



EPC™ Radio-Frequency Identity Protocols Generation-2 UHF RFID

Specification for RFID Air Interface

Protocol for Communications at 860 MHz – 960 MHz

Version 2.0.1 Ratified



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Introduction

This protocol defines the physical and logical requirements for a passive-backscatter, Interrogator-talks-first (ITF), radio-frequency identification (RFID) system operating in the 860 MHz – 960 MHz frequency range. The system comprises Interrogators, also known as Readers, and Tags, also known as Labels or Transponders.

An Interrogator transmits information to a Tag by modulating an RF signal in the 860 MHz – 960 MHz frequency range. The Tag receives both information and operating energy from this RF signal. Tags are passive, meaning that they receive all of their operating energy from the Interrogator's RF signal.

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

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

1. Scope

This protocol specifies:

- Physical interactions (the signaling layer of the communication link) between Interrogators and Tags, and
- Logical operating procedures and commands between Interrogators and Tags.

2. Conformance

2.1 Claiming conformance

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

- a) all clauses in this protocol (except those marked as optional), and
- b) the conformance document associated with this protocol, and,
- c) all local radio regulations.

To be certified as alteration-EAS, Tag-alteration, and/or consumer-electronics conformant, Tags and Interrogators shall additionally support the optional clauses or portions of optional clauses specified in [Annex N](#).

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

2.2 General conformance requirements

2.2.1 Interrogators

To conform to this protocol, an Interrogator shall:

- Meet the requirements of this protocol,
- Implement the mandatory commands defined in this protocol,
- Modulate/transmit and receive/demodulate a sufficient set of the electrical signals defined in the signaling layer of this protocol to communicate with conformant Tags, and
- Conform to all local radio regulations.

To conform to this protocol, an Interrogator may:

- Implement any subset of the optional commands defined in this protocol, and
- Implement any proprietary and/or custom commands in conformance with this protocol.

To conform to this protocol, an Interrogator shall not:

- Implement any command that conflicts with this protocol, or
- Require using an optional, proprietary, or custom command to meet the requirements of this protocol.

2.2.2 Tags

To conform to this protocol, a Tag shall:

- Meet the requirements of this protocol,
- Implement the mandatory commands defined in this protocol,
- Modulate a backscatter signal only after receiving the requisite command from an Interrogator, and
- Conform to all local radio regulations.

To conform to this protocol, a Tag may:

- Implement any subset of the optional commands defined in this protocol, and
- Implement any proprietary and/or custom commands as defined in 2.3.3 and 2.3.4, respectively.

To conform to this protocol, a Tag shall not:

- Implement any command that conflicts with this protocol,
- Require using an optional, proprietary, or custom command to meet the requirements of this protocol, or
- Modulate a backscatter signal unless commanded to do so by an Interrogator using the signaling layer defined in this protocol.

2.3 Command structure and extensibility

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

2.3.1 Mandatory commands

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

2.3.2 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.

2.3.3 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.

2.3.4 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 (1) singulating a Tag, and (2) 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.

2.4 Reserved for Future Use (RFU)

This protocol denotes some Tag memory addresses, Interrogator command codes, and bit fields within Interrogator commands as RFU. GS1 EPCglobal is reserving these RFU values for future extensibility. Under some circumstances GS1 EPCglobal may permit another standards body or organization to use one or more of these RFU values for standardization purposes. In such circumstances the permitted body shall keep GS1 EPCglobal apprised, in a timely manner, of its use or potential use of these RFU values. Third parties, including but not limited to solution providers and end users, shall not use these RFU values for proprietary purposes.

2.5 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:
 - 0000₂ – 0011₂: ISO/IEC 29167
 - 0100₂ – 1100₂: RFU
 - 1101₂: Tag manufacturer
 - 1110₂: GS1
 - 1111₂: 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 may assign.

3. Normative references

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

GS1 EPCglobal™: GS1 EPC™ Tag Data Standard

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

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

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

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

ISO/IEC 18000-63: Information technology automatic identification and data capture techniques — Radio frequency identification for item management air interface — Part 63: Parameters for air interface communications at 860–960 MHz

ISO/IEC 19762: Information technology AIDC techniques – Harmonized vocabulary – Part 3: radio-frequency identification (RFID)

ISO/IEC 29167-1: Information technology — Automatic identification and data capture techniques — Part 1: Security services for RFID air interfaces

4. Terms and definitions

The principal terms and definitions used in this protocol are described in ISO/IEC 19762.

4.1 Additional terms and definitions

Terms and definitions specific to this protocol that supersede any normative references are as follows:

Air interface

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

Asymmetric key pair

A private key and its corresponding public key, used in conjunction with an asymmetric cryptographic suite.

Authentication

The process of determining whether an entity or data is/are who or what, respectively, it claims to be. The types of entity authentication referred-to in this protocol are Tag authentication, Interrogator authentication, and Tag-Interrogator mutual authentication. For data authentication see authenticated communications.

Authenticated communications

Communications in which message integrity is protected.

Command set

The set of commands used to inventory and interact with a Tag population.

Continuous wave

Typically a sinusoid at a given frequency, but more generally any Interrogator waveform suitable for powering a passive Tag without amplitude and/or phase modulation of sufficient magnitude to be interpreted by a Tag as transmitted data.

Cover coding

A 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 bit-wise EXOR 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 bit-wise EXOR of the received cover-coded string with the original random number.

Crypto superuser

A key with an asserted CryptoSuperuser privilege.

Data element

A low-level, indivisible data construct. See file and record.

Dense-Interrogator environment

An operating environment (defined below) within which most or all of the available channels are occupied by active Interrogators (for example, 25 active Interrogators operating in 25 available channels).

Dense-Interrogator mode

A set of Interrogator-to-Tag and Tag-to-Interrogator signaling parameters used in dense-Interrogator environments.

Extended Tag identifier (XTID)

A memory construct that defines a Tag's capabilities and may include a Tag serial number, further specified in the *GS1 EPC Tag Data Standard*.

Extended temperature range

−40 °C to +65 °C (see nominal temperature range).

File type

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

File

A set of one or more records accessed as a unit (see record and data element).

File superuser

An access password or key with a 0011₂ **secured**-state file privilege value

Full-duplex communications

A communications channel that carries data in both directions at once. See half-duplex communications.

GS1 EPCglobal™ Application

An application whose usage denotes an acceptance of GS1 EPCglobal™ standards and policies (see non-GS1 EPCglobal™ Application).

Half-duplex communications

A communications channel that carries data in one direction at a time rather than in both directions at once. See full-duplex communications.

Insecure communications

Communications in which neither message integrity nor message confidentiality are protected.

Interrogator authentication

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

Inventoried flag

A flag that indicates whether a Tag may respond to an Interrogator. Tags maintain a separate **inventoried** flag for each of four sessions; each flag has symmetric *A* and *B* values. Within any given session, Interrogators typically inventory Tags from *A* to *B* followed by a re-inventory of Tags from *B* back to *A* (or vice versa).

Inventory round

The period initiated by a *Query* command and terminated by either a subsequent *Query* command (which also starts a new inventory round), a *Select* command, or a *Challenge* command.

Key

A value used to influence the output of a cryptographic algorithm or cipher.

KeyID

A numerical designator for a single key.

Message authentication code (MAC)

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

Multiple-Interrogator environment

An operating environment (defined below) within which a modest number of the available channels are occupied by active Interrogators (for example, 5 active Interrogators operating in 25 available channels).

Mutual authentication

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

Nominal temperature range

–25 °C to +40 °C (see extended temperature range).

Non-GS1 EPCglobal™ Application

An application whose usage does not denote an acceptance of GS1 EPCglobal™ standards and policies (see GS1 EPCglobal™ Application).

Nonremovable Tag

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

Operating environment

A region within which an Interrogator's RF transmissions are attenuated by less than 90dB. In free space, the operating environment is a sphere whose radius is approximately 1000m, with the Interrogator located at the center. In a building or other enclosure, the size and shape of the operating environment depends on factors such as the material properties and shape of the building, and may be less than 1000m in certain directions and greater than 1000m in other directions.

Operating procedure

Collectively, the set of functions and commands used by an Interrogator to inventory and interact with Tags (also known as the *Tag-identification layer*).

PacketCRC

A 16-bit cyclic-redundancy check (CRC) code that a Tag calculates over its PC, optional XPC word or words, and EPC and backscatters during inventory.

PacketPC

Protocol-control information that a Tag with an asserted **XI** dynamically calculates. See StoredPC.

Passive Tag (or passive Label)

A Tag (or Label) whose transceiver is powered by the RF field.

Password

A secret value sent by an Interrogator to a Tag to enable restricted Tag operations. Passwords are not keys. (Note: The only passwords defined by this protocol are the kill and access passwords).

Permalock or permalocked

A memory location whose lock status is unchangeable (i.e. the memory location is permanently locked or permanently unlocked).

Persistent memory or persistent flag

A memory or flag value whose state is maintained during a brief loss of Tag power.

Physical layer

The data coding and modulation waveforms used in Interrogator-to-Tag and Tag-to-Interrogator signaling.

Private key

The undisclosed or non-distributed key in an asymmetric, or public-private key pair, cipher. A private key is typically used for decryption or digital-signature generation. See public key.

Protocol

Collectively, a physical layer and a Tag-identification layer specification.

Public key

The disclosed or distributed key in an asymmetric, or public-private key pair, cipher. A public key is typically used for encryption or signature verification. See private key.

Q

A parameter that an Interrogator uses to regulate the probability of Tag response. 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 – see below) is zero. Q is an integer in the range (0,15); the corresponding Tag-response probabilities range from $2^0 = 1$ to $2^{-15} = 0.000031$.

Random-slotted collision arbitration

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

Record

A set of one or more data elements accessed as a unit. See data element and file.

Removable Tag

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

Secure communications

Communications in which message confidentiality is protected.

Security

A degree of protection against threats identified in a security policy. A system is secure if it is protected to the degree specified in the security policy. See security policy.

Security policy

A definition, either explicit or implicit, of the threats a system is intended to address. See security.

Session

An inventory process comprising an Interrogator and an associated Tag population. An Interrogator chooses one of four sessions and inventories Tags within that session. The Interrogator and associated Tag population operate in one and only one session for the duration of an inventory round (defined above). For each session, Tags maintain a corresponding **inventoried** flag. Sessions allow Tags to keep track of their inventoried status separately for each of four possible time-interleaved inventory processes, using an independent **inventoried** flag for each process.

Session key

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

Single-Interrogator environment

An operating environment (defined above) within which there is a single active Interrogator at any given time.

Singulation

Identifying an individual Tag in a multiple-Tag environment.

Slot

Slot corresponds to the point in an inventory round at which a Tag may respond. 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. See Q.

StoredCRC

A 16-bit cyclic-redundancy check (CRC) computed over the StoredPC and the EPC specified by the length (L) bits in the StoredPC, and stored in EPC memory.

StoredPC

Protocol-control information stored in EPC memory. See PacketPC.

Symmetric key

A shared key used in conjunction with a symmetric cipher.

Tag authentication

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

Tag-identification layer

Collectively, the set of functions and commands used by an Interrogator to inventory and interact with Tags (also known as the *operating procedure*).

Tari

Reference time interval for a data-0 in Interrogator-to-Tag signaling. The mnemonic "Tari" derives from the ISO/IEC 18000-6 (part A) specification, in which Tari is an abbreviation for Type A Reference Interval.

Traceable

Not restricting the identifying information a Tag exposes and/or the Tag's operating range. See untraceable.

Untraceable privilege

A 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.

Untraceably hidden memory

Memory that an untraceable tag hides from Interrogators with a deasserted untraceable privilege.

Untraceable

Restricting the identifying information a Tag exposes and/or the Tag's operating range. See traceable.

5. Symbols, abbreviated terms, and notation

The principal symbols and abbreviated terms used in this protocol are detailed in ISO/IEC 19762. Symbols, abbreviated terms, and notation specific to this protocol are as follows:

5.1 Symbols

BLF	Backscatter-link frequency ($BLF = 1/T_{pri} = DR/TR_{cal}$)
C	Computed-response indicator
CSI	Cryptographic suite identifier
DR	Divide ratio
F	File-services indicator (whether a Tag supports the <i>FileOpen</i> command)
FrT	Frequency tolerance
H	Hazmat indicator
K	Killable indicator
M	Number of subcarrier cycles per symbol
M_h	RF signal envelope ripple (overshoot)
M_{hh}	FHSS signal envelope ripple (overshoot)
M_l	RF signal envelope ripple (undershoot)
M_{hl}	FHSS signal envelope ripple (undershoot)
M_s	RF signal level when OFF
M_{hs}	FHSS signal level during a hop
NR	Nonremovable indicator
Q	Slot-count parameter
R=>T	Interrogator-to-Tag
RTcal	Interrogator-to-Tag calibration symbol
S	Security-services indicator (whether a Tag supports the <i>Challenge</i> and/or <i>Authenticate</i> commands)
SLI	SL indicator
T	Numbering system identifier
T₁	Time from Interrogator transmission to Tag response for an <i>immediate</i> Tag reply
T₂	Time from Tag response to Interrogator transmission
T₃	Time an Interrogator waits, after T ₁ , before it issues another command
T₄	Minimum time between Interrogator commands
T₅	Time from Interrogator transmission to Tag response for a <i>delayed</i> Tag reply
T₆	Time from Interrogator transmission to first Tag response for an <i>in-process</i> Tag reply
T₇	Time between Tag responses for an <i>in-process</i> Tag reply
T_f or T_{f,10-90%}	RF signal envelope fall time
T_{hf}	FHSS signal envelope fall time
T_{hr}	FHSS signal envelope rise time
T_{hs}	Time for an FHSS signal to settle to within a specified percentage of its final value
T_{pri}	Backscatter-link pulse-repetition interval ($T_{pri} = 1/BLF = TR_{cal}/DR$)
T_r or T_{r,10-90%}	RF signal envelope rise time
T_s	Time for an RF signal to settle to within a specified percentage of its final value
T=>R	Tag-to-Interrogator
TN	Tag-notification indicator
TRcal	Tag-to-Interrogator calibration symbol
U	Untraceability indicator
UMI	User-memory indicator
X	XTID indicator (whether a Tag implements an XTID)
XEB	XPC_W2 indicator
XI	XPC_W1 indicator
XPC	Extended protocol control
xxxx₂	binary notation
xxxx_h	hexadecimal notation

5.2 Abbreviated terms

AFI	Application family identifier
AM	Amplitude modulation
ASK	Amplitude shift keying
CRC	Cyclic redundancy check
CW	Continuous wave
dBch	Decibels referenced to the integrated power in the reference channel
DSB	Double sideband
DSB-ASK	Double-sideband amplitude-shift keying
EPC	Electronic product code
ETSI	European Telecommunications Standards Institute
FCC	Federal Communications Commission
FDM	Frequency-Division Multiplexing
FHSS	Frequency-hopping spread spectrum
Handle	16-bit Tag identifier
MAC	Message authentication code
PC	Protocol control
PIE	Pulse-interval encoding
Pivot	Decision threshold differentiating an R=>T data-0 symbol from a data-1 symbol
ppm	Parts-per-million
PSK	Phase shift keying or phase shift keyed
PR-ASK	Phase-reversal amplitude shift keying
RF	Radio frequency
RFID	Radio-frequency identification
RFU	Reserved for future use
RN16	16-bit random or pseudo-random number
RNG	Random or pseudo-random number generator
ITF	Interrogator talks first (reader talks first)
SSB	Single sideband
SSB-ASK	Single-sideband amplitude-shift keying
TDM	Time-division multiplexing or time-division multiplexed (as appropriate)
TID	Tag-identification or Tag identifier, depending on context
Word	16 bits
XPC_W1	XPC word 1
XPC_W2	XPC word 2
XTID	Extended Tag identifier

5.3 Notation

This protocol uses the following notational conventions:

- States and flags are denoted in bold. Some command parameters are also flags; a command parameter used as a flag will be bold. Example: **ready**.
- Command parameters are underlined. Some flags are also command parameters; a flag used as a command parameter will be underlined. Example: Pointer.
- Commands are denoted in italics. Variables are also denoted in italics. Where there might be confusion between commands and variables, this protocol will make an explicit statement. Example: *Query*.
- For logical negation, labels are preceded by '~'. Example: If **flag** is true, then **~flag** is false.
- The symbol, R=>T, refers to commands or signaling from an Interrogator to a Tag (Reader-to-Tag).
- The symbol, T=>R, refers to commands or signaling from a Tag to an Interrogator (Tag-to-Reader).

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).
- b) **Inventory.** Identifying individual Tags. An Interrogator begins an inventory round by transmitting a *Query* command in one of four sessions. One or more Tags may reply. The Interrogator detects a single Tag reply and requests the Tag's EPC. 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 – 960 MHz, as required by local regulations
Int:1a	Default Operating Frequency	Determined by local radio regulations and by the radio-frequency environment at the time of the communication
Int:1b	Operating Channels (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

Ref.	Parameter Name	Description
Int:2	Occupied Channel Bandwidth	In accordance with local regulations
Int:2a	Minimum Receiver Bandwidth	In accordance with local regulations
Int:3	Interrogator Transmit Maximum EIRP	In accordance with local regulations
Int:4	Interrogator Transmit Spurious Emissions	As specified; local regulation may impose tighter emission limits
Int:4a	Interrogator Transmit Spurious Emissions, In-Band (spread-spectrum systems)	As specified; local regulation may impose tighter emission limits
Int:4b	Interrogator Transmit Spurious Emissions, Out-of-Band	As specified; local regulation may impose tighter emission limits
Int:5	Interrogator Transmitter Spectrum Mask	As specified; local regulation may impose tighter emission limits
Int:6	Timing	As specified
Int:6a	Transmit-to-Receive Turn-Around Time	MAX(RT _{cal} , 10T _{pri}) nominal
Int:6b	Receive-to-Transmit Turn-Around Time	3T _{pri} minimum; 20T _{pri} maximum when Tag is in reply & acknowledged states; no limit otherwise
Int:6c	Dwell Time or Interrogator Transmit Power-On Ramp	1500 μ s, maximum settling time
Int:6d	Decay Time or Interrogator Transmit Power-Down Ramp	500 μ s, maximum
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% – 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
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 – 960 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 & 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 1500 µs 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
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

Ref.	Parameter Name	Description
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 EPC	Contained in Tag memory
P:3a	EPC Length	As specified
P:3b	EPC Format	T=0 ₂ : As specified in the GS1 EPC Tag Data Standard, T=1 ₂ : As specified in ISO/IEC 15961
P:4	Read size	Multiples of 16 bits
P:5	Write Size	Multiples of 16 bits
P:6	Read Transaction Time	Varied with R=>T & T=>R link rate and number of bits being read
P:7	Write Transaction Time	20 ms (maximum) after end of <i>Write</i> command
P:8	Error Detection	Interrogator-to-Tag: <i>Select</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, EPC: 16-bit CRC RN16: None or 16-bit CRC (varies by command) <i>handle</i> : 16-bit CRC All other: 16-bit CRC
P:9	Error Correction	None
P:10	Memory Size	Tag dependent, extensible (size is neither limited nor specified by this protocol)
P:11	Command Structure and Extensibility	As specified

Table 6.4: Collision management parameters

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

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 – 960 MHz frequency range.

6.3.1 Physical interface

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

6.3.1.1 Operational frequencies

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

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

An Interrogator communicates with one or more Tags by modulating an RF carrier using DSB-ASK, SSB-ASK, or PR-ASK with PIE encoding. Interrogators shall use a fixed modulation format and data rate for the duration of an inventory round, where "inventory round" is defined in 4.1. 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 $+40^{\circ}\text{C}$) and ± 20 ppm over the extended temperature range (-40°C to $+65^{\circ}\text{C}$). 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

The R=>T link shall use PIE, shown in Figure 6.1. T_{ari} 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

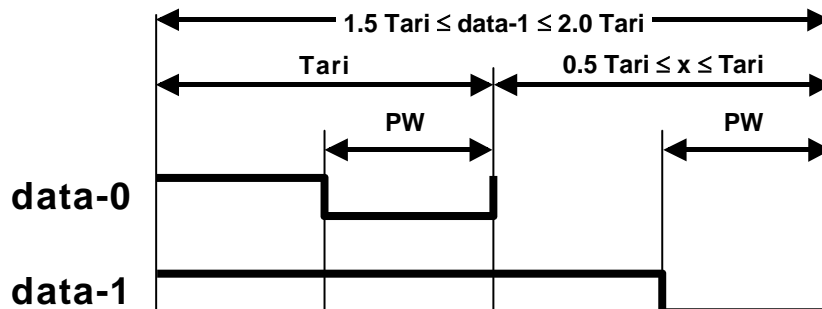


Figure 6.1: PIE symbols

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 6.25µs to 25µs. Interrogator compliance shall be evaluated using at least one Tari value between 6.25µs and 25µs 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

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

6.3.1.2.6 Interrogator power-up waveform

The Interrogator power-up RF envelope shall comply with Figure 6.3 and Table 6.6. Once the carrier level has risen above the 10% level, the power-up envelope shall rise monotonically until at least the ripple limit M_i . The RF envelope shall not fall below the 90% point in Figure 6.3 during interval T_s . Interrogators shall not issue commands before the end of the maximum settling-time interval in Table 6.6 (i.e. before the end of T_s). Interrogators shall meet the frequency-accuracy requirement specified in 6.3.1.2.1 by the end of interval T_s in Figure 6.3.

