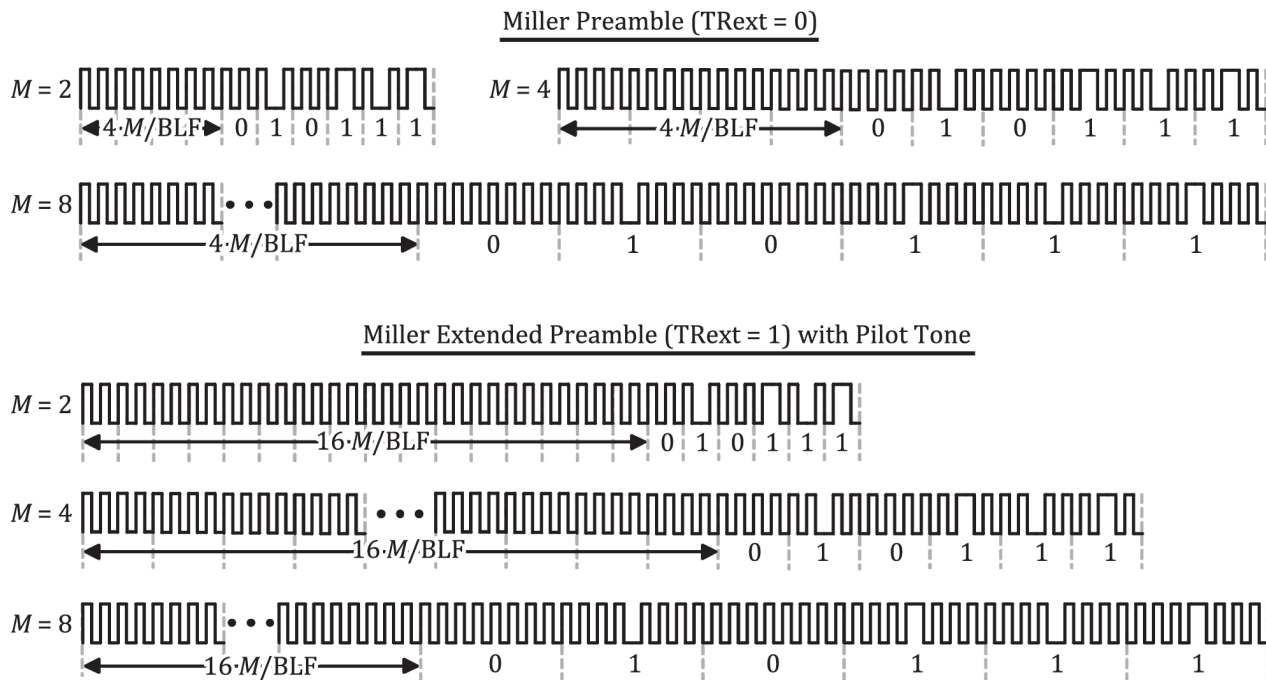


Figure 6-15 — Subcarrier T=>R preamble

6.3.1.3.3 Tag-supported Tari values and backscatter link rates

Tags shall support all R=>T Tari values in the range of 6,25 µs to 25 µs, over all parameters allowed by 6.3.1.2.3.

For inventory rounds beginning with a *Query*, Tags shall support the required T=>R backscatter link frequencies and tolerances (for *Query*) specified in Table 6-9 and the T=>R data rates specified in Table 6-10. For inventory rounds beginning with a *QueryX*, Tags shall support required T=>R backscatter link frequencies and tolerances (for *QueryX*) in Table 6-9 and the T=>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* or *QueryX* command that begins an inventory round specifies DR in Table 6-9d and M in Table 6-10, and the *QueryX* command additionally specifies DBLF. The preamble that precedes the *Query* or *QueryX* specifies TRcal. BLF is computed using Formula 6-1. These parameters define the backscatter link frequency, modulation type (FM0 or Miller), and T=>R data rate for the round for *Query* and *QueryX* (see also 6.3.1.2.8).