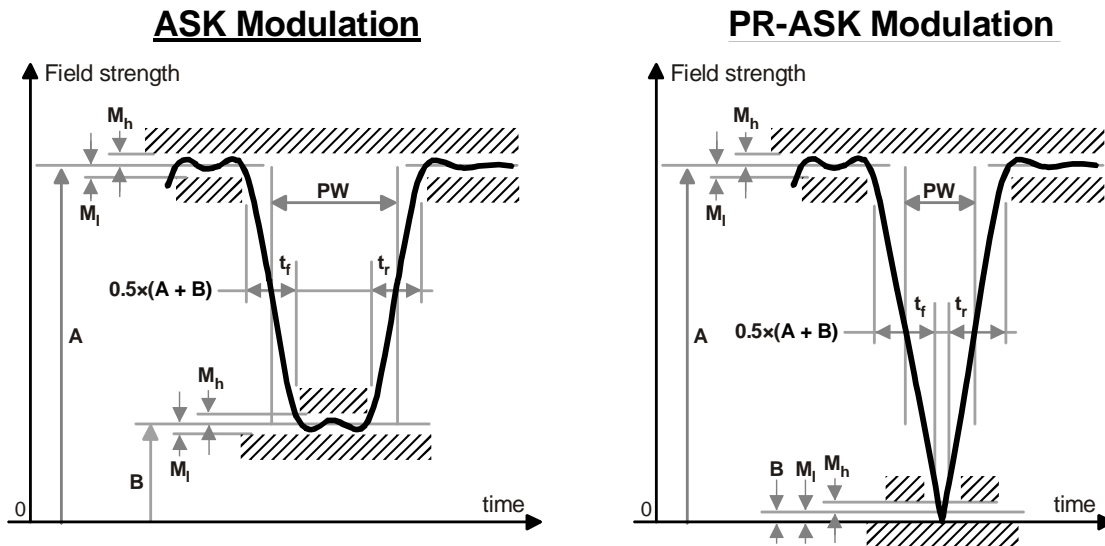


Figure 6.2: Interrogator-to-Tag RF envelope

Table 6.5: RF envelope parameters

Tari	Parameter	Symbol	Minimum	Nominal	Maximum	Units
6.25 µs to 25 µs	Modulation Depth	$(A-B)/A$	80	90	100	%
	RF Envelope Ripple	$M_h = M_i$	0		$0.05(A-B)$	V/m or A/m
	RF Envelope Rise Time	$t_{r,10-90\%}$	0		$0.33Tari$	µs
	RF Envelope Fall Time	$t_{f,10-90\%}$	0		$0.33Tari$	µs
	RF Pulsewidth	PW	$MAX(0.265Tari, 2)$		$0.525Tari$	µs

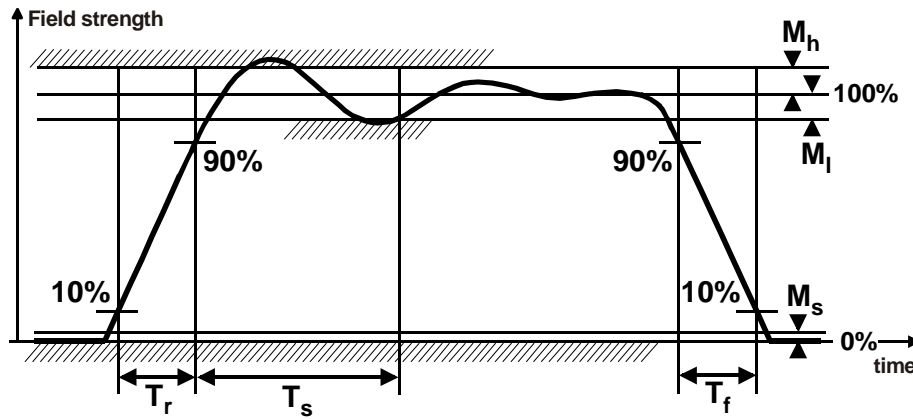


Figure 6.3: Interrogator power-up and power-down RF envelope

Table 6.6: Interrogator power-up waveform parameters

Parameter	Definition	Minimum	Nominal	Maximum	Units
T_r	Rise time	1		500	μs
T_s	Settling time			1500	μs
M_s	Signal level when OFF			1	% full scale
M_l	Undershoot			5	% full scale
M_h	Overshoot			5	% full scale

Table 6.7: Interrogator power-down waveform parameters

Parameter	Definition	Minimum	Nominal	Maximum	Units
T_f	Fall time	1		500	μs
M_s	Signal level when OFF			1	% full scale
M_l	Undershoot			5	% full scale
M_h	Overshoot			5	% full scale

6.3.1.2.7 Interrogator power-down waveform

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

6.3.1.2.8 R=>T preamble and frame-sync

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

- **RTcal:** An Interrogator shall set RTcal equal to the length of a data-0 symbol plus the length of a data-1 symbol ($RTcal = 0_{length} + 1_{length}$). A Tag shall measure the length of RTcal and compute $pivot = RTcal / 2$. A Tag shall interpret subsequent Interrogator symbols shorter than $pivot$ to be data-0s, and subsequent Interrogator symbols longer than $pivot$ to be data-1s. A Tag shall interpret symbols longer than 4 RTcal to be invalid. Prior to changing RTcal, an Interrogator shall transmit CW for a minimum of 8 RTcal.

- **TRcal:** An Interrogator shall specify a Tag's backscatter link frequency (its FM0 datarate or the frequency of its Miller subcarrier) using the TRcal and divide ratio (DR) in the preamble and payload, respectively, of a *Query* command that initiates an inventory round. Equation (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 Equation (2):

$$BLF = \frac{DR}{TRcal} \quad (1)$$

$$1.1 \times RTcal \leq TRcal \leq 3 \times RTcal \quad (2)$$

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.

6.3.1.2.9 Frequency-hopping spread-spectrum waveform

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

6.3.1.2.10 Frequency-hopping spread-spectrum channelization

Interrogators certified for operation in single-Interrogator environments shall meet local regulations for spread-spectrum channelization. Interrogators certified for operation in multiple- or dense-Interrogator environments shall meet local regulations for spread-spectrum channelization, unless the channelization is unregulated, in which case Interrogators shall adopt the channel plan at <http://www.gs1.org/epcglobal/implementation> for the chosen regulatory region (see also [Annex G](#), which describes multiple- and dense-Interrogator channelized signaling).

6.3.1.2.11 Transmit mask

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

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

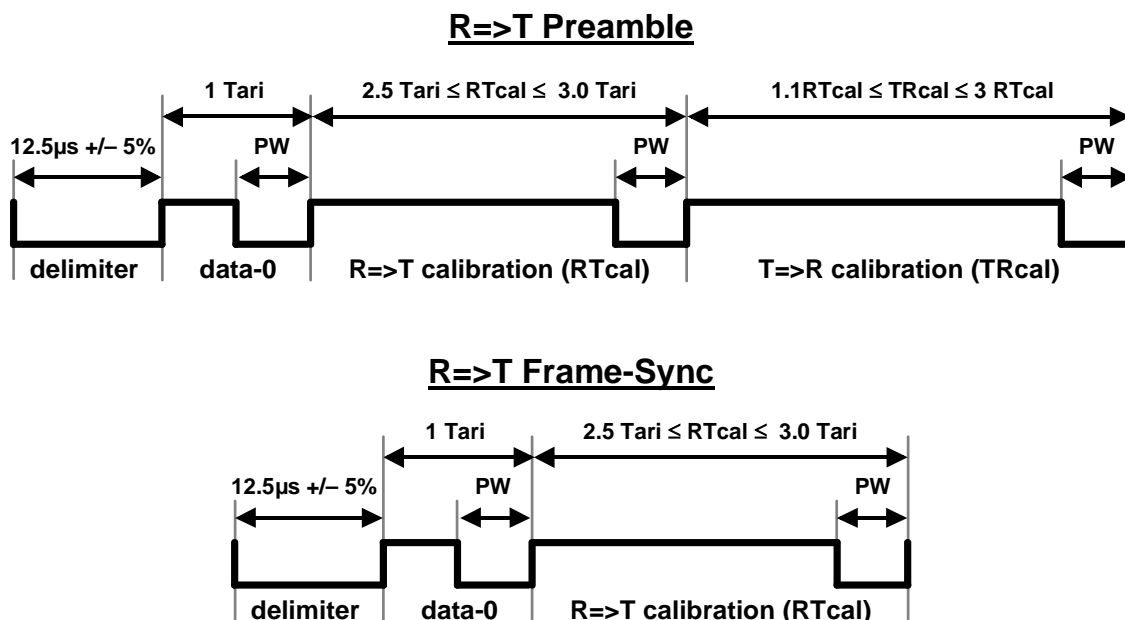


Figure 6.4: R=>T preamble and frame-sync

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

- $|R - S| = 1$: $10\log_{10}(P(S) / P(R)) < -20$ dB
- $|R - S| = 2$: $10\log_{10}(P(S) / P(R)) < -50$ dB
- $|R - S| = 3$: $10\log_{10}(P(S) / P(R)) < -60$ dB
- $|R - S| > 3$: $10\log_{10}(P(S) / P(R)) < -65$ dB

Where $P()$ denotes the total integrated power in the specified channel. This mask is shown graphically in Figure 6.6, with dBch defined as dB referenced to the integrated power in the reference channel. The channel width shall be as specified by local regulations, unless the width is unregulated, in which case Interrogators shall adopt the width shown at <http://www.gs1.org/epcglobal/implementation> for the chosen regulatory region. The channel spacing shall be set equal to the channel width (measured channel center to channel center). For any transmit channel R , two exceptions to the mask are permitted, provided that

- neither exception exceeds -50 dBch, and
- neither exception exceeds local regulatory requirements.

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

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

Dense-Interrogator Transmit Mask: For Interrogator transmissions centered at a frequency f_c , a $2.5/T_{\text{ari}}$ bandwidth R_{BW} also centered at f_c , an offset frequency $f_o = 2.5/T_{\text{ari}}$, and a $2.5/T_{\text{ari}}$ bandwidth S_{BW} centered at $(n \times f_o) + f_c$ (integer n), the ratio of the integrated power $P()$ in S_{BW} to that in R_{BW} with the Interrogator transmitting random data shall not exceed the specified values:

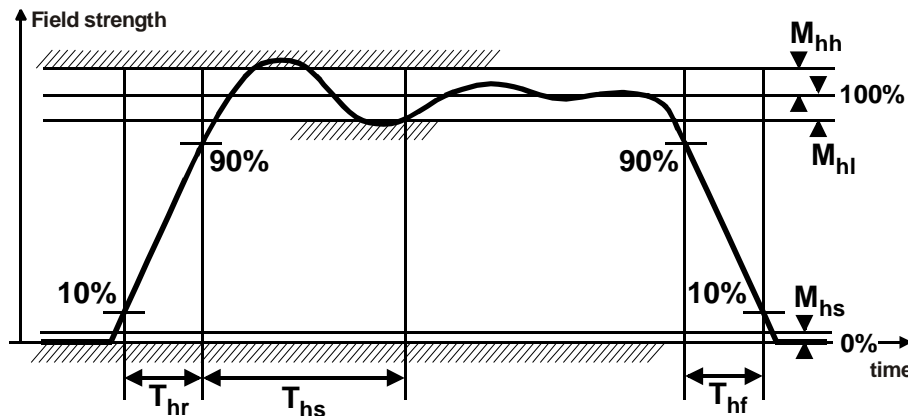


Figure 6.5: FHSS Interrogator RF envelope

Table 6.8: FHSS waveform parameters

Parameter	Definition	Minimum	Nominal	Maximum	Units
T_{hr}	Rise time			500	μs
T_{hs}	Settling time			1500	μs
T_{hf}	Fall time			500	μs
M_{hs}	Signal level during hop			1	% full scale
M_{hl}	Undershoot			5	% full scale
M_{hh}	Overshoot			5	% full scale

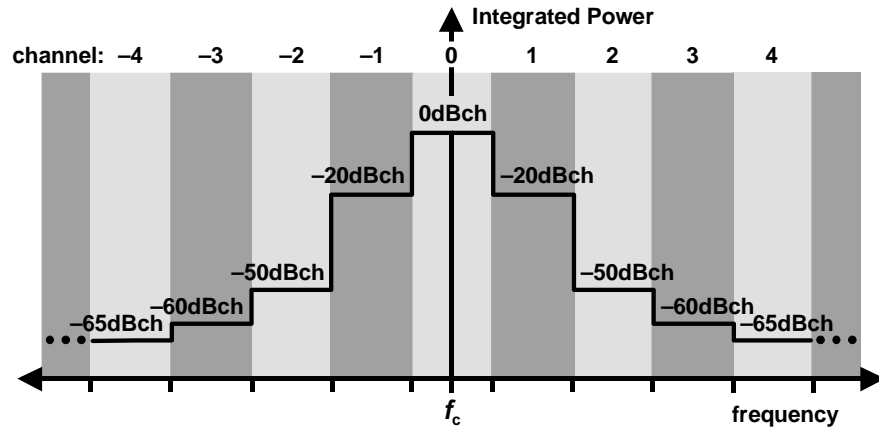


Figure 6.6: Transmit mask for multiple-Interrogator environments

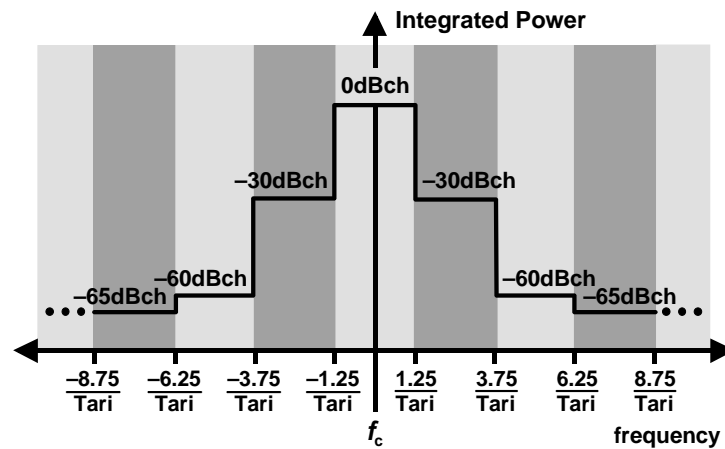


Figure 6.7: Transmit mask for dense-Interrogator environments

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

Where $P()$ denotes the total integrated power in the $2.5/T_{ari}$ reference bandwidth. This mask is shown graphically in Figure 6.7, with dBch defined as dB referenced to the integrated power in the reference channel.

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 4.1. The Tag selects the modulation format; the Interrogator selects the data encoding and data rate by means of the *Query* command that initiates the round. The low values in Figure 6.9, Figure 6.10, Figure 6.11, Figure 6.13, Figure 6.14, and Figure 6.15 correspond to the antenna-reflectivity state the Tag exhibits during the CW period prior to a T=>R preamble (e.g. ASK Tag absorbing power), whereas the high values correspond to the antenna-reflectivity state the Tag exhibits during the first high pulse of a T=>R preamble (e.g. ASK Tag reflecting power).

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.

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 – S_4 , indicate four possible FM0-encoded symbols, represented by the two phases of each of the FM0 basis functions. The state labels also represent the FM0 waveform that is transmitted upon entering the state. The labels on the state transitions indicate the logical values of the data sequence to be encoded. For example, a transition from state S_2 to S_3 is disallowed because the resulting transmission would not have a phase inversion on a symbol boundary.

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

6.3.1.3.2.2 FM0 preamble

T \Rightarrow R FM0 signaling shall begin with one of the two preambles shown in Figure 6.11. The choice depends on the TRext value specified in the *Query* that initiated the inventory round, unless a Tag is replying to a command that uses a *delayed* or *in-process* reply (see 6.3.1.6), in which case a Tag shall use the extended preamble regardless of TRext (i.e. a Tag replies as if TRext=1 regardless of the TRext value specified in the *Query*—see 6.3.2.12.3). The “v” shown in Figure 6.11 indicates an FM0 violation (i.e. a phase inversion should have occurred but did not).

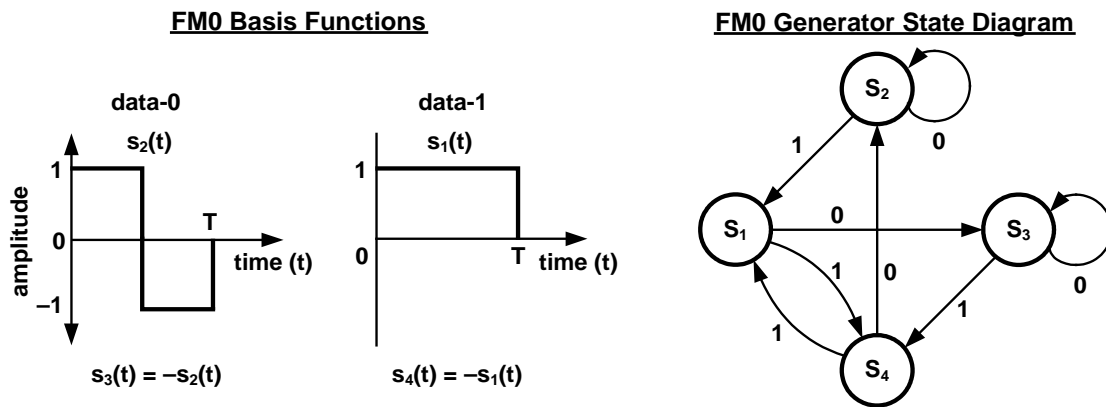


Figure 6.8: FM0 basis functions and generator state diagram

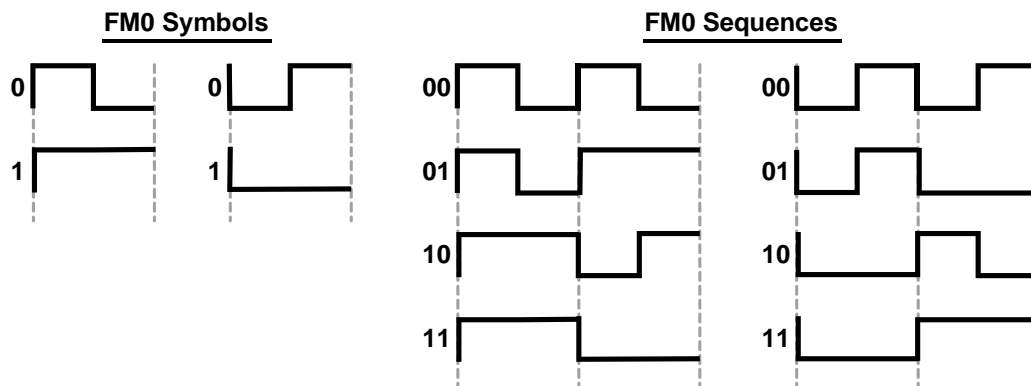


Figure 6.9: FM0 symbols and sequences

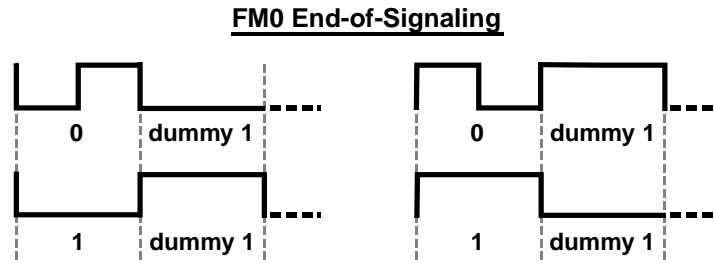


Figure 6.10: Terminating FM0 transmissions

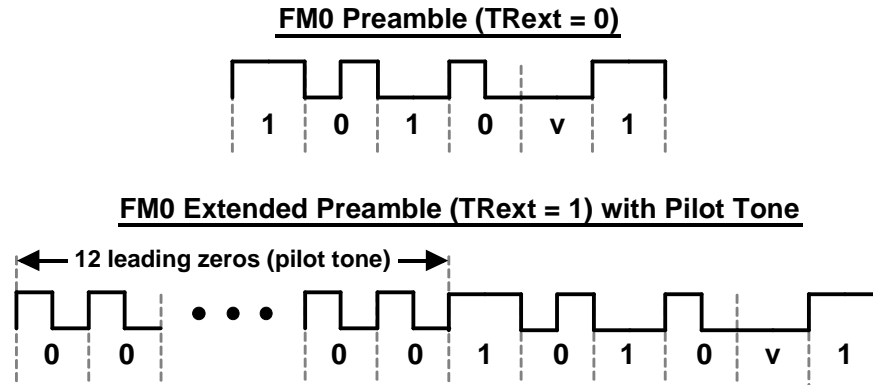


Figure 6.11: FM0 T=>R preamble

6.3.1.3.2.3 Miller-modulated subcarrier

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 – 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.

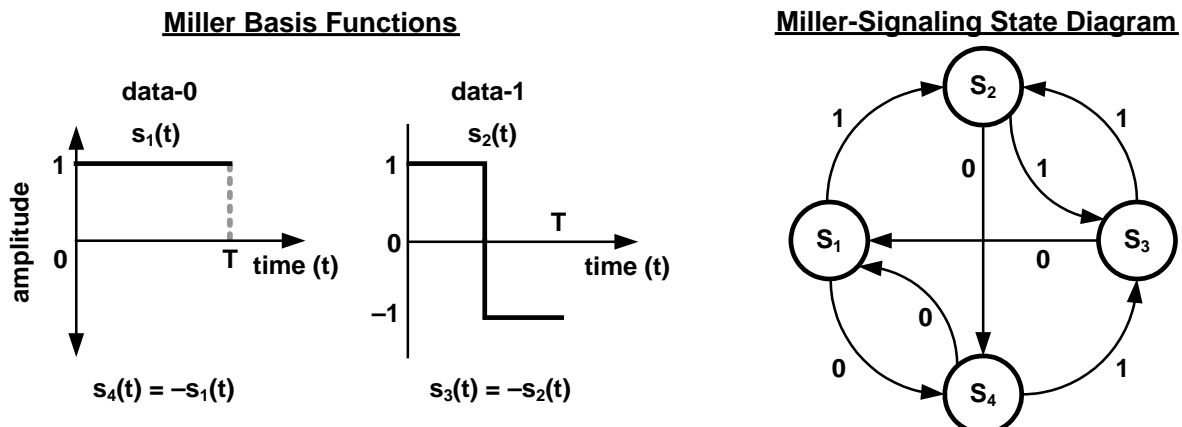


Figure 6.12: Miller basis functions and generator state diagram

Figure 6.13 shows Miller-modulated subcarrier sequences; the Miller sequence shall contain exactly two, four, or eight subcarrier cycles per bit, depending on the M value specified in the *Query* command that initiated the inventory round (see Table 6.10). The duty cycle of a 0 or 1 symbol, measured at the modulator output, shall be a minimum of 45% and a maximum of 55%, with a nominal value of 50%. Miller encoding has memory; consequently, the choice of Miller sequences in Figure 6.13 depends on prior transmissions. Miller signaling shall always end with a “dummy” data-1 bit at the end of a transmission, as shown in Figure 6.14.

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* that initiated the inventory round, unless a Tag is replying to a command that uses a *delayed* or *in-process* reply (see 6.3.1.6), in which case a Tag shall use the extended preamble regardless of TR_{ext} (i.e. a Tag replies as if $TR_{ext}=1$ regardless of the TR_{ext} value specified in the *Query*—see 6.3.2.12.3).