A Tag shall support the required T=>R backscatter link frequencies for a *QueryX* by using the DBLF parameter (“digital BLF”) and/or by using the TRcal value and the DR parameter (“analog BLF”):

- Tags may support T=>R backscatter link frequencies specified in Table 6-9 that are optional for inventory rounds beginning with a *QueryX*.
- If a Tag does not support an optional *QueryX* T=>R backscatter link frequency, then the Tag shall not participate in the inventory round (see 6.3.2.12.2.2).
- A Tag that supports a T=>R backscatter link frequency using analog BLF may ignore DBLF values.

Table 6-9 — Tag-to-Interrogator backscatter link frequencies

	For <i>QueryX</i> and <i>Query</i>		For <i>QueryX</i>			For <i>Query</i>			For <i>QueryX</i> and <i>Query</i>
<u>DR</u> : Divide Ratio	TRcal ^b ($\mu\text{s} \pm 1\%$)	BLF (kHz)	Required by Tag for <i>QueryX</i>	DBLF ^a : Digital BLF	FrT ^c ext. temp	Required by Tag for <i>Query</i>	FrT ^d nom. temp	FrT ^c ext. temp	Frequency variation during backscatter
64/3	33.3	640	yes	001 ₂	$\pm 7\%$	yes	$\pm 15\%$	$\pm 15\%$	$\pm 2.5\%$
	33.3 < TRcal < 50.0	427 < BLF < 640	optional	101 ₂	$\pm 7\%$	yes	$\pm 22\%$	$\pm 22\%$	$\pm 2.5\%$
	50.0	427	yes	010 ₂	$\pm 7\%$	yes	$\pm 22\%$	$\pm 22\%$	$\pm 2.5\%$
	50.0 < TRcal < 66.7	320 < BLF < 427	optional	101 ₂	$\pm 7\%$	yes	$\pm 22\%$	$\pm 22\%$	$\pm 2.5\%$
	66.7	320	yes	011 ₂	$\pm 7\%$	yes	$\pm 10\%$	$\pm 15\%$	$\pm 2.5\%$
	66.7 < TRcal < 83.3	256 < BLF < 320	optional	101 ₂	$\pm 7\%$	yes	$\pm 12\%$	$\pm 15\%$	$\pm 2.5\%$
	83.3	256	yes	100 ₂	$\pm 7\%$	yes	$\pm 10\%$	$\pm 10\%$	$\pm 2.5\%$
	83.3 < TRcal < 133.3	160 < BLF < 256	optional	101 ₂	$\pm 7\%$	yes	$\pm 10\%$	$\pm 12\%$	$\pm 2.5\%$
	133.3	160	yes	111 ₂	$\pm 7\%$	yes	$\pm 7\%$	$\pm 7\%$	$\pm 2.5\%$
	133.3 < TRcal $\leq$ 200	107 $\leq$ BLF < 160	optional	110 ₂	$\pm 7\%$	yes	$\pm 7\%$	$\pm 7\%$	$\pm 2.5\%$
	200 < TRcal $\leq$ 225	95 $\leq$ BLF < 107	optional	110 ₂	$\pm 5\%$	yes	$\pm 5\%$	$\pm 5\%$	$\pm 2.5\%$
^a See DBLF parameter in 6.3.2.12.2.2. ^b Allowing two different TRcal values (with two different <u>DR</u> values) to specify the same BLF offers flexibility in specifying Tari and RTcal. ^c Frequency Tolerance over extended temperature range. ^d Frequency Tolerance over nominal temperature range.									

Table 6-9 (continued)

	For QueryX and Query		For QueryX			For Query			For QueryX and Query
DR: Divide Ratio	TRcal ^b ($\mu\text{s} \pm 1\%$)	BLF (kHz)	Required by Tag for QueryX	DBLF ^a : Digital BLF	FrT ^c ext. temp	Required by Tag for Query	FrT ^d nom. temp	FrT ^c ext. temp	Frequency variation during backscatter
8	$17.2 \leq \text{TRcal} < 18.74$	$427 < \text{BLF} \leq 465$	optional	101 ₂	$\pm 7\%$	yes	$\pm 19\%$	$\pm 19\%$	$\pm 2.5\%$
	18.74	427	yes	010 ₂	$\pm 7\%$	yes	$\pm 19\%$	$\pm 19\%$	$\pm 2.5\%$
	$18.74 < \text{TRcal} < 25$	$320 < \text{BLF} < 427$	optional	101 ₂	$\pm 7\%$	yes	$\pm 19\%$	$\pm 19\%$	$\pm 2.5\%$
	25	320	yes	011 ₂	$\pm 7\%$	yes	$\pm 10\%$	$\pm 15\%$	$\pm 2.5\%$
	$25 < \text{TRcal} < 31.25$	$256 < \text{BLF} < 320$	optional	101 ₂	$\pm 7\%$	yes	$\pm 12\%$	$\pm 15\%$	$\pm 2.5\%$
	31.25	256	yes	100 ₂	$\pm 7\%$	yes	$\pm 10\%$	$\pm 10\%$	$\pm 2.5\%$
	$31.25 < \text{TRcal} < 50$	$160 < \text{BLF} < 256$	optional	101 ₂	$\pm 7\%$	yes	$\pm 10\%$	$\pm 10\%$	$\pm 2.5\%$
	50	160	yes	111 ₂	$\pm 7\%$	yes	$\pm 7\%$	$\pm 7\%$	$\pm 2.5\%$
	$50 < \text{TRcal} \leq 75$	$107 \leq \text{BLF} < 160$	optional	110 ₂	$\pm 7\%$	yes	$\pm 7\%$	$\pm 7\%$	$\pm 2.5\%$
	$75 < \text{TRcal} \leq 200$	$40 \leq \text{BLF} < 107$	optional	110 ₂	$\pm 4\%$	yes	$\pm 4\%$	$\pm 4\%$	$\pm 2.5\%$
^a See DBLF parameter in 6.3.2.12.2.2. ^b Allowing two different TRcal values (with two different DR values) to specify the same BLF offers flexibility in specifying Tari and RTcal. ^c Frequency Tolerance over extended temperature range. ^d Frequency Tolerance over nominal temperature range.									

Table 6-10 — Tag-to-Interrogator data rates

M: Number of subcarrier cycles 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 to exceed the minimum time before command, power-up (i.e. by minimum T_{cp}), specified in Table 6-6.

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); and

— 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 a checksum residue using the CRC-16 parameters in [Table 6-11](#). The Tag or Interrogator shall then take the ones-complement of the computed residue to form the CRC-16.

Table 6-11 — CRC-16 parameters (See also [Annex F](#))

CRC-16 precursor (See also Annex F)				
CRC Type	Length	Polynomial	Preset	Residue
ISO/IEC 13239:2002 [7]	16 bits	$x^{16} + x^{12} + x^5 + 1$	FFFF _h	1D0F _h

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 or a CRC-5 to those replies that use a CRC-5. See [6.3.2.12](#) for command-specific replies.

Table 6-12 — CRC-5 parameters (See also [Annex F](#))

CRC-5 definition (See also Annex F)				
CRC Type	Length	Polynomial	Preset	Residue
—	5 bits	$x^5 + x^3 + 1$	01001 ₂	00000 ₂

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 6-29](#).

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 6-29 specifies the reply type that a Tag uses for each Interrogator command.

Figure 6-18 also illustrates timing for *QueryX* and for *QueryX* followed by *QueryY* that may start a T8 timeout as defined in 6.3.1.6.5.

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 $T_{5(\text{max})}$, 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:

- 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 $T_{5(\text{max})}$ then the command completed successfully.
- 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 reply shall meet the T_5 limits in Table 6-16. An error reply uses header=1₂ (see Annex I) to differentiate it from a successful reply.
- The Tag fails to execute the command:** If the Interrogator does not observe a Tag reply within $T_{5(\text{max})}$ then the Tag may have not executed 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 $T_{\text{Rext}}=1_2$ regardless of the T_{Rext} value in the *Query* or *QueryX* that began the inventory round).