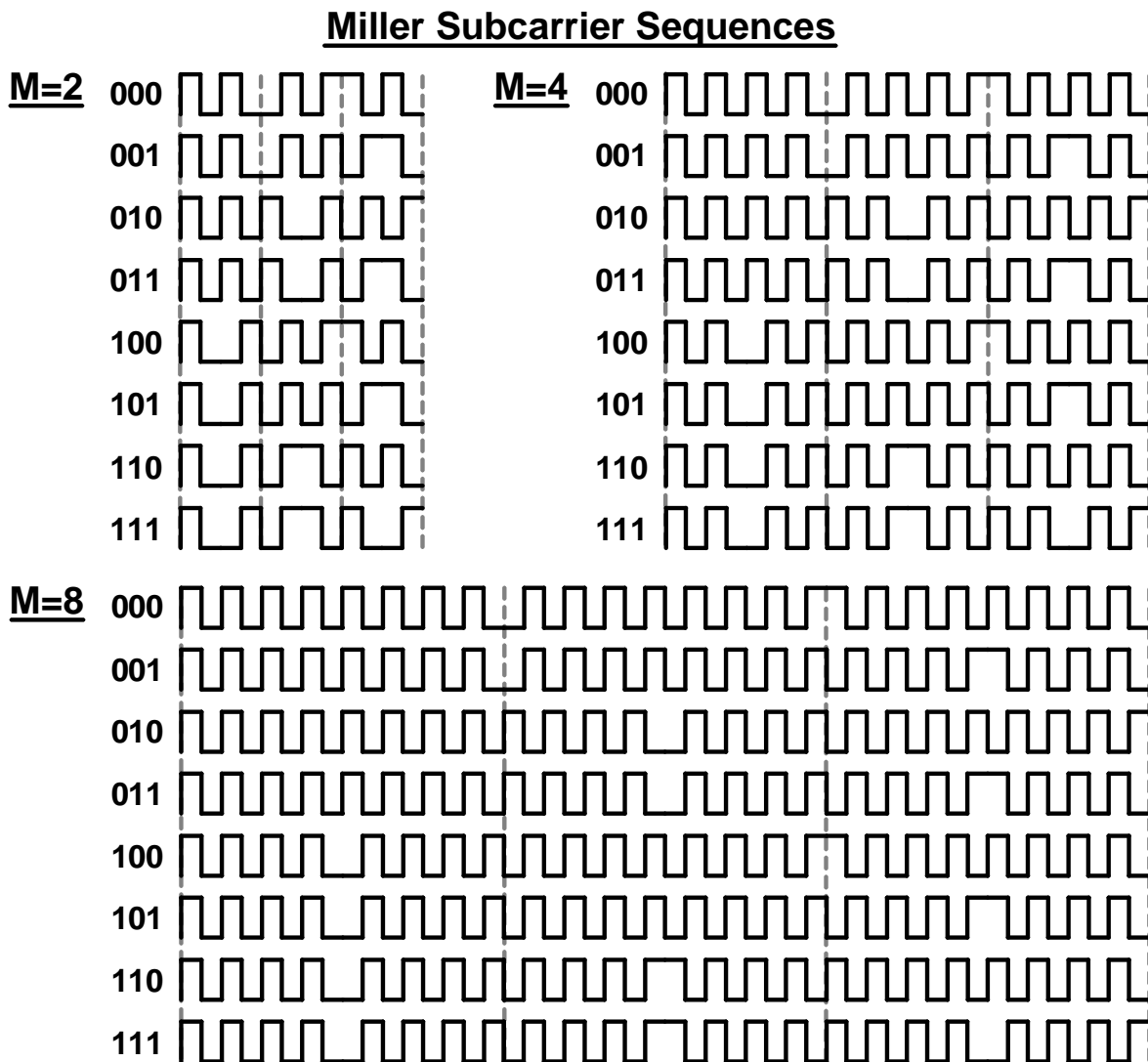


Figure 6.13: Subcarrier sequences

Miller End-of-Signaling

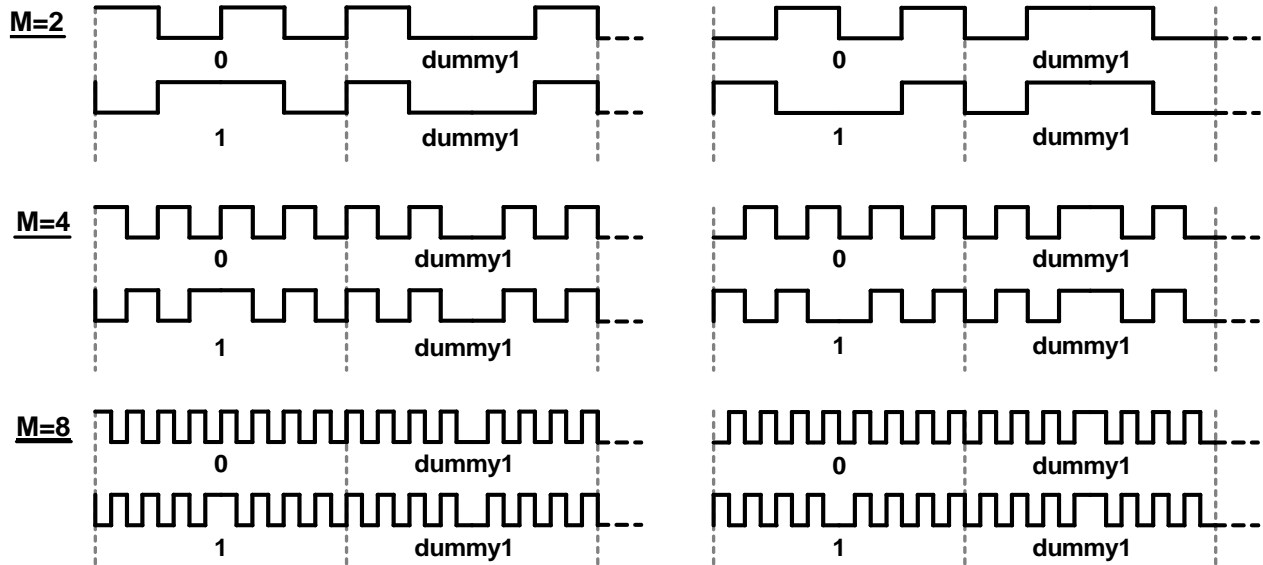
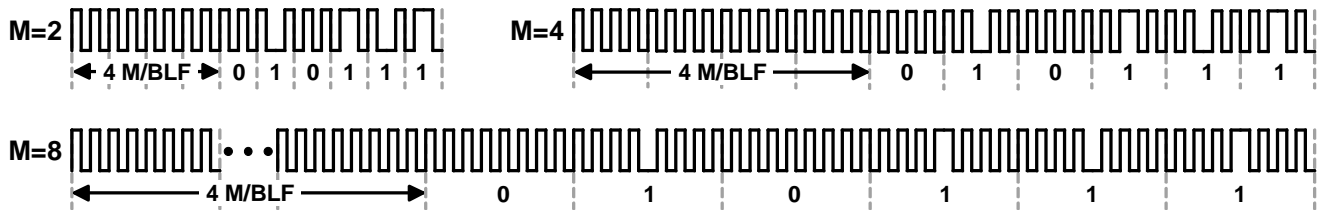


Figure 6.14: Terminating subcarrier transmissions

Miller Preamble (T_Rext = 0)



Miller Extended Preamble (T_Rext = 1) with Pilot Tone

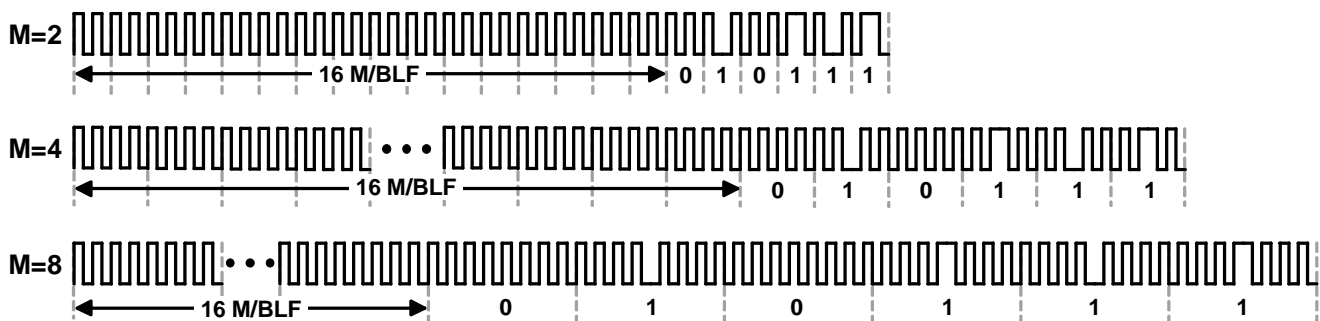


Figure 6.15: Subcarrier T=>R preamble

6.3.1.3.3 Tag supported Tari values and backscatter link rates

Tags shall support all $R \Rightarrow T$ Tari values in the range of $6.25\mu\text{s}$ to $25\mu\text{s}$, over all parameters allowed by 6.3.1.2.3.

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

6.3.1.3.4 Tag power-up timing

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

6.3.1.3.5 Minimum operating RF field strength and backscatter strength

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

1. free-space sensitivity,
2. minimum backscattered modulated power (ASK modulation) or change in radar cross-section or equivalent (phase modulation), and

Table 6.9: Tag-to-Interrogator link frequencies

DR: Divide Ratio	TRcal ¹ (μs \pm 1%)	BLF: Link Frequency (kHz)	Frequency Tolerance FrT (nominal temp)	Frequency Tolerance FrT (extended temp)	Frequency variation during backscatter
64/3	33.3	640	+ / - 15%	+ / - 15%	+ / - 2.5%
	$33.3 < \text{TRcal} < 66.7$	$320 < \text{BLF} < 640$	+ / - 22%	+ / - 22%	+ / - 2.5%
	66.7	320	+ / - 10%	+ / - 15%	+ / - 2.5%
	$66.7 < \text{TRcal} < 83.3$	$256 < \text{BLF} < 320$	+ / - 12%	+ / - 15%	+ / - 2.5%
	83.3	256	+ / - 10%	+ / - 10%	+ / - 2.5%
	$83.3 < \text{TRcal} \leq 133.3$	$160 \leq \text{BLF} < 256$	+ / - 10%	+ / - 12%	+ / - 2.5%
	$133.3 < \text{TRcal} \leq 200$	$107 \leq \text{BLF} < 160$	+ / - 7%	+ / - 7%	+ / - 2.5%
8	$200 < \text{TRcal} \leq 225$	$95 \leq \text{BLF} < 107$	+ / - 5%	+ / - 5%	+ / - 2.5%
	$17.2 \leq \text{TRcal} < 25$	$320 < \text{BLF} \leq 465$	+ / - 19%	+ / - 19%	+ / - 2.5%
	25	320	+ / - 10%	+ / - 15%	+ / - 2.5%
	$25 < \text{TRcal} < 31.25$	$256 < \text{BLF} < 320$	+ / - 12%	+ / - 15%	+ / - 2.5%
	31.25	256	+ / - 10%	+ / - 10%	+ / - 2.5%
	$31.25 < \text{TRcal} < 50$	$160 < \text{BLF} < 256$	+ / - 10%	+ / - 10%	+ / - 2.5%
	50	160	+ / - 7%	+ / - 7%	+ / - 2.5%
	$50 < \text{TRcal} \leq 75$	$107 \leq \text{BLF} < 160$	+ / - 7%	+ / - 7%	+ / - 2.5%
	$75 < \text{TRcal} \leq 200$	$40 \leq \text{BLF} < 107$	+ / - 4%	+ / - 4%	+ / - 2.5%

Note 1: Allowing two different TRcal values (with two different DR values) to specify the same BLF offers flexibility in specifying Tari and RTcal.

Table 6.10: Tag-to-Interrogator data rates

M: Number of subcarrier cycles 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

3. the manufacturer's normal operating conditions,
for the Tag mounted on one or more manufacturer-selected materials.

6.3.1.4 Transmission order

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

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

Within each word, the MSB shall be transmitted first.

6.3.1.5 Cyclic-redundancy check (CRC)

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

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

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

A Tag calculates and saves into memory a 16-bit StoredCRC. See 6.3.2.1.2.1.

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

Tags shall append a CRC-16 to those replies that use a CRC-16. See 6.3.2.12 for command-specific replies.

To generate a CRC-5 an Interrogator shall use the definition in Table 6.12.

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

Interrogators shall append the appropriate CRC to R=>T transmissions as specified in Table 6.28.

6.3.1.6 Link timing

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

Table 6.11: CRC-16 precursor

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

Table 6.12: CRC-5 definition

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

6.3.1.6.1 Immediate Tag reply

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

6.3.1.6.2 Delayed Tag reply

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

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

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

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

Table 6.13: Tag reply after successfully executing a delayed-reply command

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

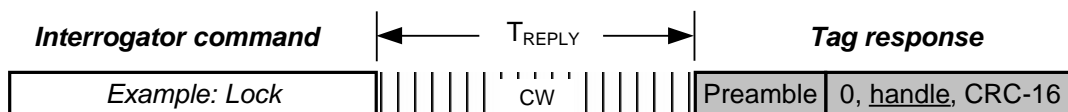


Figure 6.16: Successful delayed-reply sequence

6.3.1.6.3 In-process Tag reply

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

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

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

- (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=1, header=0, response, and optional length. All replies shall meet the T_6 and T_7 limits specified in Table 6.16. If the Interrogator observes a final reply with header=0 then the command completed successfully.
- (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=1, header=1, response, and optional length. All replies shall meet the T_6 and T_7 limits specified in Table 6.16. If the Interrogator observes a final reply with header=1 then the Tag encountered an error (see [Annex I](#)).
- (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 did not execute the command successfully. The Interrogator typically issues a subsequent *Req_RN* (containing the Tag's handle) to verify that the Tag is still in the Interrogator's energizing RF field, and may then issue another command or commands.

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

The optional length field specifies the length of a Tag's computed response (in bits), regardless of whether a Tag backscatters or stores this response. Length shall comprise a 15-bit value field followed by an even parity bit (the number of 1's in the 16-bit length field shall be an even number). An Interrogator specifies, in every command that uses an *in-process* reply, whether the Tag omits or includes length in its reply. If the Interrogator does not request length then the Tag omits length from its reply; if the Interrogator requests length then the Tag includes length in its reply. For the latter case, in the event of a stored response, length specifies the length of the stored response (and is therefore typically nonzero) but the response that the Tag actually backscatters will be null.

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

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

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

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

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

6.3.1.6.4 ResponseBuffer

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

- The **C** flag, located in the Tag's XPC_W1 (see Table 6.18), indicates whether the Tag has a stored response (result or error code) in its ResponseBuffer. If **C**=1 then the ResponseBuffer contains data; if **C**=0 then the ResponseBuffer is empty.
- A Tag shall set **C**=0 upon receiving either an access command with SenRep=0 (c.f. 6.3.2.12.3.10) or a *Challenge* command, and shall set **C**=1 after finishing its processing and storing its response (result or error code) in its ResponseBuffer.
- The **C** flag shall be selectable using a *Select* command.

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

	Barker Code	Done	Header	Response	RN	CRC
# of bits	7	1	1	variable	16	16
description	1110010	0: Working 1: Finished	0: Success 1: Error code	<u>result</u> or error code	<u>handle</u>	CRC-16

	Barker Code	Done	Header	Length	Response	RN	CRC
# of bits	7	1	1	16	variable	16	16
description	1110010	0: Working 1: Finished	0: Success 1: Error code	15 bits encoding <u>length</u> of <u>result</u> or error code followed by even parity bit	<u>result</u> or error code	<u>handle</u>	CRC-16

- If an access command with SenRep=0 or a *Challenge* command specifies IncRepLen=0 then a Tag shall not include a length field with its stored response, so the first word of the stored response shall be at ResponseBuffer location 00_h. If the command specifies IncRepLen=1 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.
- The maximum ResponseBuffer size shall be 32,784 bits (15 length bits, 1 parity bit, 32k response bits). A Tag manufacturer may limit the ResponseBuffer to a size less than this maximum. A Tag shall dynamically adjust its ResponseBuffer, on a command-by-command basis, to the required size.
- An Interrogator may read the ResponseBuffer using a *ReadBuffer* command. See 6.3.2.12.3.15.
- The ResponseBuffer shall be read-only to an Interrogator.
- A Tag shall abort command processing and instead store an error code in its ResponseBuffer if and when it determines that response will overflow the ResponseBuffer (see [Annex I](#)).
- A Tag shall retain data in its ResponseBuffer with the persistence of its **C** flag (see Table 6.20). When **C** is 1 then a Tag shall maintain the data in its ResponseBuffer. When **C** is or becomes 0 then a Tag shall deallocate its ResponseBuffer.

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

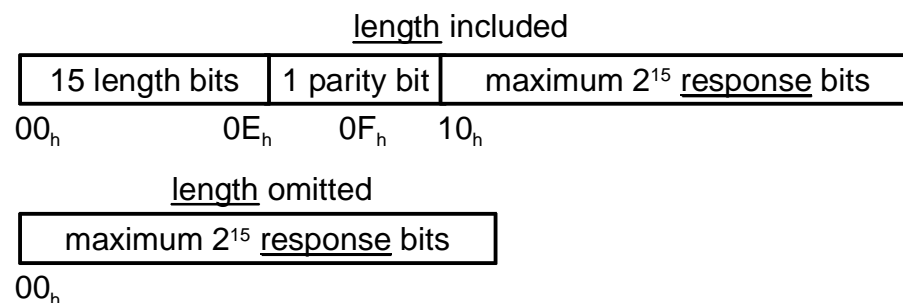
Figure 6.17: ResponseBuffer data storage

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	Done: 1 Header: 0 Response: <u>result</u>	Done: 1 Header: 1 Response: error code
		Include	Done: 1 Header: 0 Length: <u>length</u> of sent <u>result</u> Response: <u>result</u>	Done: 1 Header: 1 Length: <u>length</u> of sent error code Response: error code
	Any	Omit	Intermediate reply or replies Done: 0 Header: 0 Response: null Final reply Done: 1 Header: 0 Response: <u>result</u>	Intermediate reply or replies Done: 0 Header: 0 Response: null Final reply Done: 1 Header: 1 Response: error code
		Include	Intermediate reply or replies Done: 0 Header: 0 Length: 0000 _h Response: null Final reply Done: 1 Header: 0 Length: <u>length</u> of sent <u>result</u> Response: <u>result</u>	Intermediate reply or replies Done: 0 Header: 0 Length: 0000 _h Response: null Final reply Done: 1 Header: 1 Length: <u>length</u> of sent error code Response: error code
Stored	$\leq T_{6(max)}$	Omit	Done: 1 Header: 0 Response: null	Done: 1 Header: 1 Response: null
		Include	Done: 1 Header: 0 Length: <u>length</u> of stored <u>result</u> Response: null	Done: 1 Header: 1 Length: <u>length</u> of stored error code 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: <u>length</u> 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: <u>length</u> of stored error code Response: null

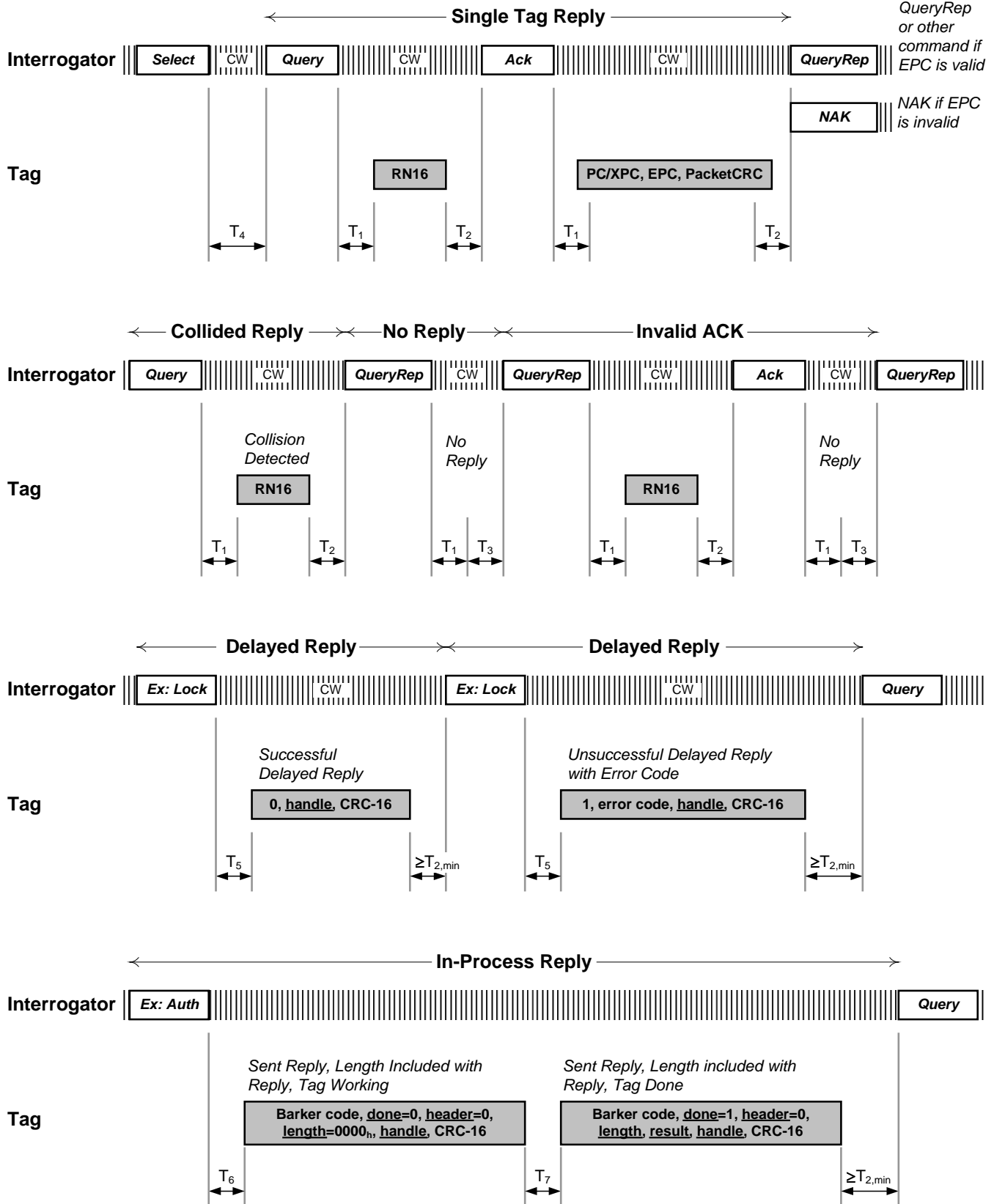


Figure 6.18: Link timing

Table 6.16: Link timing parameters

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

The following items apply to the requirements specified in Table 6.16:

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

In all other states the maximum value for T_2 shall be unrestricted. A Tag shall be allowed a tolerance of $20.0T_{\text{pri}} \leq T_{2(\text{max})} \leq 32T_{\text{pri}}$ in determining whether T_2 has expired. "Invalid command" is defined in 6.3.2.12.
- An Interrogator may transmit a new command prior to interval T_2 (i.e. during a Tag response). In this case the responding Tag may ignore the new command and, in environments with limited power availability, and may undergo a power-on reset.
- FrT is the frequency tolerance specified in Table 6.9.
- $T_1 + T_3$ shall not be less than T_4 .

6.3.2 Logical interface

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

6.3.2.1 Tag memory

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

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

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

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

User memory is optional. If a Tag implements User memory then it may partition the User memory into one or more files. If the Tag implements a single file then that file is File_0. See 6.3.2.1.4 and 6.3.2.11.3.

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

MemBank shall be defined as follows:

00 ₂	Reserved	01 ₂	EPC
10 ₂	TID	11 ₂	User

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

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

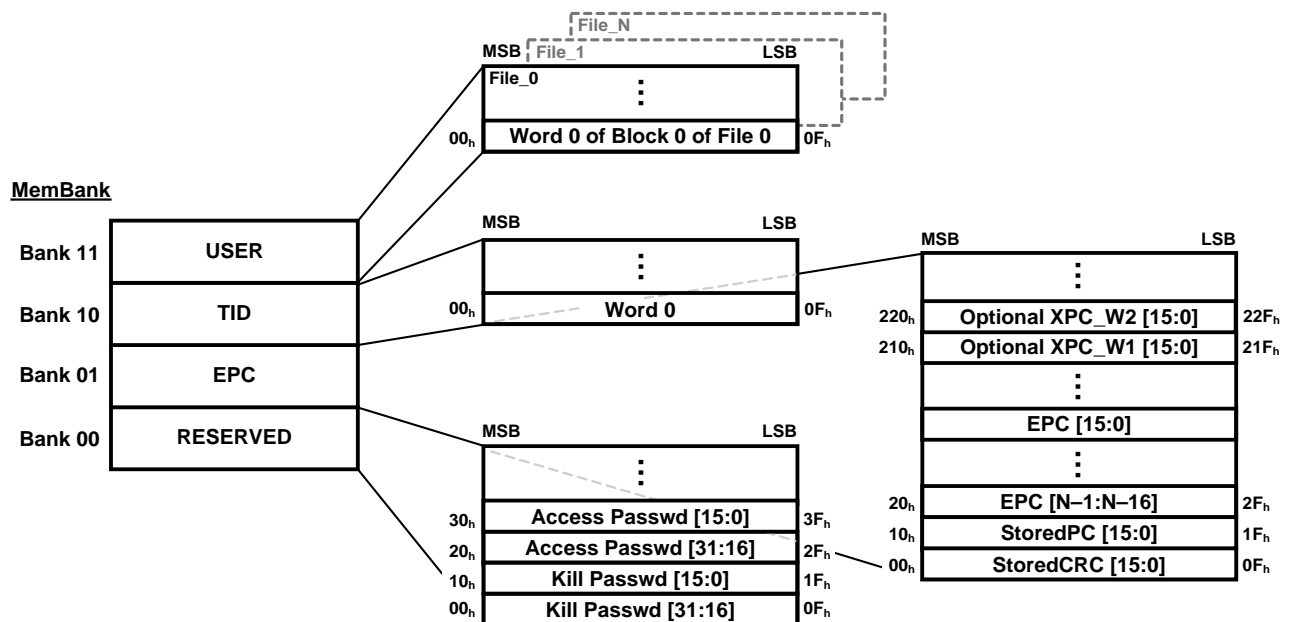


Figure 6.19: Logical memory map

An Interrogator may issue a *Lock* command (see 6.3.2.12.3.5) to lock, permanently lock, unlock, or permanently unlock the kill password, access password, EPC memory bank, TID memory bank, or File_0 of User memory, thereby preventing or allowing subsequent changes (as appropriate). If the passwords are locked or permanently locked then they are unwriteable and unreadable by any command and usable only by a *Kill* or *Access* command. If EPC memory, TID memory, or File_0 are locked or permanently locked then they are unwriteable but readable, except for the **L** and **U** bits in EPC memory; an Interrogator with an asserted *Untraceable* privilege may alter the **L** and **U** bits regardless of the lock or permalock status of EPC memory (see 6.3.2.12.3.16).

If a Tag implements User memory then it partitions each File_N, $N \geq 0$ of User memory into one or more equal-size blocks. A Tag shall use the same block size for file allocation (see 6.3.2.11.3) as it does for the *BlockPermalock* command (see 6.3.2.12.3.9). A Tag may use different block sizes for the *BlockWrite* and *BlockErase* commands. If a Tag supports the *BlockPermalock* command then an Interrogator may issue a *BlockPermalock* to permanently lock one or more memory blocks. If blocks within File_0 are permalocked then these blocks are permanently unwriteable but readable. If blocks within File_N, $N > 0$ are permalocked then these blocks are permanently unwriteable but readable by an Interrogator with appropriate read privileges (see Table 6.24 and Table 6.25).

6.3.2.1.1 Reserved Memory

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

6.3.2.1.1.1 Kill password

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

6.3.2.1.1.2 Access password

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

6.3.2.1.2 EPC Memory

EPC memory contains a StoredCRC at addresses 00_h to 0F_h, a StoredPC at 10_h to 1F_h, an EPC beginning at 20_h, and optional first and second XPC words at 210_h – 21F_h (XPC_W1) and 220_h – 22F_h (XPC_W2), respectively. The StoredCRC, StoredPC, EPC, and XPC word(s) shall be stored MSB first (i.e. the EPC's MSB is at location 20_h).

The StoredCRC and StoredPC are described in 6.3.2.1.2.1 and 6.3.2.1.2.2, respectively.

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

The XPC_W1 and XPC_W2 are described in 6.3.2.1.2.5.

6.3.2.1.2.1 CRC-16 (StoredCRC and PacketCRC)

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

A Tag shall compute and store its StoredCRC either (i) when an Interrogator writes or overwrites bits in the EPC

(including in the StoredPC), or (ii) every time the Tag powers up. The Tag manufacturer shall choose whether the Tag implements (i) or (ii). A Tag shall perform its computing and storing for these two cases as follows:

- (i) The Tag first writes or overwrites the bits, then computes and stores a new StoredCRC, all within the reply times specified in Table 6.16 for the command (*Write*, *BlockWrite*, *BlockErase*, or *Untraceable*) that wrote or overwrote the bits. A Tag shall delay backscattering the success reply shown in Table 6.13 or Table 6.14 for the command that wrote or overwrote the bits until it has stored the new StoredCRC. The Tag shall store its StoredCRC in nonvolatile memory so that the StoredCRC persists through subsequent Tag power cycles.
- (ii) The Tag computes and stores the StoredCRC before the end of interval T_s or T_{hs} (as appropriate) in Figure 6.3 or Figure 6.5, respectively. The Tag may store its StoredCRC in volatile or nonvolatile memory. If an Interrogator modifies a Tag's StoredPC or EPC after Tag powerup then the StoredCRC may be incorrect until the Interrogator power-cycles the Tag.

For both cases (i) and (ii) the Tag shall implement the StoredCRC by first calculating a CRC-16 (see 6.3.1.5) over the StoredPC and the EPC specified by the length (**L**) bits in the StoredPC, and then storing the thus-computed StoredCRC into EPC memory 00_h to $0F_h$, MSB first. The Tag shall calculate the StoredCRC on word boundaries, shall deassert all Tag-computed StoredPC bit values (**XI** and **UMI** if Tag-computed) when performing the calculation, and shall omit XPC_W1 and XPC_W2 from the calculation.

If an Interrogator attempts to write to EPC memory 00_h – $0F_h$ then the Tag shall not execute the write and instead treat the command's parameters as unsupported (see Table C.30).

In response to an *ACK* a Tag backscatters a reply comprising a PC word, in some instances an XPC word or words, the EPC (which may be truncated), and a PacketCRC to protect the backscattered data stream (see Table 6.17). A Tag shall compute the PacketCRC as specified in 6.3.1.5 over the PC word, optional XPC word(s), and backscattered EPC, and shall send the PacketCRC MSB first.

As required by 6.3.1.5 an Interrogator shall verify the integrity of the received PC word, optional XPC word or words, and EPC using the PacketCRC.

In some circumstances the PacketCRC will differ from a Tag's StoredCRC, such as, for example, if the Tag has an asserted **XI** or the EPC is truncated.

6.3.2.1.2.2 Protocol-control (PC) word (StoredPC and PacketPC)

A Tag shall implement a StoredPC in addresses 10_h – $1F_h$ of EPC memory. The bit assignments for this StoredPC shall be as shown in Table 6.18 and defined in Table 6.19. Note that some bit assignments are different for GS1 EPCglobal (**T**=0) versus non-GS1 EPCglobal (**T**=1) Applications. Similarly, some bit assignments for XPC_W1 differ with the Application (see 6.3.2.1.2.5), as does the method of computing **XI** (see below).

The StoredPC bits and values shall be as follows:

- **L (EPC length field, bits 10_h – 14_h):** Bits 10_h – 14_h are written by an Interrogator and specify the length of the EPC that a Tag backscatters in response to an *ACK*, in words:
 - 00000_2 : Zero words.
 - 00001_2 : One word (addresses 20_h to $2F_h$ in EPC memory).
 - 00010_2 : Two words (addresses 20_h to $3F_h$ in EPC memory).
 -
 -
 -
 - 11111_2 : 31 words (addresses 20_h to $20F_h$ in EPC memory).

If a Tag only supports **XI**=0 then the maximum value for the EPC length field in the StoredPC shall be 11111_2 (allows a 496-bit EPC), as shown above. If a Tag supports **XI**=1 then the maximum value for the EPC length field in the StoredPC shall be 11101_2 (allows a 464-bit EPC). A Tag that supports **XI**=1 shall not execute a *Write*, *BlockWrite*, or *Untraceable* that attempts to write an EPC length field larger than 11101_2 and shall instead treat the command's parameters as unsupported (see Table C.30).

- **UMI (User-memory indicator, bit 15_h):** Bit 15_h may be fixed by the Tag manufacturer or computed by the Tag. In the former (fixed) case, if the Tag does not have and is incapable of allocating memory to File_0 then the Tag manufacturer shall set bit 15_h to 0_2 ; if the Tag has or is capable of allocating memory to File_0 then the Tag manufacturer shall set bit 15_h to 1_2 . In the latter (computed) case, both at power-up and upon writing the first word (bits 00_h – $0F_h$) of File_0 a Tag shall compute the logical OR of bits 03_h –

07_h of File_0 and shall map the computed value into bit 15_h; if the Tag does not have memory allocated to File_0 then the logical OR result shall be 0₂. Regardless of the **UMI** method (fixed or computed), when an Interrogator writes the StoredPC the Tag shall not write and instead ignore the data value the Interrogator provides for bit 15_h. For a computed **UMI**, if an Interrogator deallocates File_0 (see 6.3.2.11.3) then the Tag shall set bit 15_h to 0₂ upon deallocation. Also for a computed **UMI**, the untraceability status of User memory (see 6.3.2.11.1) shall not change the **UMI** value (i.e. if **UMI**=1 when a Tag is traceable then **UMI** shall remain 1 even if an Interrogator instructs a Tag to untraceably hide User memory).

- **XI (XPC_W1 indicator, bit 16_h):** If a Tag does not implement XPC_W1 then bit 16_h shall be fixed at 0₂ by the Tag manufacturer. If a Tag implements XPC_W1 then a Tag shall compute **XI** both at powerup and upon changing any bits of XPC_W1 (whether these bits are written or computed) and map the computed value into bit 16_h as follows: If **T**=0 then **XI** may be either (i) the logical OR of bits 210_h–217_h of EPC memory or (ii) the logical OR of bits 210_h–218_h of EPC memory; the Tag manufacturer shall choose whether the Tag implements (i) or (ii). If **T**=1 then **XI** is the logical OR of bits 210_h–21F_h of EPC memory. Regardless of whether **XI** is fixed or computed, when an Interrogator writes the StoredPC the Tag shall not write and instead ignore the data value the Interrogator provides for bit 16_h.
- **T (numbering system identifier toggle, bit 17_h):** If bit 17_h is 0₂ then the application is referred to as a GS1 EPCglobal™ Application and PC bits 18_h – 1F_h shall be as defined in this protocol. If bit 17_h is 1₂ then the application is referred to as a non-GS1 EPCglobal™ Application and bits 18_h – 1F_h shall be as defined in ISO/IEC 15961.
- **RFU or AFI (Reserved for Future Use or Application Family Identifier, bits 18_h – 1F_h):** If **T**=0 then the Tag manufacturer (if the bits are not writeable) or an Interrogator (if the bits are writeable) shall set these bits to 00_h. If **T**=1 then the Tag manufacturer (if the bits are not writeable) or an Interrogator (if the bits are writeable) shall set these bits as specified in ISO/IEC 15961.

If an Interrogator changes the EPC length (via a memory write operation), and if it wishes the Tag to subsequently backscatter the new EPC length, then it must write new **L** bits into the Tag's StoredPC. If an Interrogator attempts to write **L** bit values that the Tag does not support then the Tag shall not execute the write operation and instead treat the command's parameters as unsupported (see Table C.30).

A Tag that supports **XI**=1 shall implement a PacketPC in addition to a StoredPC. Which PC word a Tag backscatters in reply to an **ACK** shall be as defined in Table 6.17. A PacketPC differs from a StoredPC in its **L** bits, which a Tag adjusts to match the length of the backscattered data that follow the PC word. Specifically, if **XI**=1 but **XEB**=0 then a Tag backscatters an XPC_W1 before the EPC, so the Tag shall add one to (i.e. increment) its **L** bits. If both **XI**=1 and **XEB**=1 then the Tag backscatters both an XPC_W1 and an XPC_W2 before the EPC, so the Tag shall add two to (i.e. double increments) its **L** bits. Because Tags that support XPC functionality have a maximum **L** value of 11101₂, double incrementing increases the value to 11111₂. A Tag shall not, under any circumstances, allow its **L** bits to roll over to 00000₂. Note that incrementing or double incrementing the **L** bits does not alter the bit values stored in EPC memory 10_h – 14_h; rather, a Tag increments the **L** bits in the backscattered PacketPC but leaves the memory contents unaltered.

A Tag that does not implement an XPC_W1 or untraceability need not implement a PacketPC.

The fields that a Tag includes in its reply to an **ACK** (Table 6.17) depend on the values of **T**, **C**, **XI**, and **XEB** (see Table 6.19); whether the Tag implements an XPC_W1; whether the Tag is truncating its reply (see 6.3.2.12.1.1); and the value of immed (see 6.3.2.12.1.2). If a Tag has **T**=0, **XI**=0, implements an XPC_W1, and is not truncating then the Tag substitutes the 8 LSBs of XPC_W1 (i.e. EPC memory 218_h – 21F_h) for the 8 LSBs of the StoredPC (i.e. PC memory 18_h – 1F_h) in its reply. Because a Tag calculates its PacketCRC over the backscattered data bits (see 6.3.2.1.2.1), when the Tag does this substitution then it shall calculate its PacketCRC over the 8 substituted XPC_W1 LSBs rather than over the 8 StoredPC LSBs.

An Interrogator shall support Tag replies with **XI**=0, **XI**=1, or both **XI**=1 and **XEB**=1.

When sending a truncated EPC a Tag substitutes 00000₂ for its PC field — see Table 6.17 and 6.3.2.12.1.1.

If a Tag has a response (result or error code) in its ResponseBuffer (i.e. **C**=1) and the Interrogator set immed=1 in the *Challenge* command that preceded the inventory round then a Tag shall concatenate response and a CRC-16 calculated over response to its reply to an **ACK** (see Table 6.17).

Table 6.17: Tag reply to an *ACK* command

T	XI	XEB	Trun- cation	C AND immed	Tag Backscatter					
					PC	XPC	EPC ¹	CRC	Response	CRC
0	0	0	0	0	It Tag does not implement XPC_W1: ⇒ StoredPC(10 _h –1F _h) If Tag implements XPC_W1 (see note 2): ⇒ StoredPC(10 _h –17 _h), XPC_W1(218 _h –21F _h)	None	Full	PacketCRC	–	–
0	0	0	0	1	C=1 so Tag implements XPC_W1 (note 2): ⇒ StoredPC(10 _h –17 _h), XPC_W1(218 _h –21F _h)	None	Full	PacketCRC	<u>response</u>	CRC-16
0	0	0	1	0	00000 ₂	None	Truncated	PacketCRC	–	–
0	0	0	1	1	00000 ₂	None	Truncated	PacketCRC	<u>response</u>	CRC-16
0	0	1	All		Disallowed ³					
0	1	0	0	0	PacketPC	XPC_W1	Full	PacketCRC	–	–
0	1	0	0	1	PacketPC	XPC_W1	Full	PacketCRC	<u>response</u>	CRC-16
0	1	0	1	0	00000 ₂	None	Truncated	PacketCRC	–	–
0	1	0	1	1	00000 ₂	None	Truncated	PacketCRC	<u>response</u>	CRC-16
0	1	1	0	0	PacketPC	XPC_W1, XPC_W2	Full	PacketCRC	–	–
0	1	1	0	1	PacketPC	XPC_W1, XPC_W2	Full	PacketCRC	<u>response</u>	CRC-16
0	1	1	1	0	00000 ₂	None	Truncated	PacketCRC	–	–
0	1	1	1	1	00000 ₂	None	Truncated	PacketCRC	<u>response</u>	CRC-16
1	0	0	0	0 (C=0)	StoredPC(10 _h –1F _h)	None	Full	PacketCRC	–	–
1	0	0	0	0 (C=1)	Disallowed ⁴					
1	0	0	0	1	Disallowed ⁴					
1	0	0	1	0 (C=0)	00000 ₂	None	Truncated	PacketCRC	–	–
1	0	0	1	0 (C=1)	Disallowed ⁴					
1	0	0	1	1	Disallowed ⁴					
1	0	1	All		Disallowed ³					
1	1	0	0	0	PacketPC	XPC_W1	Full	PacketCRC	–	–
1	1	0	0	1	PacketPC	XPC_W1	Full	PacketCRC	<u>response</u>	CRC-16
1	1	0	1	0	00000 ₂	None	Truncated	PacketCRC	–	–
1	1	0	1	1	00000 ₂	None	Truncated	PacketCRC	<u>response</u>	CRC-16
1	1	1	0	0	PacketPC	XPC_W1, XPC_W2	Full	PacketCRC	–	–
1	1	1	0	1	PacketPC	XPC_W1, XPC_W2	Full	PacketCRC	<u>response</u>	CRC-16
1	1	1	1	0	00000 ₂	None	Truncated	PacketCRC	–	–
1	1	1	1	1	00000 ₂	None	Truncated	PacketCRC	<u>response</u>	CRC-16

Note 1: Full means an EPC whose length is specified by the **L** bits in the StoredPC; truncated means an EPC whose length is shortened by a prior *Select* command specifying truncation (see 6.3.2.12.1.1).

Note 2: If a Tag has **T**=0, **XI**=0, implements an XPC_W1, and is not truncating then the Tag substitutes EPC memory bits 218_h–21F_h for EPC memory bits 18_h–1F_h in its reply to an *ACK*.

Note 3: If **T**=0 then **XI** may be either (i) the logical OR of bits 210_h–217_h of XPC_W1 or (ii) the logical OR of bits 210_h–218_h of XPC_W1; the Tag manufacturer chooses whether a Tag implements (i) or (ii). If **T**=1 then **XI** is the logical OR of the entirety of XPC_W1 (210_h–21F_h). Because **XEB** is the MSB (210_h) of XPC_W1, if **XEB**=1 then **XI**=1 regardless of the **T** value.

Note 4: If **T**=1 then **XI** is the logical OR of the entirety of XPC_W1 (210_h–21F_h), so if **C**=1 then **XI**=1.

Table 6.18: StoredPC and XPC_W1 bit assignments

StoredPC bit assignments

Application	MSB															LSB
	10 _h	11 _h	12 _h	13 _h	14 _h	15 _h	16 _h	17 _h	18 _h	19 _h	1A _h	1B _h	1C _h	1D _h	1E _h	1F _h
GS1 EPCglobal	L4	L3	L2	L1	L0	UMI	XI	T=0	RFU							
Non-GS1 EPCglobal	L4	L3	L2	L1	L0	UMI	XI	T=1	AFI as defined in ISO/IEC 15961							

XPC_W1 bit assignments

Application	MSB															LSB
	210 _h	211 _h	212 _h	213 _h	214 _h	215 _h	216 _h	217 _h	218 _h	219 _h	21A _h	21B _h	21C _h	21D _h	21E _h	21F _h
GS1 EPCglobal	XEB	RFU							B	C	SLI	TN	U	K	NR	H
Non-GS1 EPCglobal	XEB	As defined in ISO/IEC 18000-63							B	C	SLI	TN	U	K	NR	H

Table 6.19: StoredPC and XPC_W1 bit values

Hex	Name	How Set? ¹	Descriptor	Settings
10:14	L4:L0	Written	EPC length field	L4:L0 encode a numeric value. See 6.3.2.1.2.2.
15	UMI	Fixed or computed	File_0 indicator	0: If fixed then Tag does not have and is incapable of allocating memory to File_0. If computed then File_0 is not allocated or does not contain data. 1: If fixed then Tag has or is capable of allocating memory to File_0. If computed then File_0 is allocated and contains data.
16	XI	Computed	XPC_W1 indicator	0: Either (i) Tag has no XPC_W1, or (ii) T=0 and either bits 210 _h –217 _h or bits 210 _h –218 _h (at Tag-manufacturers option) of EPC memory are all zero, or (iii) T=1 and bits 210 _h –21F _h of EPC memory are all zero. 1: Tag has an XPC_W1 and either (i) T=0 and at least one bit of 210 _h –217 _h or 210 _h –218 _h (at Tag-manufacturer's option) of EPC memory is nonzero, or (ii) T=1 and at least one bit of 210 _h –21F _h of EPC memory is nonzero
17	T	Written	Numbering System Identifier Toggle	0: Tag is used in a GS1 EPCglobal™ Application 1: Tag is used in a non-GS1 EPCglobal™ Application
18:1F	RFU or AFI	Per the Application	RFU or AFI	GS1 EPCglobal™ Application: RFU and fixed ¹ at zero Non-GS1 EPCglobal™ Application: See ISO/IEC 15961
210	XEB	Computed	XPC_W2 indicator	0: Tag has no XPC_W2 or all bits of XPC_W2 are zero-valued 1: Tag has an XPC_W2 and at least one bit of XPC_W2 is nonzero
211: 217	RFU	Per the Application	RFU or assigned by ISO/IEC 18000-63	GS1 EPCglobal™ Application: RFU and fixed ¹ at zero Non-GS1 EPCglobal™ Application: See ISO/IEC 18000-63
218	B	Tag mfg defined	Battery-Assisted Passive indicator	0: Tag is passive or does not support the B flag 1: Tag is battery-assisted
219	C	Computed	Computed response indicator	0: ResponseBuffer is empty or Tag does not support a ResponseBuffer 1: ResponseBuffer contains a <u>response</u>
21A	SLI	Computed	SL indicator	0: Tag has a deasserted SL flag or does not support the SLI bit 1: Tag has an asserted SL flag
21B	TN	Tag mfg defined	Notification indicator	0: Tag does not assert a notification or does not support the TN bit 1: Tag asserts a notification
21C	U	Written	Untraceable indicator	0: Tag is traceable or does not support the U bit 1: Tag is untraceable
21D	K	Computed	Killable indicator	0: Tag is not killable by <i>Kill</i> command or does not support the K bit 1: Tag can be killed by <i>Kill</i> command.
21E	NR	Written	Nonremovable indicator	0: Tag is removable from its host item or does not support the NR bit 1: Tag is not removable from its host item
21F	H	Written	Hazmat indicator	0: Tagged item is not hazardous material or Tag does not support the H bit 1: Tagged item is hazardous material

Note 1: "Written" indicates that an Interrogator writes the value; "computed" indicates that a Tag computes the value; "fixed" indicates that the Tag manufacturer fixes the value; "Tag mfg defined" indicates that the Tag manufacturer defines the bit settability (written, computed, or fixed). Written bits inherit the lock/permalock status of the EPC memory bank (note: An *Untraceable* command may alter **L** and/or **U** regardless of the lock/permalock status of the EPC memory bank). Computed bits are not writeable and may change despite the lock/permalock status of the EPC memory bank. Fixed bits are not writeable and not changeable in the field.

6.3.2.1.2.3 EPC for a GS1 EPCglobal™ Application

The EPC for an EPCglobal™ Application shall be as defined in the GS1 EPC Tag Data Standard.

6.3.2.1.2.4 EPC for a non-GS1 EPCglobal™ Application

The EPC for a non-EPCglobal™ Application shall be as defined in ISO/IEC 15962.

6.3.2.1.2.5 Extended Protocol Control (XPC) word or words (optional)

A Tag may implement an XPC_W1 logically located at addresses 210_h to 21F_h of EPC memory. If a Tag implements an XPC_W1 then it may additionally implement an XPC_W2 logically located at address 220_h to 22F_h of EPC memory. A Tag shall not implement an XPC_W2 without also implementing an XPC_W1. If implemented, these XPC words shall be exactly 16 bits in length and stored MSB first. If a Tag does not support one or both of these XPC words then the specified memory locations need not exist. When an Interrogator writes the XPC a Tag shall not write and shall instead ignore the data values the Interrogator provides for the **C**, **SLI**, and **K** flags.

A Tag shall not implement any non-XPC memory element at EPC memory locations 210_h to 22F_h, inclusive. This requirement shall apply both to Tags that support an XPC word or words and to those that do not.

If a Tag implements an XPC_W1 then the Tag shall compute **XI** as described in 6.3.2.1.2.2. If a Tag implements an XPC_W2 then the Tag shall compute **XEB** as the logical OR of bits 220_h to 22F_h of EPC memory, inclusive. A Tag shall perform these calculations both at powerup and upon changing any bits 220_h to 22F_h of EPC memory. A Tag shall perform its **XEB** calculation prior to performing its **XI** calculation so that if **XEB**=1 then **XI**=1.

If a Tag computes a bit in XPC_W1 or XPC_W2 and, as a result of a commanded operation, the Tag alters the bit value then the Tag shall map the new value into memory prior to executing a subsequent command.

An Interrogator may issue a *Select* command (see 6.3.2.12.1) with a Mask covering all or part of XPC_W1 and/or XPC_W2. An Interrogator may read a Tag's XPC_W1 and XPC_W2 using a *Read* command (see 6.3.2.12.3.2).