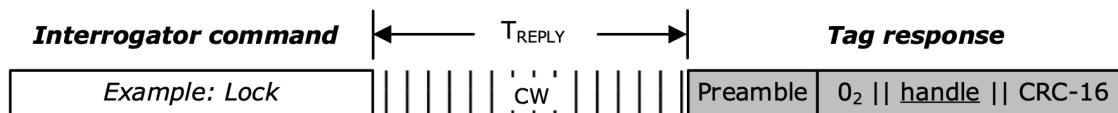


Figure 6-16 — Successful *delayed-reply* sequence

6.3.1.6.3 In-process Tag reply

An *in-process* reply allows a Tag to spend longer than $T_{5(\text{max})}$ 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 6.3.2.12.3.12), 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 first reply includes length then all subsequent replies shall include length.

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:

- a) **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_h. When the Tag has finished processing it sends a final reply, also as shown in Table 6-14, including done=1₂, header=0₂, 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=0₂ then the command completed successfully.
- b) **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_h. When a Tag encounters an error it sends a final reply, also as shown in Table 6-14, including done=1₂, header=1₂, 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).
- c) **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 may have 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=0₂ means the Tag is still processing; done=1₂ means the Tag has finished processing. Header indicates whether computation was successful or not: header=0₂ means the response includes a result; header=1₂ means response includes 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_h 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=1₂ 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=1₂ regardless of the TRExt value in the *Query* or *QueryX* that began the inventory round).

6.3.1.6.4 ResponseBuffer

A Tag that implements a *Challenge* command, or supports SenRep=0₂ in an access command 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 6-19](#)), indicates whether the Tag has a stored response (result or error code) in its ResponseBuffer. **C**=1₂ indicates that the ResponseBuffer contains data; **C**=0₂ indicates that the ResponseBuffer is empty.
- A Tag shall set **C**=1₂ after storing a response (result or error code) in its ResponseBuffer.
- A Tag shall set **C**=0₂ upon (1) receiving an access command containing SenRep=0₂ (c.f. [6.3.2.12.3](#)), (2) receiving a *Challenge* command, or (3) when specified by a cryptographic suite. A Tag may set **C**=0₂ upon receiving an access command containing SenRep=1₂, or when the Tag transitions from the **acknowledged**, **open**, or **secured** states.
- The **C** flag shall be selectable using a *Select*, *QueryX* or *QueryY* command.
- If an access command with SenRep=0₂ or a *Challenge* command specifies IncRepLen=0₂ 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_h. If the command specifies IncRepLen=1₂ then ResponseBuffer bits 00_h – 0E_h shall contain the length of the stored response in bits, ResponseBuffer bit 0F_h shall contain an even parity bit that the Tag computes over bits 00_h – 0E_h, and the first word of the stored response shall be at ResponseBuffer location 10_h. 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	Length	Response	RN	CRC
number of bits	7	1	1	0 / 16	variable	16	16
description (omitting <u>length</u> field)	1110010	0: Working 1: Finished	0: Success 1: Error code	--	<u>result</u> or error code	<u>handle</u>	CRC-16
description (including <u>length</u> field)	1110010	0: Working 1: Finished	0: Success 1: Error code	15 bits encoding <u>length of result</u> or <u>error code</u> followed by even parity bit	<u>result</u> or error code	<u>handle</u>	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 [6.3.2.12.3.16](#).
- 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 6-21](#)). When **C**=1₂ then a Tag shall maintain the data in its ResponseBuffer. When **C** is or becomes 0₂ then a Tag shall deallocate its ResponseBuffer.