The XPC_W1 bits and values shall be as follows (see also Table 6.18 and Table 6.19):

- **XEB (bit 210_h):** If bit 210_h is 0₂ then either a Tag has no XPC_W2 or all bits of XPC_W2 are zero-valued. If bit 210_h is 1₂ then a Tag has an XPC_W2 and at least one bit of XPC_W2 is nonzero.
- **RFU or As Defined in ISO/IEC 18000-63 (bits 211_h–217_h):** If T=0 then the Tag manufacturer (if the bits are not writeable) or an Interrogator (if the bits are writeable) shall set bits 211_h–217_h to zero. If T=1 then a Tag and/or an Interrogator shall set bits 211_h–217_h as defined in ISO/IEC 18000-63.
- **B (Battery-assisted passive indicator, bit 218_h):** If bit 218_h is 0₂ then a Tag is either passive or does not support the **B** flag. If bit 218_h is 1₂ then a Tag is battery assisted.
- **C (Computed response indicator, bit 219_h):** If bit 219_h is 0₂ then the Tag's ResponseBuffer is empty or the Tag does not support a ResponseBuffer. If bit 219_h is 1₂ then a Tag has a response in its ResponseBuffer. See 6.3.1.6.4.
- **SLI (SL-flag indicator, bit 21A_h):** If bit 21A_h is 0₂ then a Tag has a deasserted **SL** flag or does not support an **SL** indicator. If bit 21A_h is 1₂ then a Tag has an asserted **SL** flag. Upon receiving a *Query* a Tag that implements the **SL** indicator shall map its **SL** flag into the **SLI** and shall retain this **SLI** setting until starting a subsequent inventory round.
- **TN (Tag-notification indicator, bit 21B_h):** If bit 21B_h is 0₂ then a Tag does not have a Tag notification or does not support the **TN** flag. If bit 21B_h is 1₂ then a Tag has a Tag notification. The indication provided by the **TN** bit is Tag-manufacturer defined and not specified by this protocol. A Tag manufacturer may configure the **TN** bit to be writeable, computed, or fixed. Depending on the manufacturer's implementation the **TN** bit may or may not inherit the permalock status of the EPC memory bank.
- **U (Untraceable indicator, bit 21C_h):** If bit 21C_h is 0₂ then either (i) the Tag does not support the **U** bit or (ii) an Interrogator has not asserted the **U** bit. If bit 21C_h is 1₂ then an Interrogator has asserted the **U** bit, typically for the purpose of indicating that the Tag is persistently reducing its operating range and/or is untraceably hiding memory. See 6.3.2.12.3.16.
- **K (Killable indicator, bit 21D_h):** If bit 21D_h is 0₂ then a Tag is not killable or does not support the **K** bit. If bit 21D_h is 1₂ then a Tag is killable. Logically, **K** is defined as:

K = [(logical OR of *AuthKill* privilege for all keys) OR (logical OR of all 32 bits of the kill password) OR (kill-pwd-read/write=0) OR (kill-pwd-permalock=0)]. See also Table 6.21. In words:

- If the Tag supports authenticated kill and any key has a AuthKill=1 then the Tag is killable
- If any bits of the kill password are 1₂ then the Tag is killable
- If **kill-pwd-read/write** (see 6.3.2.12.3.5) is 0₂ then the Tag is killable
- If **kill-pwd-permalock** (see 6.3.2.12.3.5) is 0₂ then the Tag is killable
- **NR (Nonremovable indicator, bit 21E_h):** If bit 21E_h is 0₂ then a Tag is either removable or does not support the **NR** flag. If bit 21E_h is 1₂ then a Tag is nonremovable. See 4.1.
- **H (Hazmat indicator, bit 21F_h):** If bit 21F_h is 0₂ then a Tag is either not affixed to hazardous material or does not support the **H** flag. If bit 21F_h is 1₂ then a Tag is affixed to hazardous material.

If **T**=0 then a Tag manufacturer (if XPC_W2 exists but is not writeable) or an Interrogator (if XPC_W2 exists and is writeable) shall set all XPC_W2 bits to 0₂. If **T**=1 then a Tag and/or an Interrogator shall set the XPC_W2 bits as defined in ISO/IEC 18000-63.

6.3.2.1.3 TID Memory

TID memory locations 00_h to 07_h shall contain either an E0_h or E2_h ISO/IEC 15963 class-identifier value. The Tag manufacturer assigns the class identifier (E0_h or E2_h), for which ISO/IEC 15963 defines the registration authority. The class-identifier does not specify the Application. TID memory locations above 07_h shall be defined according to the registration authority defined by this class-identifier value and shall contain, at a minimum, sufficient information for an Interrogator to uniquely identify the custom commands and/or optional features that a Tag supports. TID memory may also contain Tag- and manufacturer-specific data (for example, a Tag serial number).

If the class identifier is E0_h then TID memory locations 08_h to 0F_h contain an 8-bit manufacturer identifier, TID memory locations 10_h to 3F_h contain a 48-bit Tag serial number (assigned by the Tag manufacturer), the composite 64-bit TID (i.e. TID memory 00_h to 3F_h) is unique among all classes of Tags defined in ISO/IEC 15963, and TID memory is permalocked at the time of manufacture.

If the class identifier is E2_h then TID memory above 07_h shall be configured as follows:

- 08_h: XTID (**X**) indicator (whether a Tag implements an XTID – see 5.2)
- 09_h: Security (**S**) indicator (whether a Tag supports the *Authenticate* and/or *Challenge* commands)
- 0A_h: File (**F**) indicator (whether a Tag supports the *FileOpen* command)
- 0B_h to 13_h: A 9-bit Tag mask-designer identifier (obtainable from the registration authority)
- 14_h to 1F_h: A Tag-manufacturer-defined 12-bit Tag model number
- Above 1F_h: As defined in the GS1 EPC Tag Data Standard

If the class identifier is E2_h then TID memory locations 00_h to 1F_h shall be permalocked at time of manufacture. If the Tag implements an XTID then the entire XTID shall also be permalocked at time of manufacture.

6.3.2.1.4 User Memory

A Tag may support User memory, configured as one or more files. User memory allows user data storage.

If File_0 of User memory exists and has not yet been written then the 5 LSBs of the first byte (i.e. File_0 memory addresses 03_h to 07_h) shall have the default value 00000₂.

6.3.2.1.4.1 User memory for a GS1 EPCglobal™ Application

If a Tag implements User memory then the file encoding shall be as defined in the GS1 EPC Tag Data Standard.

6.3.2.1.4.2 User memory for a non-GS1 EPCglobal™ Application

If a Tag implements User memory then the file encoding shall be as defined in ISO/IEC 15961 and 15962.

6.3.2.2 Sessions and inventoried flags

Interrogators shall support and Tags shall provide 4 sessions (denoted S0, S1, S2, and S3). Tags shall participate in one and only one session during an inventory round. Two or more Interrogators can use sessions to independently inventory a common Tag population. The sessions concept is illustrated in Figure 6.20.

A Tag shall maintain an independent **inventoried** flag for each of its four sessions. Each **inventoried** flag has two

values, denoted *A* and *B*. At the beginning of each and every inventory round an Interrogator chooses to inventory either *A* or *B* Tags in one of the four sessions. Tags participating in an inventory round in one session shall neither use nor modify an **inventoried** flag for a different session. The **inventoried** flags are the only resource that a Tag provides separately and independently to a session; all other Tag resources are shared among sessions.

After singulating a Tag an Interrogator may issue a command that causes the Tag to invert its **inventoried** flag for that session (i.e. $A \rightarrow B$ or $B \rightarrow A$).

The following example illustrates how two Interrogators can use sessions and **inventoried** flags to independently and completely inventory a common Tag population, on a time-interleaved basis:

- Interrogator #1 powers-on, then
 - It initiates an inventory round during which it singulates *A* Tags in session S2 to *B*,
 - It powers off.
- Interrogator #2 powers-on, then
 - It initiates an inventory round during which it singulates *B* Tags in session S3 to *A*,
 - It powers off.

This process repeats until Interrogator #1 has placed all Tags in session S2 into *B*, after which it inventories the Tags in session S2 from *B* back to *A*. Similarly, Interrogator #2 places all Tags in session S3 into *A*, after which it inventories the Tags in session S3 from *A* back to *B*. By this multi-step procedure each Interrogator can independently inventory all Tags in its field, regardless of the initial state of their **inventoried** flags.

A Tag's **inventoried** flags shall have the set and persistence times shown in Table 6.20. A Tag shall power-up with its **inventoried** flags set as follows:

- The S0 **inventoried** flag shall be set to *A*.
- The S1 **inventoried** flag shall be set to either *A* or *B*, depending on its stored value, unless the flag was set longer in the past than its persistence time, in which case the Tag shall power-up with its S1 **inventoried** flag set to *A*. Because the S1 **inventoried** flag is not automatically refreshed, it may revert from *B* to *A* even when the Tag is powered.
- The S2 **inventoried** flag shall be set to either *A* or *B*, depending on its stored value, unless the Tag has lost power for a time greater than its persistence time, in which case the Tag shall power-up with the S2 **inventoried** flag set to *A*.
- The S3 **inventoried** flag shall be set to either *A* or *B*, depending on its stored value, unless the Tag has lost power for a time greater than its persistence time, in which case the Tag shall power-up with its S3 **inventoried** flag set to *A*.

A Tag shall refresh its S2 and S3 flags while powered, meaning that every time a Tag loses power its S2 and S3 **inventoried** flags shall have the set and persistence times shown in Table 6.20.

A Tag shall not change the value of its S1 **inventoried** flag from *B* to *A*, as the result of a persistence timeout, while the Tag is participating in an inventory round, is in the midst of being inventoried, or is in the midst of being accessed. If a Tag's S1 flag persistence time expires during an inventory round then the Tag shall change the flag to *A* only (i) as instructed by an Interrogator (e.g. by a *QueryAdjust* or *QueryRep* with matching session at the end of an inventory or access operation), or (ii) at the end of the round (e.g. upon receiving a *Select* or *Query*). In case (i), if the Tag's S1 flag persistence time expires while the Tag is in the midst of being inventoried or accessed then the Tag shall change the flag to *A* at the end of the inventory or access operation. In case (ii), the Tag shall invert its S1 flag prior to evaluating the *Select* or *Query*.

6.3.2.3 Selected flag

A Tag shall implement a selected flag, **SL**, which an Interrogator may assert or deassert using a *Select* command. The Sel parameter in the *Query* command allows an Interrogator to inventory Tags that have **SL** either asserted or deasserted (i.e. **SL** or \sim **SL**), or to ignore the flag and inventory Tags regardless of their **SL** value. **SL** is not associated with any particular session; **SL** may be used in any session, and is common to all sessions.

A Tag's **SL** flag shall have the set and persistence times shown in Table 6.20. A Tag shall power-up with its **SL** flag either asserted or deasserted, depending on the stored value, unless the Tag has lost power for a time greater than the **SL** persistence time, in which case the Tag shall power-up with its **SL** flag deasserted (set to \sim **SL**). A Tag shall refresh its **SL** flag when powered, meaning that every time a Tag loses power its **SL** flag shall have the persistence times shown in Table 6.20.

6.3.2.4 C flag

A Tag's **C** flag (see 6.3.2.1.2.5) shall have the set and persistence times shown in Table 6.20. A Tag retains data in its ResponseBuffer (see 6.3.1.6.4) with the same persistence as its **C** flag. A Tag shall refresh its **C** flag when powered, meaning that every time a Tag loses power its **C** flag shall have the persistence shown in Table 6.20 (of course, if a Tag has a zero-second persistence time then even if the Tag powers down momentarily its **C** flag will be deasserted).

6.3.2.5 Security timeout

A Tag may implement a security timeout after a failed *Access-command* sequence, authenticated *Kill*, password-based *Kill-command* sequence, *Challenge*, *Authenticate*, *SecureComm*, *AuthComm*, and/or *KeyUpdate*. During a security timeout a Tag may participate in an inventory round and access, but until the end of the timeout the Tag does not execute those commands for which it implements a security timeout and instead backscatters an error code (see [Annex I](#)). If a Tag implements a security timeout then it shall use a single timeout timer, so a security timeout caused by one command failure (such as a failed *Challenge*) shall cause a Tag to disallow all commands for which the Tag implements a security timeout until the end of the timeout period. Although this protocol gives Tag manufacturers the option of choosing which commands are subject to a security timeout, it recommends that Tags implement a security timeout at least for the *Access-command* sequence. This protocol further recommends that a Tag's security timer have the set and persistence times shown in Table 6.20.

6.3.2.6 Tag states and slot counter

A Tag shall implement the states and slot counter shown in Figure 6.21. Note that the states in Figure 6.21 are metastates that characterize a Tag's behavior and response to Interrogator commands; an actual Tag realization is likely to have more internal states than the metastates shown in the Figure 6.21. [Annex B](#) shows the associated state-transition tables; [Annex C](#) shows the associated command-response tables.

6.3.2.6.1 Ready state

Tags shall implement a **ready** state. **Ready** can be viewed as a "holding state" for energized Tags that are neither killed nor currently participating in an inventory round. Upon entering an energizing RF field a Tag that is not killed shall enter **ready**. The Tag shall remain in **ready** until it receives a *Query* command (see 6.3.2.12.2.1) whose inventoried parameter (for the session specified in the *Query*) and sel parameter match its current flag values. Matching Tags shall draw a Q-bit number from their RNG (see 6.3.2.7), load this number into their slot counter, and transition to the **arbitrate** state if the number is nonzero, or to the **reply** state if the number is zero. If a Tag in any state except **killed** loses power then it shall return to **ready** upon regaining power.

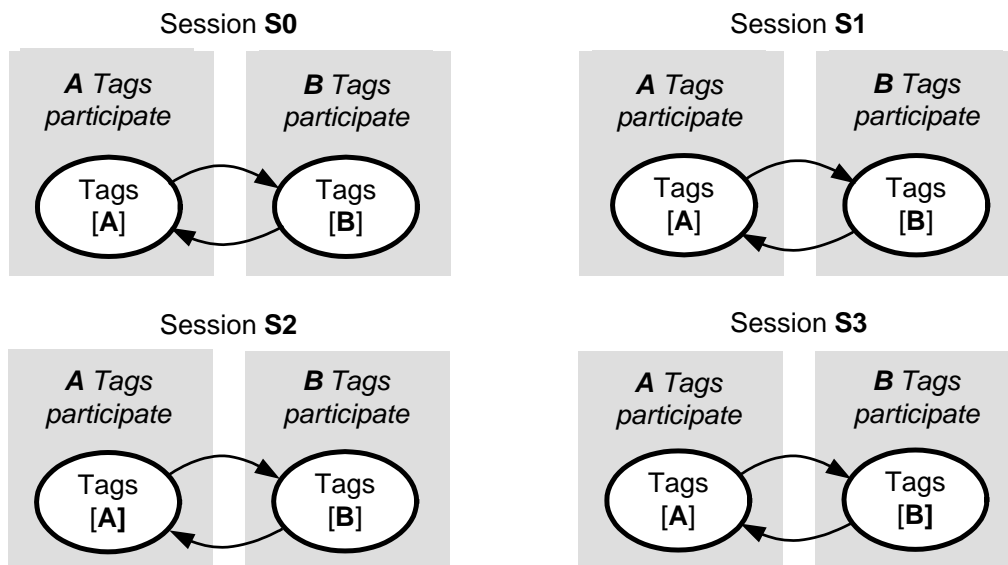


Figure 6.20: Session diagram

Table 6.20: Tag flags and persistence values

Flag	Time to Set	Required persistence
S0 inventoried flag	$\leq 2\text{ms}$ regardless of initial or final value ³	Tag energized: Indefinite Tag not energized: None
S1 inventoried flag ¹	$\leq 2\text{ms}$ regardless of initial or final value ³	Tag energized: Nominal temperature range: $500\text{ms} < \text{persistence} < 5\text{s}$ Extended temperature range: Not specified Tag not energized: Nominal temperature range: $500\text{ms} < \text{persistence} < 5\text{s}$ Extended temperature range: Not specified
S2 inventoried flag ¹	$\leq 2\text{ms}$ regardless of initial or final value ³	Tag energized: Indefinite Tag not energized: Nominal temperature range: $2\text{s} < \text{persistence}$ Extended temperature range: Not specified
S3 inventoried flag ¹	$\leq 2\text{ms}$ regardless of initial or final value ³	Tag energized: Indefinite Tag not energized: Nominal temperature range: $2\text{s} < \text{persistence}$ Extended temperature range: Not specified
Selected (SL) flag ¹	$\leq 2\text{ms}$ regardless of initial or final value ³	Tag energized: Indefinite Tag not energized: Nominal temperature range: $2\text{s} < \text{persistence}$ Extended temperature range: Not specified
C flag ^{1,2}	Deassert: $\leq 2\text{ms}^3$ Assert: $\leq 0\text{ms}$ measured relative to the first rising edge of the Tag's response indicating that the Tag has finished its computation	Tag energized: Indefinite Tag not energized: Nominal temperature range: $0\text{s} \leq \text{persistence} < 5\text{s}$ Extended temperature range: Not specified
Optional security timeout	$< T_{1(\text{min})}$ (see Table 6.16), measured relative to the last rising edge of the last bit of the Interrogator command that caused the security timeout.	Tag energized ⁴ : Nominal temperature range: $20\text{ms} \leq \text{persistence} < 200\text{ms}$ Extended temperature range: Not specified Tag not energized ⁴ : Nominal temperature range: $20\text{ms} \leq \text{persistence} < 200\text{ms}$ Extended temperature range: Not specified

Note 1: For a randomly chosen and sufficiently large Tag population, 95% of the Tag persistence times shall meet the persistence requirement, with a 90% confidence interval.

Note 2: A Tag retains data in its ResponseBuffer with the same persistence as its C flag (see 6.3.1.6.4).

Note 3: Measured from the last rising edge of the last bit of the Interrogator transmission that caused the change.

Note 4: The indicated persistence times are recommended but not required.

6.3.2.6.2 Arbitrate state

Tags shall implement an **arbitrate** state. **Arbitrate** can be viewed as a “holding state” for Tags that are participating in the current inventory round but whose slot counters (see 6.3.2.6.8) hold nonzero values. A Tag in **arbitrate** shall decrement its slot counter every time it receives a *QueryRep* command (see 6.3.2.12.2.3) whose session parameter matches the session for the inventory round currently in progress, and it shall transition to the **reply** state and backscatter an RN16 when its slot counter reaches 0000_h. Tags that return to **arbitrate** (for example, from the **reply** state) with a slot value of 0000_h shall decrement their slot counter from 0000_h to 7FFF_h at the next *QueryRep* (with matching session) and, because their slot value is now nonzero, shall remain in **arbitrate**.

6.3.2.6.3 Reply state

Tags shall implement a **reply** state. Upon entering **reply** a Tag shall backscatter an RN16. If the Tag receives a valid acknowledgement (ACK) then it shall transition to the **acknowledged** state, backscattering the reply shown in Table 6.17. If the Tag fails to receive an ACK within time $T_{2(\text{max})}$, or receives an invalid ACK or an ACK with an erroneous RN16 then it shall return to **arbitrate**. Tag and Interrogator shall meet all timing requirements specified in Table 6.16.

6.3.2.6.4 Acknowledged state

Tags shall implement an **acknowledged** state. A Tag in **acknowledged** may transition to any state except **killed**, depending on the received command (see Figure 6.21). If a Tag in the **acknowledged** state receives a valid *ACK* containing the correct RN16 then it shall re-backscatter the reply shown in Table 6.17. If a Tag in the **acknowledged** state fails to receive a valid command within time $T_{2(max)}$ then it shall return to **arbitrate**. Tag and Interrogator shall meet all timing requirements specified in Table 6.16.

6.3.2.6.5 Open state

Tags shall implement an **open** state. A Tag in the **acknowledged** state whose access password is nonzero shall transition to **open** upon receiving a *Req_RN* command, backscattering a new RN16 (denoted handle) that the Interrogator shall use in subsequent commands and the Tag shall use in subsequent replies. A Tag in the **open** state may execute some access commands – see Table 6.27. A Tag in **open** may transition to any state except **acknowledged**, depending on the received command (see Figure 6.21). If a Tag in the **open** state receives a valid *ACK* containing the correct handle then it shall re-backscatter the reply shown in Table 6.17. Tag and Interrogator shall meet all timing requirements specified in Table 6.16 except $T_{2(max)}$; in the **open** state the maximum delay between Tag response and Interrogator transmission is unrestricted.

6.3.2.6.6 Secured state

Tags shall implement a **secured** state. A Tag in the **acknowledged** state whose access password is zero shall transition to **secured** upon receiving a *Req_RN* command, backscattering a new RN16 (denoted handle) that the Interrogator shall use in subsequent commands and the Tag shall use in subsequent replies. A Tag in the **open** state shall transition to **secured** following a successful *Access* command sequence or Interrogator authentication (where success in the latter case is defined by the cryptographic suite specified in the *Authenticate* command that initiated the authentication), maintaining the same handle that it previously backscattered when it transitioned from the **acknowledged** state to the **open** state. A Tag in the **secured** state with the appropriate Tag and file privileges (see 6.3.2.11.2 and 6.3.2.11.3) may execute all access commands. A Tag in **secured** may transition to any state except **acknowledged**, depending on the received command (see Figure 6.21). If a Tag in the **secured** state receives a valid *ACK* containing the correct handle then it shall re-backscatter the reply shown in Table 6.17. Tag and Interrogator shall meet all timing requirements specified in Table 6.16 except $T_{2(max)}$; in the **secured** state the maximum delay between Tag response and Interrogator transmission is unrestricted.

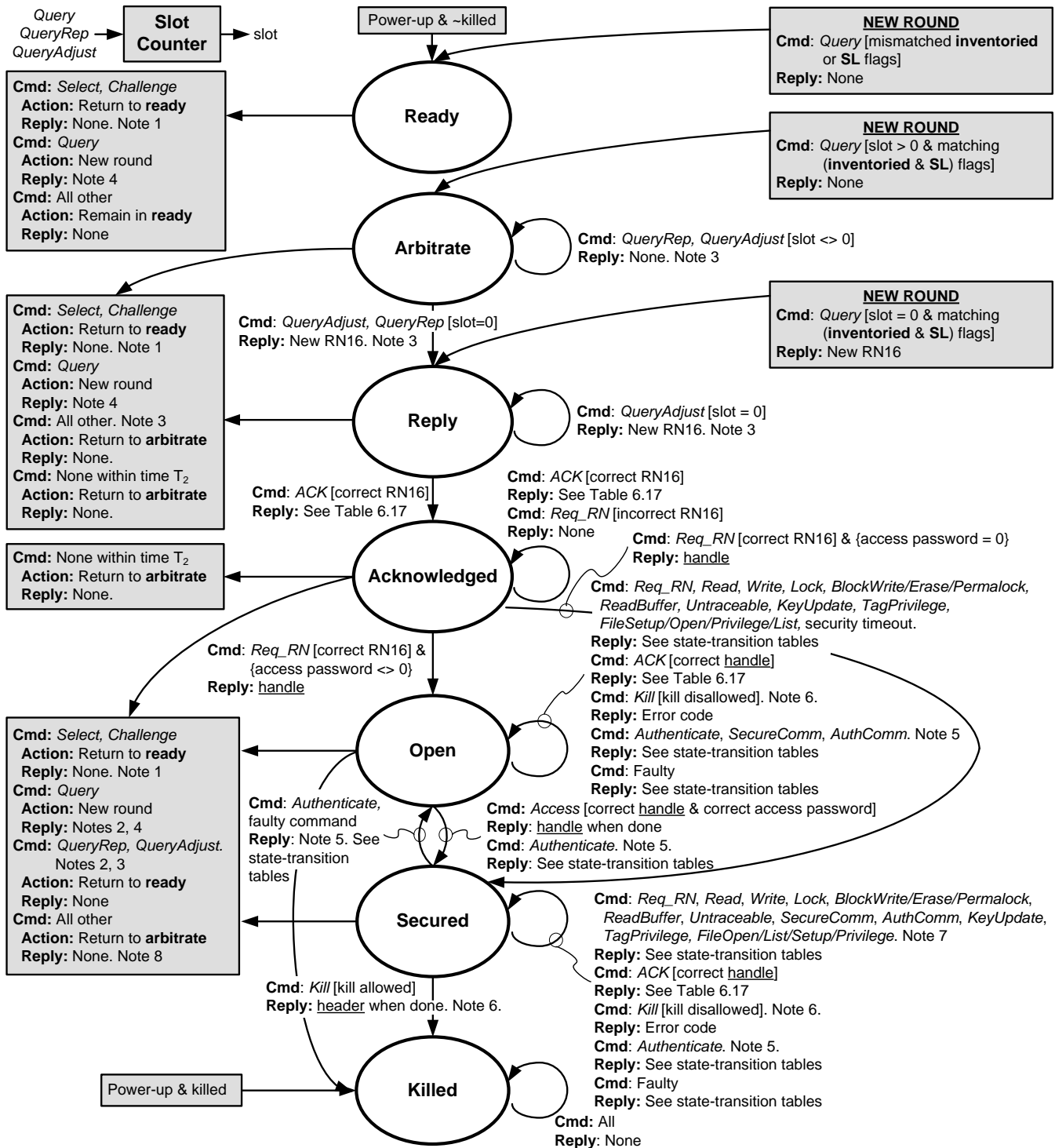
6.3.2.6.7 Killed state

Tags shall implement a **killed** state. A Tag in either the **open** or **secured** state shall enter the **killed** state upon receiving a successful password-based *Kill*-command sequence with a correct nonzero kill password and handle. A Tag in the **secured** states shall enter the **killed** state upon a successful authenticated *Kill* (see 6.3.2.12.3.4). *Kill* permanently disables a Tag. Upon entering the **killed** state a Tag shall notify the Interrogator that the kill was successful and shall not respond to an Interrogator thereafter. Killed Tags shall remain in the **killed** state under all circumstances, and shall immediately enter killed upon subsequent power-ups. Killing a Tag is irreversible.

6.3.2.6.8 Slot counter

Tags shall implement a 15-bit slot counter. Upon receiving a *Query* or *QueryAdjust* command a Tag shall preload into its slot counter a value between 0 and 2^Q-1 , drawn from the Tag's RNG (see 6.3.2.7). Q is an integer in the range (0, 15). A *Query* specifies Q ; a *QueryAdjust* may modify Q from the prior *Query*.

Tags in the **arbitrate** state decrement their slot counter every time they receive a *QueryRep* with matching session, transitioning to the **reply** state and backscattering an RN16 when their slot counter reaches 0000_h. Tags whose slot counter reached 0000_h, who replied, and who were not acknowledged (including Tags that responded to an original *Query* and were not acknowledged) shall return to **arbitrate** with a slot value of 0000_h and shall decrement this slot value from 0000_h to 7FFF_h at the next *QueryRep*. The slot counter shall be capable of continuous counting, meaning that, after the slot counter rolls over to 7FFF_h it begins counting down again, thereby effectively preventing subsequent replies until the Tag loads a new random value into its slot counter. See also [Annex J](#).



NOTES

1. Select: Assert/deassert **SL** or set **inventoried** to A or B.
Challenge: Perform action(s) indicated by message, store result, and assert **C** flag in *XPC_W1*.
2. Query: A → B or B → A if the new session matches the prior session; otherwise no change to the **inventoried** flag.
QueryRep/QueryAdjust: A → B or B → A if session matches that of the prior Query.
3. If the command is a QueryRep or QueryAdj and session does not match that of the prior Query then the Tag ignores the command.
4. Query starts a new round and may change the session. Tags may go to **ready**, **arbitrate**, or **reply**.
5. See the state-transition tables and the cryptographic suite for conditions, message formatting, tag responses, and state changes.
6. Whether a kill is allowed or disallowed depends on the kill pwd, Tag privileges, and security timeout. See the Kill command-response table.
7. If the Interrogator is authenticated then certain commands require encapsulation in an AuthComm or a SecureComm. See Table 6.28.
8. A Tag that returns to **arbitrate** as a result of an unsuccessful access or kill, or a cryptographic error, may set a security timeout. See 6.3.2.5.

Figure 6.21: Tag state diagram

6.3.2.7 Tag random or pseudo-random number generator

A Tag shall implement a random or pseudo-random number generator (RNG). The RNG shall meet the following randomness criteria independent of the strength of the energizing RF field, the R=>T link rate, and the data stored in the Tag (including but not limited to the StoredPC, XPC word or words, EPC, and StoredCRC). Tags shall generate 16-bit random or pseudo-random numbers (RN16) using the RNG, and shall have the ability to extract Q-bit subsets from its RNG to preload the Tag's slot counter (see 6.3.2.6.8). Tags shall have the ability to temporarily store at least two RN16s while powered, to use, for example, as a handle and a 16-bit cover-code during password transactions (see Figure 6.24 or Figure 6.26).

Probability of a single RN16: The probability that any RN16 drawn from the RNG has value $RN16 = j$, for any j , shall be bounded by $0.8/2^{16} < P(RN16 = j) < 1.25/2^{16}$.

Probability of simultaneously identical sequences: For a Tag population of up to 10,000 Tags, the probability that any two or more Tags simultaneously generate the same sequence of RN16s shall be less than 0.1%, regardless of when the Tags are energized.

Probability of predicting an RN16: An RN16 drawn from a Tag's RNG 10ms after the end of T_r in Figure 6.3 shall not be predictable with a probability greater than 0.025% if the outcomes of prior draws from the RNG, performed under identical conditions, are known.

This protocol recommends that Interrogators wait 10ms after T_r in Figure 6.3 or T_{hr} in Figure 6.5 before issuing passwords to Tags.

A cryptographic suite defines RNG requirements and randomness criteria for cryptographic operations. These requirements and criteria may be different, and in particular may be more stringent, than those defined above for inventory and password operations.

6.3.2.8 Managing Tag populations

Interrogators manage Tag populations using the three basic operations shown in Figure 6.22. Each of these operations comprises multiple commands. The operations are defined as follows:

- Select:** The process by which an Interrogator selects a Tag population for subsequent inventory or cryptographically challenges a Tag population for subsequent authentication. Select comprises the *Select* and *Challenge* commands.
- Inventory:** The process by which an Interrogator identifies Tags. An Interrogator begins an inventory round by transmitting a *Query* command in one of four sessions. One or more Tags may reply. The Interrogator detects a single Tag reply and requests the PC, optional XPC word(s), EPC, and CRC-16 from the Tag. An inventory round operates in one and only one session at a time. [Annex E](#) shows an example of an Interrogator inventorying and accessing a single Tag. Inventory comprises multiple commands.
- Access:** The process by which an Interrogator transacts with (reads, writes, authenticates, or otherwise engages with) an individual Tag. An Interrogator singulates and uniquely identifies a Tag prior to access. Access comprises multiple commands.

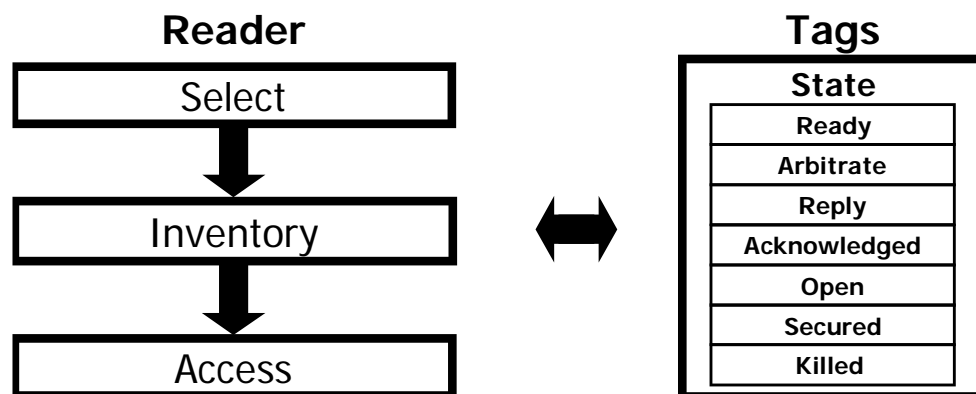


Figure 6.22: Interrogator/Tag operations and Tag state

6.3.2.9 Selecting Tag populations

The select process comprises two commands, *Select* and *Challenge*. *Select* allows an Interrogator to select a Tag population for subsequent inventorying. *Challenge* allows an Interrogator to challenge a Tag population for subsequent authentication. *Select* and *Challenge* are the only two commands that an Interrogator may issue prior to inventory, and they are not mutually exclusive (i.e. an Interrogator may issue both a *Select* and a *Challenge* prior to starting an inventory round). *Select* is a mandatory command; *Challenge* is optional.

A *Select* command allows an Interrogator to select a particular Tag population prior to inventorying. The selection is based on user-defined criteria, enabling union (U), intersection (\cap), and negation (\sim) based Tag partitioning. Interrogators perform U and \cap operations by issuing successive *Select* commands. *Select* can assert or deassert a Tag's **SL** flag, or it can set a Tag's **inventoried** flag to either *A* or *B* in any one of the four sessions.

Upon receiving a *Select* a not-killed Tag returns to the **ready** state, evaluates the criteria, and depending on the evaluation may modify the indicated **SL** or **inventoried** flag. A *Query* command uses these flags to choose which Tags participate in a subsequent inventory round. An Interrogator may inventory and access **SL** or \sim **SL** Tags, or it may choose to not use the **SL** flag at all. *Select* may begin with a Tag in any state except **killed**, and ends with a Tag in **ready**.

Select contains the parameters Target, Action, MemBank, Pointer, Length, Mask, and Truncate.

- Target and Action indicate whether and how a *Select* modifies a Tag's **SL** or **inventoried** flag, and in the case of an **inventoried** flag, for which session. A *Select* that modifies the **SL** flag does not modify an **inventoried** flag, and vice versa.
- MemBank specifies if the Mask applies to EPC, TID, or User memory. *Select* commands apply to a single memory bank. Successive *Selects* may apply to different memory banks.
- Pointer, Length, and Mask: Pointer and Length describe a memory range. Mask, which is Length bits long, contains a bit string that a Tag compares against the specified memory range.
- Truncate specifies whether a Tag backscatters its entire EPC, or only that portion of the EPC immediately following Mask, when replying to an *ACK*.

A *Challenge* command allows an Interrogator to instruct multiple Tags to simultaneously yet independently precompute and store a cryptographic result for use in a subsequent authentication. Because cryptographic algorithms often require significant computation time, parallel precomputation may significantly accelerate the authentication of a Tag population. *Challenge* contains an immed parameter which, if asserted, instructs the Tags to concatenate their response (result or error code) to the EPC backscattered in reply to an *ACK*.

Upon receiving a *Challenge* a not-killed Tag that supports the command returns to the **ready** state, evaluates the command (including whether it supports the CSI specified in the *Challenge*), and depending on the evaluation may compute and store a cryptographic result in its ResponseBuffer. In some instances a Tag may use the stored result during a subsequent authentication. In such instances the Interrogator will transmit a subsequent *Authenticate* command (see 6.3.2.12.3.10) to the previously challenged Tag. In other instances the Tag's stored result may be usable without a subsequent *Authenticate*. For an example of the latter case, in some cryptographic suites an Interrogator can verify a Tag's authenticity simply by evaluating the precomputed result. *Challenge* may begin with a Tag in any state except **killed**, and ends with a Tag in **ready**.

6.3.2.10 Inventorying Tag populations

The inventory command set includes *Query*, *QueryAdjust*, *QueryRep*, *ACK*, and *NAK*. *Query* initiates an inventory round and decides which Tags participate in the round ("inventory round" is defined in 4.1).

Query contains a slot-count parameter *Q*. Upon receiving a *Query* participating Tags pick a random value in the range $(0, 2^Q - 1)$, inclusive, and load this value into their slot counter. Tags that pick a zero transition to the **reply** state and reply immediately. Tags that pick a nonzero value transition to the **arbitrate** state and await a *QueryAdjust* or *QueryRep* command. Assuming a single Tag replies, the query-response algorithm proceeds as follows:

- The Tag backscatters an RN16 as it enters **reply**,
- The Interrogator acknowledges the Tag with an *ACK* containing this same RN16,
- The acknowledged Tag transitions to the **acknowledged** state, backscattering a reply as in Table 6.17,
- The Interrogator issues a *QueryAdjust* or *QueryRep*, causing the identified Tag to invert its **inventoried** flag (i.e. $A \rightarrow B$ or $B \rightarrow A$) and transition to **ready**, and potentially causing another Tag to initiate a query-response dialog with the Interrogator, starting in step (a), above.

If the Tag fails to receive the *ACK* in step (b) within time T_2 (see Figure 6.18), or receives the *ACK* with an erroneous RN16, then it returns to **arbitrate**.

If multiple Tags reply in step (a) but the Interrogator, by detecting and resolving collisions at the waveform level, can resolve an RN16 from one of the Tags, the Interrogator can *ACK* the resolved Tag. Unresolved Tags receive erroneous RN16s and return to **arbitrate** without backscattering the reply shown in Table 6.17.

If the Interrogator sends a valid *ACK* (i.e. an *ACK* containing the correct RN16) to the Tag in the **acknowledged** state, the Tag re-backscatters the reply shown in Table 6.17.

At any point the Interrogator may issue a *NAK*, in response to which all Tags in the inventory round that receive the *NAK* return to **arbitrate** without changing their **inventoried** flag.

After issuing a *Query* to initiate an inventory round, the Interrogator typically issues one or more *QueryAdjust* or *QueryRep* commands. *QueryAdjust* repeats a previous *Query* and may increment or decrement Q , but does not introduce new Tags into the round. *QueryRep* repeats a previous *Query* without changing any parameters and without introducing new Tags into the round. An inventory round can contain multiple *QueryAdjust* or *QueryRep* commands. At some point the Interrogator will issue a new *Query*, thereby starting a new inventory round.

Tags in the **arbitrate** or **reply** states that receive a *QueryAdjust* first adjust Q (increment, decrement, or leave unchanged), then pick a random value in the range $(0, 2^Q - 1)$, inclusive, and load this value into their slot counter. Tags that pick zero transition to the **reply** state and reply immediately. Tags that pick a nonzero value transition to the **arbitrate** state and await a *QueryAdjust* or a *QueryRep* command.

Tags in the **arbitrate** state decrement their slot counter every time they receive a *QueryRep*, transitioning to the **reply** state and backscattering an RN16 when their slot counter reaches 0000_h . Tags whose slot counter reached 0000_h , who replied, and who were not acknowledged (including Tags that responded to the original *Query* and were not acknowledged) return to **arbitrate** with a slot value of 0000_h and decrement this slot value from 0000_h to $7FFF_h$ at the next *QueryRep*, thereby effectively preventing subsequent replies until the Tag loads a new random value into its slot counter.

Although Tag inventory is based on a random protocol, the Q -parameter affords network control by allowing an Interrogator to regulate the probability of Tag responses. Q is an integer in the range $(0, 15)$; thus, the associated Tag-response probabilities range from $2^0 = 1$ to $2^{-15} = 0.000031$.


[Annex D](#) describes an exemplary Interrogator algorithm for choosing Q .


The scenario outlined above assumed a single Interrogator operating in a single session. However, as described in 6.3.2.2, an Interrogator can inventory a Tag population in one of four sessions. Furthermore, as described in 6.3.2.12.2, the *Query*, *QueryAdjust*, and *QueryRep* commands each contain a session parameter. How a Tag responds to these commands varies with the command, session parameter, and Tag state, as follows:

- *Query*: A *Query* command starts an inventory round and chooses the session for the round. Tags in any state except **killed** execute a *Query*, starting a new round in the specified session and transitioning to **ready**, **arbitrate**, or **reply**, as appropriate (see Figure 6.21).
 - If a Tag in the **acknowledged**, **open**, or **secured** states receives a *Query* whose session parameter matches the prior session then it inverts its **inventoried** flag (i.e. $A \rightarrow B$ or $B \rightarrow A$) for the session before it evaluates whether to transition to **ready**, **arbitrate**, or **reply**.
 - If a Tag in the **acknowledged**, **open**, or **secured** states receives a *Query* whose session parameter does not match the prior session then it leaves its **inventoried** flag for the prior session unchanged as it evaluates whether to transition to **ready**, **arbitrate**, or **reply**.
- *QueryAdjust*, *QueryRep*: Tags in any state except **ready** or **killed** execute a *QueryAdjust* or *QueryRep* command if, and only if, (i) the session parameter in the command matches the session parameter in the *Query* that started the round, and (ii) the Tag is not in the middle of a *Kill* or *Access* command sequence (see 6.3.2.12.3.4 or 6.3.2.12.3.6, respectively). Tags ignore a *QueryAdjust* or *QueryRep* with mismatched session.
 - If a Tag in the **acknowledged**, **open**, or **secured** states receives a *QueryAdjust* or *QueryRep* whose session parameter matches the session parameter in the prior *Query*, and the Tag is not in the middle of a *Kill* or *Access* command sequence (see 6.3.2.12.3.4 or 6.3.2.12.3.6, respectively), then it inverts its **inventoried** flag (i.e. $A \rightarrow B$ or $B \rightarrow A$) for the current session and then transitions to **ready**.

To illustrate an inventory operation, consider a specific example: Assume a population of 64 powered Tags in the **ready** state. An Interrogator first issues a *Select* to select a subpopulation of Tags. Assume that 16 Tags match the selection criteria. Further assume that 12 of the 16 selected Tags have their **inventoried** flag set to A in ses-

Condition	Description	Symbol	Description
<u>immed</u>	<u>immed</u> field in <i>Challenge</i>	P	Preamble (R=>T or T=>R)
C	C flag in XPC_W1	FS	Frame-Sync
XI	XI flag in StoredPC	RN16	16-bit Random Number
		PC	Either StoredPC or PacketPC
		XPC	Optional XPC word or words
		result	ResponseBuffer contents
		CRC-16	16-bit CRC computed over result

 R=>T Signaling

 T=>R Signaling

XI=0, (immed=0 OR **C**=0)



XI=1, (immed=1 AND **C**=1)



Figure 6.23: One Tag reply

sion S0. The Interrogator issues a *Query* specifying (**SL**, Q = 4, S0, A). Each of the 12 Tags picks a random number in the range (0,15) and loads the value into its slot counter. Tags that pick a zero respond immediately. The *Query* has 3 possible outcomes:

- No Tags reply:** The Interrogator may issue another *Query*, or it may issue a *QueryAdjust* or *QueryRep*.
- One Tag replies** (see Figure 6.23): The Tag transitions to the **reply** state and backscatters an RN16. The Interrogator acknowledges the Tag by sending an *ACK*. If the Tag receives the *ACK* with a correct RN16 it backscatters the reply shown in Table 6.17 and transitions to the **acknowledged** state. If the Tag receives the *ACK* with an incorrect RN16 it transitions to **arbitrate**. Assuming a successful *ACK*, the Interrogator may either access the acknowledged Tag or issue a *QueryAdjust* or *QueryRep* with matching session parameter to invert the Tag's **inventoried** flag from A→B and send the Tag to **ready** (a *Query* with matching prior-round session parameter will also invert the **inventoried** flag from A→B).
- Multiple Tags reply:** The Interrogator observes a backscattered waveform comprising multiple RN16s. It may try to resolve the collision and issue an *ACK*; not resolve the collision and issue a *QueryAdjust*, *QueryRep*, or *NAK*; or quickly identify the collision and issue a *QueryAdjust* or *QueryRep* before the collided Tags have finished backscattering. In the latter case the collided Tags, not observing a valid reply within T₂ (see Figure 6.18), return to **arbitrate** and await the next *Query* or *QueryAdjust* command.

6.3.2.11 Accessing individual Tags

An Interrogator may choose to access a Tag after acknowledging it. The access commands are *Req_RN*, *Read*, *Write*, *Lock*, *Kill*, *Access*, *BlockWrite*, *BlockErase*, *BlockPermalock*, *Authenticate*, *ReadBuffer*, *SecureComm*, *AuthComm*, *KeyUpdate*, *Untraceable*, *FileOpen*, *FileList*, *FilePrivilege*, *FileSetup*, and *TagPrivilege*. A Tag shall execute access commands only in the states shown in Table 6.27. A Tag shall treat as invalid (see Table C.30) optional access commands that it does not support. See [Annex K](#) for an example of a data-flow exchange during which an Interrogator accesses a Tag and reads its kill password.

Access always begins with an Interrogator moving a Tag from the **acknowledged** state to either the **open** or the **secured** state as follows:

Step 1: The Interrogator issues a *Req_RN* to the acknowledged Tag.

Step 2: The Tag generates and stores a new RN16 (denoted handle), backscatters the handle, and transitions to the **open** state if its access password is nonzero, or to the **secured** state if its access password is zero. The Interrogator may now issue further access commands.

All access commands include a Tag's handle. Upon receiving an access command a Tag verifies that the handle is correct prior to executing the command, and does not execute access commands with an incorrect handle. The handle value is fixed for the entire duration of a Tag access.

An Interrogator may issue an *ACK* to a Tag in the **open** or **secured** states, with the Tag's handle as the RN in the command, thereby causing the Tag to backscatter the reply shown in Table 6.17. A Tag in the **open** or **secured**

states that receives an *ACK* with an incorrect handle transitions to the **arbitrate** state without replying and without changing its inventoried flag.

As shown in Table 6.27, some access commands require a prior *Req_RN* and some a prior authentication before execution. A Tag's response to an access command includes, at a minimum, the Tag's handle; the response may include other information as well (for example, the result of a *Read*).

The *Authenticate* and *Access* commands provide the only means to transition a Tag from the **open** state to the **secured** state. The *Authenticate* command or a faulty security command provide the only means to transition a Tag from the **secured** state back to the **open** state. See Table C.18 and Table C.30.

The privileges that a Tag in the **open** state grants to an Interrogator depend on the authorization level of the **open** state. The privileges that a Tag in the **secured** state grants to an Interrogator depend on the authorization level of the access or authentication that most recently moved the Tag to that state. An Interrogator that moved a Tag to the **secured** state using one means (for example, an *Access* command) may later cause the Tag to re-enter the **secured** state using a different means (for example, an *Authenticate* command), affording the Interrogator different privileges. See 6.3.2.11.2 for a discussion of privileges and keys.

A Tag may enter the **secured** state by means of a:

- *Req_RN*: If a Tag's access password is zero then the Tag transitions from the **acknowledged** state to the **secured** state at the beginning of access (i.e. upon receiving a *Req_RN*), bypassing the **open** state.
- *Access*: A Tag whose access password is nonzero transitions from the **open** or **secured** state to the **secured** state upon successfully executing an *Access*-command sequence.
- *Authenticate*: A Tag transitions from the **open** or **secured** state to the **secured** state upon successfully executing an Interrogator or mutual authentication.

A Tag may limit an Interrogator's access to the **secured** state via one or more physical mechanisms. For example, a Tag may require that its received RF power exceed a threshold before it will enter the **secured** state. This protocol does not specify such physical mechanisms but allows them at a Tag manufacturer's discretion.

An Interrogator and a Tag can communicate indefinitely in the **open** or **secured** states. The Interrogator may end the communications at any time by issuing a *Select*, *Challenge*, *Query*, *QueryAdjust*, *QueryRep*, or *NAK*. The Tag's response to a *Query*, *QueryAdjust*, or *QueryRep* is described in 6.3.2.10. A *NAK* causes all Tags in the inventory round to return to **arbitrate** without changing their **inventoried** flag(s).

Interrogators in some regulatory regions are required to hop frequency at periodic intervals, ending the inventory round and any access operations. Unfortunately, some cryptographic operations take longer than a hop interval to complete. This protocol allows a cryptographic suite to specify that a Tag retain one or more cryptographic state variables during a temporary power loss such as a frequency hop, and allows an Interrogator to re-acquire the Tag in a subsequent inventory round and resume the cryptographic operation.