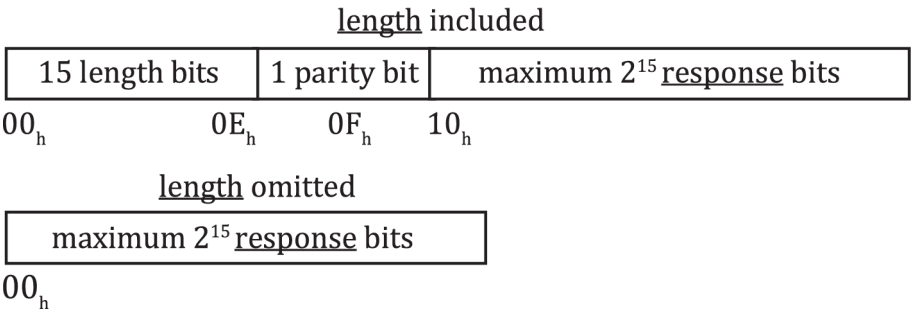


Figure 6-17 — ResponseBuffer data storage

The Tag memory for the ResponseBuffer is Tag-manufacturer defined. Also, because a ResponseBuffer is not writable 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 <u>length</u> ?	Reply	
			Tag executed command	Tag failed to execute command
Sent	$\leq T_{6(\max)}$	Omit	<u>done</u> : 1 <u>header</u> : 0 <u>response</u> : <u>result</u>	<u>done</u> : 1 <u>header</u> : 1 <u>response</u> : <u>error code</u>
		Include	<u>done</u> : 1 <u>header</u> : 0 <u>length</u> : length of sent <u>result</u> <u>response</u> : <u>result</u>	<u>done</u> : 1 <u>header</u> : 1 <u>length</u> : length of sent <u>error code</u> <u>response</u> : <u>error code</u>
	Any	Omit	Intermediate reply or replies <u>done</u> : 0 <u>header</u> : 0 <u>response</u> : null Final reply <u>done</u> : 1 <u>header</u> : 0 <u>response</u> : <u>result</u>	Intermediate reply or replies <u>done</u> : 0 <u>header</u> : 0 <u>response</u> : null Final reply <u>done</u> : 1 <u>header</u> : 1 <u>response</u> : <u>error code</u>
		Include	Intermediate reply or replies <u>done</u> : 0 <u>header</u> : 0 <u>length</u> : 0000 _h <u>response</u> : null Final reply <u>done</u> : 1 <u>header</u> : 0 <u>length</u> : length of sent result <u>response</u> : <u>result</u>	Intermediate reply or replies <u>done</u> : 0 <u>header</u> : 0 <u>length</u> : 0000 _h <u>response</u> : null Final reply <u>done</u> : 1 <u>header</u> : 1 <u>length</u> : length of sent <u>error code</u> <u>response</u> : <u>error code</u>

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 header: 0 response: null	done: 1 header: 1 response: null
		Include	done: 1 header: 0 length: length of stored <u>result</u> response: null	done: 1 header: 1 length: length of stored <u>error code</u> response: null
	Any	Omit	Intermediate reply or replies done: 0 header: 0 response: null Final reply done: 1 header: 0 response: null	Intermediate reply or replies done: 0 header: 0 response: null Final reply done: 1 header: 1 response: null
		Include	Intermediate reply or replies done: 0 header: 0 length: 0000 _h Response: null Final reply done: 1 header: 0 length: length of stored <u>result</u> response: null	Intermediate reply or replies done: 0 header: 0 length: 0000 _h response: null Final reply done: 1 header: 1 length: length of stored <u>error code</u> response: null