This protocol recommends that Interrogators avoid powering-off while a Tag is in the **reply**, **acknowledged**, **open** or **secured** states. Rather, Interrogators should end (or in the case of a long cryptographic operation, suspend) their dialog with a Tag before powering off, leaving the Tag in either the **ready** or **arbitrate** state.

This protocol partitions the access commands into the subclasses Core, Security, and File Management (see also Table 6.27). The purpose of this subclass partitioning is solely for ease of discussion and the particular subclass does not convey or deny requirements to or from any access command.

6.3.2.11.1 Core access commands

The core access commands are *Req_RN*, *Read*, *Write*, *Lock*, *Kill*, *Access*, *BlockWrite*, *BlockErase*, *BlockPermalock*, and *Untraceable*. *Req_RN*, *Read*, *Write*, *Lock*, and *Kill* are mandatory. *Access*, *BlockWrite*, *BlockErase*, *BlockPermalock*, and *Untraceable* are optional. A Tag may implement one or more of the optional commands regardless of whether the Tag supports cryptographic security or file management.

A *Req_RN* command allows an Interrogator to (a) transition a Tag from the **acknowledged** state to the **open** or **secured** states, obtaining the Tag's handle in the process, or (b) ask a Tag in the **open** or **secured** states to backscatter a 16-bit random number.

A *Read* command allows an Interrogator to read Tag memory. An Interrogator may read a Tag's kill and/or access passwords depending on Tag state and the password's lock status. An Interrogator with an asserted Untraceable privilege may read EPC and TID memory, and User-memory files for which it has read privileges. An Interrogator with a deasserted Untraceable privilege may read the portions of EPC and TID memory that are not untraceably hidden and may read User-memory files for which it has read privileges if User memory is not untraceably hidden.

Table 6.21: Conditions for Killing a Tag

Tag supports authenticated kill?	Kill Pwd	Kill-Pwd Locked?	Tag Killable?	How?
No	Zero	Permalocked	No	—
		Locked, unlocked, permaunlocked	Yes	Write nonzero kill pwd then use <i>Kill</i> command. If kill pwd is locked and access pwd is nonzero then requires access before writing new kill pwd
	Nonzero	All	Yes	Use <i>Kill</i> command with kill pwd.
Yes (and at least one key has <u>AuthKill</u> =1)	Zero	Permalocked	Yes	Authenticate Interrogator then perform authenticated kill.
		Locked, unlocked, permaunlocked	Yes	Authenticate Interrogator then perform authenticated kill, or write nonzero kill pwd then use <i>Kill</i> command. If kill pwd is locked and access pwd is nonzero then requires access before writing new kill pwd
	Nonzero	All	Yes	Authenticate Interrogator then perform authenticated kill or use <i>Kill</i> command with kill pwd.

The *Write*, *BlockWrite*, and *BlockErase* commands allow an Interrogator to write or erase portions of Tag memory. Whether, in what states, and with what privileges an Interrogator may write/erase Tag memory is described in Table 6.24, Table 6.25, and Table 6.27.

The *Lock* and *BlockPermalock* commands allow an Interrogator to configure portions of Tag memory to be changeably or permanently writeable or unwriteable. The EPC memory bank, TID memory bank, File_0, and the access and kill passwords may be unlocked, permanently unlocked, locked, or permanently locked for writing. Blocks within File_0 and File_N (N>0) may also be unlocked or permanently locked for writing. An *Untraceable* is the only command that can write to permanently locked memory, but its writing ability is limited to the **L** and **U** bits in EPC memory (see 6.3.2.12.3.16).

An *Access* command allows an Interrogator to transition a Tag from the **open** to the **secured** state. The transition is a multi-step procedure described in 6.3.2.12.3.6 and outlined in Figure 6.26, in which an Interrogator sends two successive *Access* commands to a Tag. The first *Access* command contains the first half of the access password; the second *Access* command contains the second half. If a Tag receives a properly formatted *Access*-command sequence with the correct access password then it transitions to the **secured** state.

The *Untraceable* command allows an Interrogator with an asserted Untraceable privilege (Table 6.22 and Table 6.23) to instruct a Tag to (a) overwrite the **L** bits in its StoredPC and **U** bit in XPC_W1, (b) hide part of its memory from Interrogators with a deasserted Untraceable privilege and/or (c) reduce its operating range. An Interrogator may use the **U** bit of XPC_W1, if supported, to indicate whether a Tag is hiding memory and/or is reducing its operating range (collectively, untraceable). An untraceable Tag behaves identically, from a command-response and state-machine perspective, to a traceable Tag, but behaves as though portions of its memory do not exist and/or as though it has reduced sensitivity. An untraceable Tag does not erase hidden memory; an Interrogator with an asserted Untraceable privilege may subsequently reexpose untraceably hidden memory to all Interrogators and/or reenables full operating range. An Interrogator may also subsequently overwrite the **L** and **U** bits.

A *Kill* command allows an Interrogator to kill a Tag. If a Tag's kill password is nonzero then an Interrogator may kill the Tag using the multi-step password-based *Kill*-command sequence shown in Figure 6.24. If a Tag supports authenticated killing then an Interrogator that authenticated itself using a key with an AuthKill privilege (see Table 6.23) may kill the Tag regardless of its kill-password value (zero or nonzero) using the abbreviated, authenticated kill process shown in Figure 6.24. A Tag that does not implement a kill password, or whose kill password is zero, is not killable except by the authenticated kill process. A successful *Kill* moves a Tag from the **open** or **secured** state to the **killed** state. A Tag, once killed, shall not respond to an Interrogator thereafter.

To minimize the risk of illicit Tag killing, this protocol recommends that killable Tags use either (1) unique kill passwords or (2) permalocked zero-valued kill passwords and authenticated kill. This protocol also recommends against a zero-valued access password.

The **K** flag of XPC_W1 indicates whether a Tag is killable. As shown in Table 6.21, the only situation in which a Tag is not killable by over-the-air commands is if the Tag has a permalocked, zero-valued kill password and either does not support authenticated kill or does not grant the AuthKill privilege to any key.

The *Write*, *Kill*, and *Access* commands send 16-bit words (either data or half-passwords) from Interrogator to Tag using one-time-pad-based link cover coding to obscure the word being transmitted, as follows:

Step 1: The Interrogator issues a *Req_RN*, to which the Tag responds by backscattering a new RN16. The Interrogator then generates a 16-bit string comprising a bit-wise EXOR of the 16-bit word to be transmitted with this new RN16, both MSB first, and issues the command with this string as a parameter.

Step 2: The Tag recovers the 16-bit word by performing a bit-wise EXOR of the received 16-bit string with the original RN16.

If an Interrogator issues a command containing cover-coded data or half-password and fails to receive a response from the Tag then the Interrogator may subsequently reissue the command unchanged. If the Interrogator issues a subsequent command containing new data or a new half-password then it shall first issue a *Req_RN* to obtain a new RN16 and shall use this new RN16 for the cover-coding.

The *BlockWrite* command (see 6.3.2.12.3.7) communicates multiple 16-bit words from Interrogator to Tag. Unlike a *Write*, *BlockWrite* does not use link cover coding.

Although the *Access* command uses a password, an *Access*-command sequence is not cryptographically secure. Neither Tag nor Interrogator shall consider themselves authenticated following an *Access*-command sequence. A Tag or an Interrogator shall only consider themselves authenticated after executing a cryptographic authentication in accordance with a cryptographic suite.

6.3.2.11.2 Security access commands

The security access commands are *Authenticate*, *SecureComm*, *AuthComm*, *KeyUpdate*, and *TagPrivilege*. All are optional. A Tag may implement one or more of these commands regardless of whether the Tag supports optional core commands and/or file management. Some of these commands require prior authentication.

An *Authenticate* command may implement Tag, Interrogator, and/or mutual authentication, depending on the Tag's implementation of the cryptographic suite specified by CSI in the command. Authentication may include deriving session keys and exchanging parameters for subsequent communications. Depending on the cryptographic suite, the message field in the *Authenticate* command may include a KeyID, the type of authentication, and for some multi-step authentications the step number in the authentication sequence.

An *AuthComm* command allows authenticated R=>T communications. Table 6.28 shows which commands an Interrogator may, and an authenticated Interrogator shall, encapsulate in an *AuthComm*. An *AuthComm* protects communications according to the cryptographic suite specified by CSI in the *Challenge* or *Authenticate* that preceded the *AuthComm*.

A *SecureComm* command allows secure R=>T communications. Table 6.28 shows which commands an Interrogator may, and an authenticated Interrogator shall, encapsulate in a *SecureComm*. A *SecureComm* protects communications according to the cryptographic suite specified by CSI in the *Challenge* or *Authenticate* that preceded the *SecureComm*.

A *SecureComm* is configured to allow more robust security than an *AuthComm*; an *AuthComm* is configured to be faster with simplified Tag processing. This protocol recommends that Interrogators not intermix *SecureComm* and *AuthComm* commands when engaging in an authenticated dialog with a Tag.

A *KeyUpdate* command allows an authenticated Interrogator to write or change a key. If a Tag does not write the new key successfully then it defaults to the prior stored key. An Interrogator may use a *KeyUpdate* to change the key that it used during authentication; if the Interrogator has an asserted CryptoSuperuser privilege (see Table 6.23) then it may also change value(s) for other key(s) in the cryptographic suite. A cryptographic suite may place additional restrictions, beyond those specified in this protocol, on when and whether a key may be updated.

A *TagPrivilege* command allows an Interrogator to read or modify the privileges in Table 6.22 or Table 6.23 for the access password or for a key, respectively. Whether a Tag executes a *TagPrivilege* depends on the privilege level of the access password or the key that the Interrogator supplied during the access or authentication.

A Tag may support zero, one, or more than one cryptographic suite(s). A cryptographic suite defines how a Tag and an Interrogator implement a cryptographic algorithm and its functions. The Tag manufacturer shall choose the number and type of cryptographic suites that a Tag supports; this assignment shall not be alterable in the field. An Interrogator selects one from among the implemented cryptographic suites using the CSI field in the *Challenge* and *Authenticate* commands.

A Tag may support up to 256 keys, numbered Key_0 to Key_255. The Tag manufacturer shall choose the number of available keys and assign them to the cryptographic suite(s); this assignment shall not be alterable in the field. No two keys shall have the same number, even if used for different cryptographic suites. A Tag shall not indicate where in memory it stores its keys, nor shall it allow an Interrogator to read this memory location.

Although the functions and security of cryptographic suites may vary, this protocol anticipates that some suites may perform only Tag authentication, whereas others may perform Interrogator and/or mutual authentication.

A Tag that supports the *Untraceable* command shall provide the Tag privileges shown in Table 6.22. A Tag that supports one or more cryptographic suites shall provide the Tag privileges shown in Table 6.23.

The privileges field in a *TagPrivilege* command is 16 bits in length, with a bit for each corresponding Tag privilege. Privileges 12–15 in Table 6.22 and Table 6.23 are assigned by this protocol. Privileges 8–11 are RFU for the access password (Table 6.22); they are assigned by the cryptographic suite for all keys (Table 6.23). Privileges 4–7 are RFU for all keys. Privileges 0–3 are defined by the Tag manufacturer and not specified by this protocol.

The labels in Table 6.22 and Table 6.23 are defined as follows:

- **Privilege Name:** The name of the Tag privilege
- **Bit Assignment:** The bit location in the privileges field for the named privilege, MSB first (i.e. bit 15 is the leading bit in the privileges field in a *TagPrivilege* command and in a Tag's reply).
- **Privilege:** Whether a Tag grants or denies the privilege. A 1₂ means an asserted or granted privilege; a 0₂ means a deasserted or denied privilege.
- **CryptoSuperuser:** Whether a Tag grants the crypto superuser privilege to a key. If **CryptoSuperuser**=1 then a Tag grants the crypto superuser privilege to the key; if **CryptoSuperuser**=0 then a Tag denies the privilege. See below for a description of the crypto superuser privilege.
- **AuthKill:** Whether a Tag grants the authenticated-kill privilege to a key. If **AuthKill**=1 then a Tag grants the authenticated-kill privilege to the key; if **AuthKill**=0 then a Tag denies the privilege.
- **Untraceable:** Whether a Tag executes an *Untraceable* command from, and exposes untraceably hidden memory to, an Interrogator that supplies the access password or key. If **Untraceable**=1 then a Tag grants the privilege; if **Untraceable**=0 then a Tag denies the privilege.
- **DecFilePriv:** Whether a Tag allows an Interrogator that supplies the access password or key the privilege of decrementing file privileges using a *FilePrivilege* command. If **DecFilePriv**=1 in Table 6.22 then a Tag permits an Interrogator that supplies the access password to decrement file privileges for the **open** state and for the access password. If **DecFilePriv**=1 in Table 6.23 then a Tag permits an Interrogator that supplies the key to decrement file privileges for the **open** state and for that key. If **DecFilePriv**=0 then the Tag denies the associated privilege.
- **KeyProperty_N:** One of four key properties (N = 1, 2, 3, 4) defined by the cryptographic suite with which the key is associated.
- **Custom:** One of four key properties (N = 1, 2, 3, 4) defined by the Tag manufacturer.

A Tag that implements the *TagPrivilege* command shall permit an Interrogator that authenticated itself as a crypto superuser in a cryptographic suite to:

- change the value of any key in that cryptographic suite, including its own, using a *KeyUpdate*.
- read or modify privileges (value in Table 6.23) for any key in that cryptographic suite, including its own.

A Tag shall not permit an Interrogator that did not authenticate itself as a crypto superuser to:

- change the value of any key other than the one it used to authenticate itself.
- read or modify privileges (value in Table 6.23) for any key other than the one it used to authenticate itself
- assert a deasserted privilege (value in Table 6.23) for the key it used to authenticate itself.

A Tag that supports the *TagPrivilege* command shall permit an Interrogator that supplies the access password (even if zero-valued) or a key to deassert a privilege for the access password or that key, respectively, regardless of the CryptoSuperuser value.

Because only a crypto superuser can assert a deasserted privilege but there is no crypto superuser for the access password, an access-password privilege, once deasserted, cannot be reasserted.

A Tag manufacturer may configure one or more Tag privileges as permanent and unchangeable, in which case these Tag privileges will not be changeable even by a crypto superuser. A Tag that receives a *TagPrivilege* that attempts to change an unchangeable Tag privilege value shall not execute the *TagPrivilege* and instead treat the command's parameters as unsupported (see Table C.30).

If a Tag supports the *TagPrivilege* command then this protocol recommends that the Tag manufacturer provide at least one nonzero-valued key with crypto superuser privileges for each cryptographic suite supported by the Tag.

Table 6.22: Tag privileges associated with the access password

Privilege Name	Bit Assignment	Privilege
CryptoSuperuser	15	0 (unchangeable)
AuthKill	14	0 (unchangeable)
Untraceable	13	0/1
DecFilePriv	12	0/1
RFU	11	0
RFU	10	0
RFU	9	0
RFU	8	0
RFU	7	0
RFU	6	0
RFU	5	0
RFU	4	0
Custom_1	3	Defined by Tag manufacturer
Custom_2	2	Defined by Tag manufacturer
Custom_3	1	Defined by Tag manufacturer
Custom_4	0	Defined by Tag manufacturer

Table 6.23: Tag privileges associated with a cryptographic suite

Privilege Name	Bit Assignment	Privilege for Key_0 ¹	...	Privilege for Key_N ¹
CryptoSuperuser	15	0/1		0/1
AuthKill	14	0/1		0/1
Untraceable	13	0/1		0/1
DecFilePriv	12	0/1		0/1
KeyProperty_1	11	Defined by crypto suite		Defined by crypto suite
KeyProperty_2	10	Defined by crypto suite		Defined by crypto suite
KeyProperty_3	9	Defined by crypto suite		Defined by crypto suite
KeyProperty_4	8	Defined by crypto suite		Defined by crypto suite
RFU	7	0		0
RFU	6	0		0
RFU	5	0		0
RFU	4	0		0
Custom_1	3	Defined by Tag manufacturer		Defined by Tag manufacturer
Custom_2	2	Defined by Tag manufacturer		Defined by Tag manufacturer
Custom_3	1	Defined by Tag manufacturer		Defined by Tag manufacturer
Custom_4	0	Defined by Tag manufacturer		Defined by Tag manufacturer

Note 1: Each key is assigned to one and only one cryptographic suite.

A cryptographic suite defines whether and when:

- a Tag considers an Interrogator to be authenticated.
- an Interrogator considers a Tag to be authenticated.

The cryptographic suite also defines:

- cryptographic conditions that cause a Tag to treat a command's parameters as unsupported.
- cryptographic errors that cause a Tag to transition from the **open** or **secured** state to the **arbitrate** state.

After a successful Interrogator authentication a Tag in the **open** state shall transition to the **secured** state. If the Tag was already in the **secured** state then it remains in the **secured** state. The authenticated Interrogator shall subsequently encapsulate all commands designated “Mandatory Encapsulation” in Table 6.28 in an *AuthComm* or *SecureComm*. If a Tag receives such a command from an authenticated Interrogator without encapsulation then it shall not execute the command and instead treat the command’s parameters as unsupported (see Table C.30).

A Tag shall transition back to the **open** state, reset its cryptographic engine, and revert to **open**-state file privileges (see below) when an authenticated Interrogator loses its authentication. There are many reasons why an Interrogator may lose its authentication, including but not limited to the Tag receiving a security access command with an incorrect handle, the Tag receiving an invalid command, or the Interrogator starting a new authentication. As a consequence of an Interrogator losing its authentication a Tag with a zero-valued access password may be in the **open** state, in which case the Interrogator may issue an *Access*-command sequence with the zero-valued access password to move the Tag back to the **secured** state (but the Interrogator will still not be authenticated — only a successful *Authenticate* command or *Authenticate*-command sequence authenticates an Interrogator).

An unauthenticated Interrogator may issue an *AuthComm* or a *SecureComm* to an authenticated Tag in the **open** or **secured** state. If the Tag was not previously authenticated by a *Challenge* or *Authenticate* command then it shall not execute the command and instead treat the command’s parameters as unsupported (see Table C.30).

If a condition of a cryptographic suite causes a Tag to transition from the **open** or **secured** state to the **arbitrate** state then the Tag (i) shall not change the value of its inventoried flag, and (ii) shall reset its cryptographic engine.

6.3.2.11.3 File-management access commands

The file-management access commands are *FileOpen*, *FileList*, *FileSetup*, and *FilePrivilege*. All are optional. A Tag that supports *File_N*, $N > 0$ shall implement *FileOpen*; it may implement *FileList*, *FileSetup*, and *FilePrivilege* as well. A Tag may implement one or more of these commands regardless of whether the Tag supports optional core commands and/or cryptographic security.

A Tag may implement zero, one, or more than one file in User memory. If a Tag implements a single file then that file shall be *File_0*. A Tag with User memory shall open *File_0* upon first entering the **open** or **secured** state. If a Tag implements multiple files then it may subsequently close *File_0* and open another file. A Tag shall have only a single file open at any time. All access commands operate on the currently open file.

Each file shall have an 8-bit FileType and a 10-bit FileNum, unless a Tag does not support any file-management access commands, in which case a Tag that implements *File_0* may omit FileType and FileNum.

- A Tag manufacturer shall preassign a FileType to each file supported by the Tag. If a Tag does not support the *FileSetup* command then FileType is not changeable in the field and all files have FileType=00_h. If a Tag supports the *FileSetup* command then FileType is changeable in the field and FileType=00_h indicates that a file’s type is currently unassigned.
- A Tag manufacturer shall preassign a unique FileNum to each file supported by the Tag. FileNum is not changeable in the field. A Tag may support up to 1023 files, numbered 0 to 1022 (0000000000₂ – 111111110₂). The files may have different size (including zero size). FileNum=0000000000₂ shall be reserved for the base file (*File_0*) of User memory. FileNum=111111111₂ shall be RFU. This protocol recommends, but does not require, that Tag manufacturers number files sequentially.

A *FileOpen* command allows an Interrogator to open a file. Upon receiving a *FileOpen* a Tag shall first close the currently open file and then open the new file, with the new file’s starting address mapped to 00_h of User memory. An Interrogator may be able to subsequently read, write, erase, blockpermalock, resize, or modify privileges for the newly opened file depending on the Tag state and if/how the Interrogator authenticated itself.

A *FileList* command allows an Interrogator to determine the existence of, size of, attributes of, and its privileges to, one or more files.

A *FileSetup* command allows an Interrogator to change the FileType for, and/or resize, the currently open file. Only a *dynamic* Tag (see below) is capable of resizing a file.

A *FilePrivilege* command allows an Interrogator to read or alter the privileges (see below) granted by the currently open file to the **open** state, access password, or a key.

A Tag manufacturer shall precreate all files; the number of files shall not be changeable in the field. This protocol defines two types of Tags, *static* and *dynamic*, according to their memory-allocation features as follows:

Static: A manufacturer of a *static* Tag shall preallocate all User memory to files. A *static* Tag may permit changing a file’s FileType but shall not permit file resizing.

Dynamic: A manufacturer of a *dynamic* Tag may preallocate no, some, or all User memory to files. A *dynamic* Tag may permit file resizing by an Interrogator that has a file superuser privilege.

A Tag manufacturer shall decide where a Tag stores its FileType and FileNum data and may choose a readable portion of memory (if desired). Regardless of the location, a Tag shall not allow an Interrogator to modify a file's type by any command except *FileSetup*, and shall not allow an Interrogator to modify a FileNum by any means.

Files may range in size from a minimum of zero to a maximum of 1022 blocks. Commands that include a FileSize parameter use 10 bits to specify sizes from zero to 1022 blocks (0000000000₂ – 1111111110₂, respectively). FileSize 111111111₂ shall be RFU.

Block size may be one to 1024 words. A Tag manufacturer shall predefine a single fixed, unchangeable block size that the Tag shall use for all file allocation as well as for the *BlockPermalock* command. Tag manufacturers shall not use block sizes exceeding 1024 words. Tag replies that return a BlockSize value use 10 bits to specify the size from one (0000000000₂) to 1024 (111111111₂) words. BlockSize does not have an RFU value.

This protocol allows file sizes from 0 to 16,744,448 bits (max FileSize=1022 blocks, max BlockSize=1024 words, word=16 bits).

If a Tag supports File_0 then it shall provide the file privileges shown in Table 6.24. If a Tag supports File_N, N>0 then it shall also provide the file privileges shown in Table 6.25. Each file has a 4-bit privilege for the **open** state, for the access password in the **secured** state, and for each key in the **secured** state, as follows:

Open state: Each file has a 4-bit **open**-state privilege. A Tag with M files shall implement M 4-bit **open**-state file privileges, one for each file.

Access password (secured state): Each file has a single 4-bit privilege for the access password (even if the access password is zero-valued). A Tag with M files shall implement M 4-bit **secured**-state access-password file privileges, one for each file.

Key (secured state): Each file has a 4-bit privilege for each key implemented by the Tag. A Tag with M files and N keys shall implement M×N 4-bit **secured**-state key file privileges.

Given the above, a Tag with N keys and M files supports (2+N)×M independent 4-bit privileges. For example, suppose a Tag implements N=2 keys and File_0, File_1, and File_2. Then the Tag has 4×3=12 4-bit privileges.

A *FilePrivilege* may assign privileges 0000₂–0011₂ and 1100₂–1111₂ in Table 6.24 and Table 6.25. If a Tag does not implement any manufacturer-defined privileges then the Tag may store only the 2 LSBs of the 4-bit privilege, but all communications still use 4-bit values. In this latter case, if an Interrogator sends a 4-bit privilege with either MSB being nonzero then the Tag shall not execute the *FilePrivilege* and instead treat the command's parameters as unsupported (see Table C.30).

The access password or a key with a 0011₂ **secured**-state file privilege in Table 6.24 or Table 6.25 is defined to be a superuser for that file.