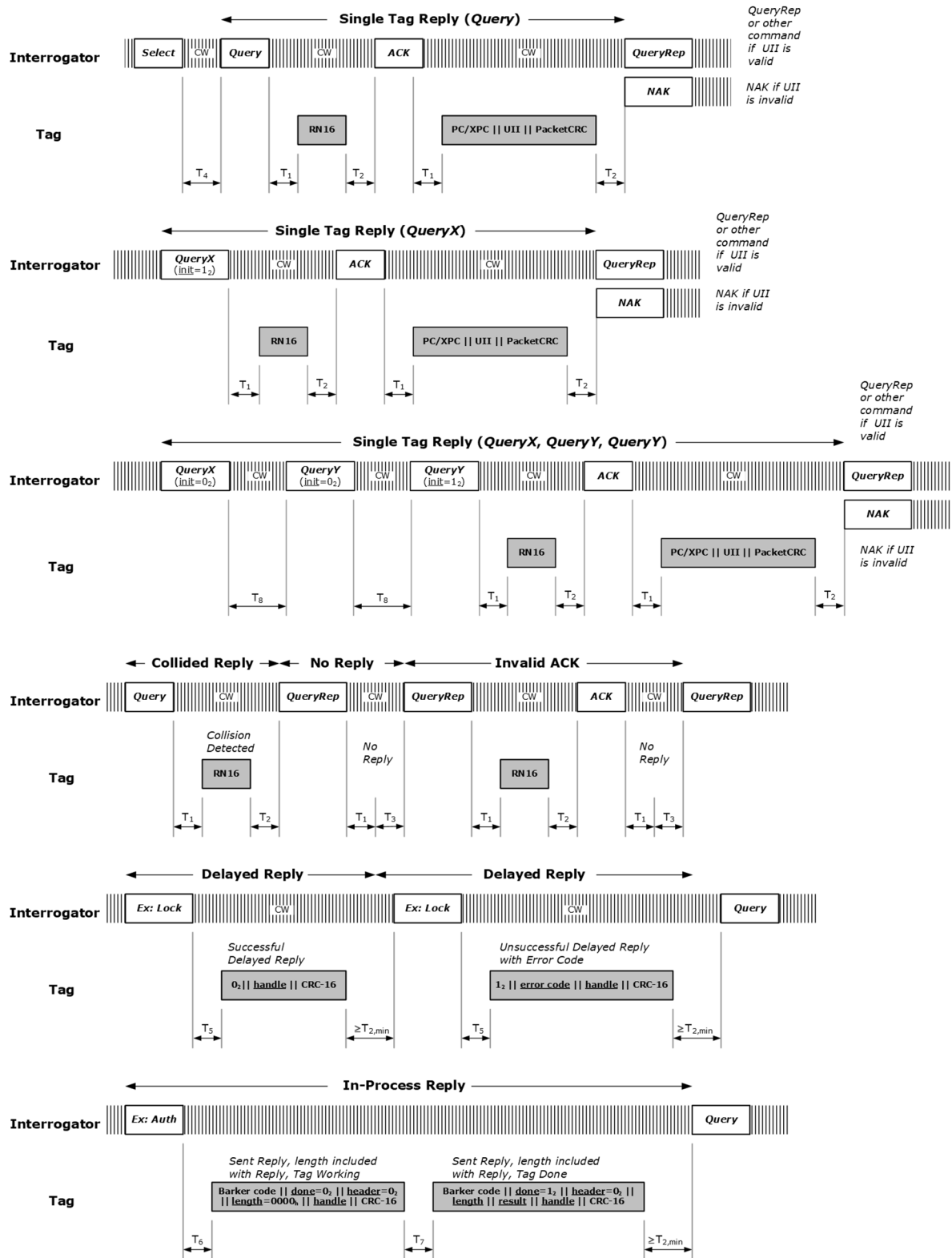


Figure 6-18 — Link timing

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	2.0RTcal			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
T_8	2.0RTcal	3.0RTcal	4.0RTcal	Interrogator time between the last rising edge of a previous <i>QueryX/QueryY</i> (<i>Init</i> =0 ₂) and the falling edge of the delimiter from a following <i>QueryY</i>

The following items apply to the requirements specified in [Table 6-16](#):

- 1) T_{pri} denotes either the commanded period of an FM0 symbol or the commanded period of a single subcarrier cycle, as appropriate.
- 2) 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,