A Tag shall permit an Interrogator that accessed or authenticated itself as a file superuser to:

- read or assign a new 4-bit privilege for the **open** state, access password, or any key (including its own) regardless of the cryptographic suite to which the key is assigned, for the currently open file, using a *FilePrivilege* command.
- change the FileType of the currently open file using a *FileSetup* command, for a *static* or a *dynamic* Tag.
- resize the currently open file using a *FileSetup* command, but only if the file contains no permalocked or permaunlocked memory and only if the Tag is *dynamic*.

A Tag shall not permit an Interrogator that did not access or authenticate itself as a file superuser to:

- read or assign the 4-bit privilege for the **open** state, for the currently open file.
- read or assign the 4-bit privilege for the access password or for any key other than the one it used to enter the **secured** state, for the currently open file.
- increase the privileges (move down one or more rows in Table 6.24 or Table 6.25) for the access password or for any key, for the currently open file.

If the access password or key that a Tag used to enter the **secured** state has DecFilePriv=1 (see Table 6.22 and Table 6.23) then a Tag shall permit an Interrogator to self-reduce its privileges (move up one or more rows in Table 6.24 or Table 6.25) to the currently open file for this access password or key. To be clear, if DecFilePriv=1 then an Interrogator may, via a *FilePrivilege* command, instruct a Tag to decrement a 0011₂ privilege to 0010₂, 0001₂, or 0000₂; a 0010₂ privilege to 0001₂ or 0000₂; or a 0001₂ privilege to 0000₂ for the currently open file for the access password or key that the Tag used to enter the **secured** state.

Table 6.24: File_0 privileges

Privilege value	Open State (Privilege by File)					Privilege value	Secured State (Privilege by Access Password or Key)				
	Read	Write BlockWrite BlockErase	Lock Block-Permalock	File-Privilege	File-Setup		Read	Write BlockWrite BlockErase	Lock Block-Permalock	File-Privilege	File-Setup
0000	✓	x	D	D	D	0000	✓	x	x	x	x
0001	✓	x	D	D	D	0001	✓	L	x	P	x
0010	✓	L	D	D	D	0010	✓	L	✓	P	x
0011	✓	L	D	D	D	0011 ¹	✓	L	✓	✓	✓
0100	RFU					0100	RFU				
0101	RFU					0101	RFU				
0110	RFU					0110	RFU				
0111	RFU					0111	RFU				
1000	RFU					1000	RFU				
1001	RFU					1001	RFU				
1010	RFU					1010	RFU				
1011	RFU					1011	RFU				
1100	Manufacturer defined					1100	Manufacturer defined				
1101	Manufacturer defined					1101	Manufacturer defined				
1110	Manufacturer defined					1110	Manufacturer defined				
1111	Manufacturer defined					1111	Manufacturer defined				

Key: ✓=allowed by privilege; x=disallowed by privilege; L=allowance determined by lock and blockpermalock status of the specified memory banks/blocks; P=allowance determined by DecFilePriv for the password or key; D=command not permitted in the state.

Note 1: This 0011 **secured**-state privilege is a superuser for File_0.

Table 6.25: File_N (N>0) privileges

Privilege value	Open State (Privilege by File)					Privilege value	Secured State (Privilege by Access Password or Key)				
	Read	Write BlockWrite BlockErase	Block-Permalock	File-Privilege	File-Setup		Read	Write BlockWrite BlockErase	Block-Permalock	File-Privilege	File-Setup
0000	x	x	D	D	D	0000	x	x	x	x	x
0001	✓	x	D	D	D	0001	✓	x	x	P	x
0010	✓	L	D	D	D	0010	✓	L	x	P	x
0011	✓	L	D	D	D	0011 ¹	✓	L	✓	✓	✓
0100	RFU					0100	RFU				
0101	RFU					0101	RFU				
0110	RFU					0110	RFU				
0111	RFU					0111	RFU				
1000	RFU					1000	RFU				
1001	RFU					1001	RFU				
1010	RFU					1010	RFU				
1011	RFU					1011	RFU				
1100	Manufacturer defined					1100	Manufacturer defined				
1101	Manufacturer defined					1101	Manufacturer defined				
1110	Manufacturer defined					1110	Manufacturer defined				
1111	Manufacturer defined					1111	Manufacturer defined				

Key: ✓=allowed by privilege; x=disallowed by privilege; L=allowance determined by the blockpermalock status of the specified memory blocks; P=allowance determined by DecFilePriv for the password or key; D=command not permitted in the state.

Note 1: This 0011 **secured**-state privilege is a superuser for File_N, N>0.

Table 6.26: Allowed file resizing

File number	File is permalocked or permaunlocked	One or more file blocks are permalocked or permaunlocked	Increasing file size allowed?	Decreasing file size allowed?
N = 0	No	No	Yes	Yes
	No	Yes	Yes	No
	Yes	No	No	No
	Yes	Yes	No	No
N > 0	N/A	No	Yes	Yes
		Yes	Yes	No

Table 6.27: Access commands and Tag states in which they are permitted

Command	State			Subclass	Remark
	Acknowledged	Open	Secured		
<i>Req_RN</i>	allowed	allowed	allowed	Core	mandatory command
<i>Read</i>	disallowed	allowed	allowed	Core	mandatory command
<i>Write</i>	disallowed	allowed	allowed	Core	mandatory command; requires prior <i>Req_RN</i>
<i>Kill</i> (password-based)	disallowed	allowed	allowed	Core	mandatory command; requires prior <i>Req_RN</i>
<i>Kill</i> (authenticated)	disallowed	disallowed	allowed	Core	optional usage of mandatory <i>Kill</i> command
<i>Lock</i>	disallowed	disallowed	allowed	Core	mandatory command
<i>Access</i>	disallowed	allowed	allowed	Core	optional command; requires prior <i>Req_RN</i>
<i>BlockWrite</i>	disallowed	allowed	allowed	Core	optional command
<i>BlockErase</i>	disallowed	allowed	allowed	Core	optional command
<i>BlockPermalock</i>	disallowed	disallowed	allowed	Core	optional command
<i>ReadBuffer</i>	disallowed	allowed	allowed	Core	optional command
<i>Untraceable</i>	disallowed	disallowed	allowed	Core	optional command
<i>Authenticate</i>	disallowed	allowed	allowed	Security	optional command
<i>AuthComm</i>	disallowed	allowed	allowed	Security	optional command; requires prior authentication
<i>SecureComm</i>	disallowed	allowed	allowed	Security	optional command; requires prior authentication
<i>KeyUpdate</i>	disallowed	disallowed	allowed	Security	optional command; requires prior authentication
<i>TagPrivilege</i>	disallowed	disallowed	allowed	Security	optional command
<i>FileOpen</i>	disallowed	allowed	allowed	File	optional command
<i>FileList</i>	disallowed	allowed	allowed	File	optional command
<i>FilePrivilege</i>	disallowed	disallowed	allowed	File	optional command
<i>FileSetup</i>	disallowed	disallowed	allowed	File	optional command

A Tag manufacturer may assign file privileges to the **open** state and to the access password or keys as required by the Tag's intended use case. A Tag manufacturer may assign file superuser privileges to the access password or to any key. Although this protocol recommends against a Tag manufacturer assigning file superuser privileges to a zero-valued access password or key, it does not prohibit a Tag manufacturer from doing so.

As described above, a Tag opens File_0 upon first entering the **open** or **secured** state. If an Interrogator attempts to subsequently open another file for which its privilege level is 0000₂ then the Tag opens the file but does not grant the Interrogator any file privileges.

Some privilege fields in Table 6.24 and Table 6.25 show "x" (disallowed by privilege). If *Read* is "x" for a privilege value then a Tag shall behave as if the memory location does not exist. Otherwise, if *Write*, *BlockWrite*, or *BlockErase* are "x" then the Tag shall behave as if the memory location is permalocked; and if *Lock* or *BlockPermalock* are "x" then the Tag shall behave as if the memory location is neither lockable nor unlockable. If *FilePrivilege* or *FileSetup* are "x" then the Tag shall behave as if the Interrogator has insufficient privileges. If a Tag implements the *BlockPermalock* command then all files shall support the *BlockPermalock* command.

If a Tag's User memory is untraceably hidden then the Tag shall only execute a *FileOpen*, *FileList*, *FileSetup*, or *FilePrivilege* issued by an Interrogator with an asserted Untraceable privilege (see Table 6.22 and Table 6.23); if the Interrogator has a deasserted Untraceable privilege then the Tag shall treat these commands' parameters as unsupported (see Table C.30).

A Tag shall not permit a permalocked portion of memory to be erased or overwritten, except for the **L** and **U** bits in EPC memory, which an Interrogator with an asserted Untraceable privilege may overwrite.

In some instances a *dynamic* Tag may allow file resizing. Whether a Tag allows resizing shall depend on whether the Tag accepts a *FileSetup* command (varies by privilege and state), whether the Tag has free memory available for the resizing, and whether the file or any blocks in it are permalocked or permaunlocked. See Table 6.26.

6.3.2.12 Interrogator commands and Tag replies

Interrogator-to-Tag commands shall use the command codes, protection, and parameters shown in Table 6.28.

- *QueryRep* and *ACK* have 2-bit command codes beginning with 0₂.
- *Query*, *QueryAdjust*, and *Select* have 4-bit command codes beginning with 10₂.
- Other commands that are sensitive to link throughput use 8-bit command codes beginning with 110₂.
- Other commands that are insensitive to link throughput use 16-bit command codes beginning with 1110₂.
- *QueryRep*, *ACK*, *Query*, *QueryAdjust*, and *NAK* have the unique command lengths shown in Table 6.28. No other commands shall have these lengths. If a Tag receives one of these commands with an incorrect length then it shall treat the command as invalid (see Table C.30).
- *Query* is protected by a CRC-5, shown in Table 6.12 and detailed in [Annex F](#).
- *Select*, *Req_RN*, *Read*, *Write*, *Kill*, *Lock*, *Access*, *BlockWrite*, *BlockErase*, *BlockPermalock*, *Authenticate*, *SecureComm*, *AuthComm*, *KeyUpdate*, *ReadBuffer*, *Challenge*, *Untraceable*, *FileOpen*, *FileList*, *FilePrivilege*, *FileSetup*, and *TagPrivilege* are protected by a CRC-16, defined in 6.3.1.5 and detailed in [Annex F](#).
- R=>T commands begin with either a preamble or a frame-sync, as described in 6.3.1.2.8. The command-code lengths specified in Table 6.28 do not include the preamble or frame-sync.
- A Tag's behavior upon receiving a faulty command depends on the fault type and the Tag state. [Annex B](#) and [Annex C](#) define the fault types by state. In general, the faults are (1) unsupported parameters, (2) incorrect handle, (3) improper, and (4) invalid. Note that, for some cryptographic suites, a Tag may reset its cryptographic engine and change state upon receiving a faulty command.

Table 6.28: Interrogator Commands

Command	Code	Length (bits)	Mandatory Command (Y/N)?	Reply Type	Encapsulation			Protection
					SecureComm ² (Y/N)?	AuthComm ² (Y/N)?	Mandatory ³ (Y/N)?	
<i>QueryRep</i>	00	4	Yes	Immediate	No	No	No	Unique length
<i>ACK</i>	01	18	Yes	Immediate	Yes	Yes	No	Unique length
<i>Query</i>	1000	22	Yes	Immediate	No	No	No	Unique length and a CRC-5
<i>QueryAdjust</i>	1001	9	Yes	Immediate	No	No	No	Unique length
<i>Select</i>	1010	> 44	Yes	None	No	No	No	CRC-16
<i>Reserved for future use</i>	1011	–	–	–	–	–	–	–
<i>NAK</i>	11000000	8	Yes	Immediate	No	No	No	Unique length
<i>Req_RN</i>	11000001	40	Yes	Immediate	Yes	Yes	No	CRC-16
<i>Read</i>	11000010	> 57	Yes	Immediate	Yes	Yes	Yes	CRC-16
<i>Write</i>	11000011	> 58	Yes	Delayed	No	No	No	CRC-16
<i>Kill</i>	11000100	59	Yes	Delayed	Yes ¹	Yes ¹	Yes ¹	CRC-16
<i>Lock</i>	11000101	60	Yes	Delayed	Yes	Yes	Yes	CRC-16
<i>Access</i>	11000110	56	No	Immediate	No	No	No	CRC-16
<i>BlockWrite</i>	11000111	> 57	No	Delayed	Yes	Yes	Yes	CRC-16
<i>BlockErase</i>	11001000	> 57	No	Delayed	Yes	Yes	Yes	CRC-16
<i>BlockPermalock</i>	11001001	> 66	No	Immediate & Delayed	Yes	Yes	Yes	CRC-16
<i>Used by ISO 18000-63</i>	11001010 ... 11010001	–	–	–	–	–	–	–
<i>ReadBuffer</i>	11010010	67	No	Immediate	No	Yes	No	CRC-16
<i>FileOpen</i>	11010011	52	No ⁴	Immediate	Yes	Yes	Yes	CRC-16
<i>Challenge</i>	11010100	> 48	No	None	No	No	No	CRC-16
<i>Authenticate</i>	11010101	> 64	No	In-process	No	No	No	CRC-16
<i>SecureComm</i>	11010110	> 56	No	In-process	No	No	No	CRC-16
<i>AuthComm</i>	11010111	> 42	No	In-process	No	No	No	CRC-16
<i>Reserved for future use</i>	11011000	–	–	–	–	–	–	–
<i>Used by ISO 18000-63</i>	11011001	–	–	–	–	–	–	–
<i>Reserved for future use</i>	11011010 ... 11011111	–	–	–	–	–	–	–
<i>Reserved for custom commands</i>	11100000 00000000 ... 11100000 11111111	–	–	–	–	–	–	Manufacturer defined
<i>Reserved for proprietary commands</i>	11100001 00000000 ... 11100001 11111111	–	–	–	–	–	–	Manufacturer defined
<i>Untraceable</i>	11100010 00000000	62	No	Delayed	Yes	Yes	Yes	CRC-16
<i>FileList</i>	11100010 00000001	71	No	In-process	Yes	Yes	Yes	CRC-16
<i>KeyUpdate</i>	11100010 00000010	> 72	No	In-process	Yes	Yes	No	CRC-16
<i>TagPrivilege</i>	11100010 00000011	78	No	In-process	Yes	Yes	Yes	CRC-16
<i>FilePrivilege</i>	11100010 00000100	68	No	In-process	Yes	Yes	Yes	CRC-16
<i>FileSetup</i>	11100010 00000101	71	No	In-process	Yes	Yes	Yes	CRC-16
<i>Reserved for future use</i>	11100010 00000110 ... 11101111 11111111	–	–	–	–	–	–	–

Note 1: An authenticated *Kill* shall be encapsulated in a *SecureComm* or an *AuthComm*; a password-based *Kill* shall not be encapsulated.

Note 2: Commands with a “yes” may be encapsulated in a *SecureComm* or an *AuthComm*, as appropriate.

Note 3: For an authenticated Interrogator and commands with a “yes”, encapsulation in a *SecureComm* or an *AuthComm* is mandatory.

Note 4: If a Tag supports File_N, N>0 then *FileOpen* is mandatory.

6.3.2.12.1 Select commands

The select command set comprises *Select* and *Challenge*.

6.3.2.12.1.1 *Select* (mandatory)

Interrogators and Tags shall implement the *Select* command shown in Table 6.29. A *Select* allows an Interrogator to select a Tag subpopulation based on user-defined criteria, enabling union (\cup), intersection (\cap), and negation (\sim) based Tag partitioning. Interrogators perform \cup and \cap operations by issuing successive *Select* commands. *Select* can assert or deassert a Tag's **SL** flag, which applies across all four sessions, or it can set a Tag's **inventoried** flag to either *A* or *B* in any one of the four sessions. A Tag executes a *Select* from any state except **killed**. *Select* passes the following parameters from Interrogator to Tags:

- Target indicates whether the *Select* modifies a Tag's **SL** flag or its **inventoried** flag, and in the case of **inventoried** it further specifies one of four sessions. A *Select* that modifies the **SL** flag shall not modify an **inventoried** flag, and vice versa. A Tag shall ignore a *Select* whose Target is 101₂, 110₂, or 111₂.
- Action elicits the Tag behavior in Table 6.30, in which matching and not-matching Tags assert or deassert **SL** or set their **inventoried** flag to *A* or *B*. A Tag conforming to the contents of the MemBank, Pointer, Length, and Mask fields is matching. A Tag not conforming to the contents of these fields is not-matching. The criteria for determining whether a Tag is matching or not-matching are specified by the MemBank, Pointer, Length and Mask fields.
- MemBank specifies how a Tag applies Mask. If MemBank=00₂ then the Tag searches for at least one file whose FileType matches Mask. If MemBank=01₂, 10₂, 11₂ then a Tag applies Mask to the EPC memory bank, TID memory bank, or File_0, respectively. A *Select* specifies a single FileType or memory bank. Successive *Selects* may apply to different file types and/or memory banks.
- Pointer specifies a starting bit address for the Mask comparison. Pointer uses EBV formatting (see [Annex A](#)) and bit (not word) addressing. If MemBank=00₂ then an Interrogator shall set Pointer to 00_n; if a Tag receives a *Select* with MemBank=00₂ and a nonzero Pointer value then it shall ignore the *Select*.
- Length specifies the length of Mask. Length is 8 bits, allowing Masks from 0 to 255 bits in length. If MemBank=00₂ then an Interrogator shall set Length=00001000₂; if a Tag receives a *Select* with MemBank=00₂ and Length<>00001000₂ then it shall ignore the *Select*.
- Mask is either a FileType (if MemBank=00₂) or a bit string that a Tag compares to a memory location that begins at Pointer and ends Length bits later (if MemBank<>00₂). An untraceable Tag shall process a *Select* with MemBank=00₂ whose User memory is traceable, or with MemBank<>00₂ whose Mask operates on a completely traceable bit string. A Tag shall treat as not-matching a *Select* command whose Mask includes untraceably hidden memory.
 - MemBank=00₂: If a Tag has a file with the specified FileType then the Tag is matching. If the Tag does not support files or does not have a file with the specified FileType then the Tag is not-matching.
 - MemBank<>00₂: If Mask matches the string specified by Pointer and Length then the Tag is matching. If Pointer and Length reference a memory location that does not exist then the Tag is not-matching. If Length is zero then the Tag is matching, unless Pointer references a memory location that does not exist, or Truncate=1 and Pointer is outside the EPC specified in the length field in the StoredPC, in which case the Tag is not-matching.
- Truncate indicates whether a Tag's backscattered reply shall be truncated to those EPC bits that follow Mask. If an Interrogator asserts Truncate, and if a subsequent *Query* specifies Sel=10 or Sel=11, then a matching Tag shall truncate its *ACK* reply to the portion of the EPC immediately following Mask, followed by a PacketCRC. If an Interrogator asserts Truncate then it shall assert it:
 - in the last *Select* that the Interrogator issues prior to sending a *Query*,
 - only if the *Select* has Target=100₂, and
 - only if Mask ends in the EPC.

These constraints *do not* preclude an Interrogator from issuing multiple *Select* commands that target the **SL** and/or **inventoried** flags. They *do* require that an Interrogator that is requesting Tags to truncate their replies assert Truncate in the last *Select*, and that this last *Select* targets the **SL** flag. A Tag shall decide whether to truncate its backscattered EPC on the basis of the most recently received valid *Select* (i.e. not ignored and matching or not-matching).

If a Tag receives a *Select* with Truncate=1 and

- Target<>100₂ or MemBank<>01₂ then the Tag shall ignore the *Select*.
- MemBank=01₂ but Mask ends outside the EPC specified by the **L** bits in the StoredPC then the Tag shall be not-matching.

A Tag shall preface a truncated reply with five leading zeros (00000₂) inserted between the preamble and the truncated reply. Specifically, when truncating its replies a Tag backscatters 00000₂, then the portion of its EPC following Mask, and then a PacketCRC. See Table 6.17.

A Tag shall power-up with Truncate=0.

Mask may end at the last bit of the EPC, in which case a truncating Tag shall backscatter 00000₂ followed by a PacketCRC.

Truncated replies never include an XPC_W1 or an XPC_W2, because Mask must end in the EPC.

Because a Tag stores its StoredPC and StoredCRC in EPC memory, a *Select* command may select on them. Because a Tag computes its PacketPC and PacketCRC dynamically and does not store them in memory, a *Select* command is unable to select on them.

A *Select* whose Pointer, Length, and Mask include the StoredPC may produce unexpected behavior. Specifically, if a Tag's *ACK* reply uses a PacketPC then the reply may appear to not match Mask even though the Tag's behavior indicates matching, and vice versa. For example, suppose that an Interrogator sends a *Select* to match a 00100₂ length field in the StoredPC. Further assume that the Tag is matching, but has an asserted **XI**. The Tag will increment its length field to 00101₂ when replying to the *ACK*. The Tag was matching, but the backscattered length field in the PacketPC appears to be not-matching.

An Interrogator shall prepend a *Select* command with a frame-sync (see 6.3.1.2.8). The CRC-16 that protects a *Select* is calculated over the first command-code bit to the Truncate bit.

A Tag shall not reply to a *Select*.

Table 6.29: *Select* command

	Command	Target	Action	MemBank	Pointer	Length	Mask	Truncate	CRC
# of bits	4	3	3	2	EBV	8	Variable	1	16
description	1010	000: Inventoried (S0) 001: Inventoried (S1) 010: Inventoried (S2) 011: Inventoried (S3) 100: SL 101: RFU 110: RFU 111: RFU	See Table 6.30	00: FileType 01: EPC 10: TID 11: File_0	Starting Mask address	Mask length (bits)	Mask value	0: Disable truncation 1: Enable truncation	CRC-16

Table 6.30: Tag response to Action parameter

Action	Tag Matching	Tag Not-Matching
000	assert SL or inventoried → A	deassert SL or inventoried → B
001	assert SL or inventoried → A	do nothing
010	do nothing	deassert SL or inventoried → B
011	negate SL or (A → B, B → A)	do nothing
100	deassert SL or inventoried → B	assert SL or inventoried → A
101	deassert SL or inventoried → B	do nothing
110	do nothing	assert SL or inventoried → A
111	do nothing	negate SL or (A → B, B → A)

6.3.2.12.1.2 *Challenge* (optional)

Interrogators and Tags may implement the *Challenge* command; if they do then they shall implement it as shown in Table 6.31. A *Challenge* allows an Interrogator to instruct multiple Tags to simultaneously yet independently precompute and store a cryptographic value or values for use in a subsequent authentication. The generic nature of the *Challenge* command allows it to support a wide variety of cryptographic suites. A Tag executes a *Challenge* from any state except **killed**. *Challenge* has the following fields:

- IncRepLen specifies whether the Tag omits or includes length in its stored reply. If IncRepLen=0 then the Tag omits length from its stored reply; if IncRepLen=1 then the Tag includes length in its stored reply.
- Immed specifies whether a Tag concatenates response to its EPC when replying to an *ACK*. If immed=0 then the Tag does not concatenate response to its EPC when replying to an *ACK*; if immed=1 then the Tag backscatters EPC + response when replying to an *ACK*.
- CSI selects the cryptographic suite that Tag and Interrogator use for the *Challenge*.
- Length is the message length in bits.
- Message includes parameters for the authentication.

Upon receiving a *Challenge* a Tag that supports the command shall return to the **ready** state and deassert its **C** flag. If the Tag supports the CSI and can execute message then it shall perform the requested action(s); otherwise the Tag shall not execute message. A Tag shall not reply to a *Challenge*.

A *Challenge* contains 2 RFU bits. An Interrogator shall set these bits to 00₂. If a Tag receives a *Challenge* containing nonzero RFU bits then it shall return to the **ready** state and deassert its **C** flag but not execute message. Future protocols may use these RFU bits to expand the functionality of the *Challenge* command.

An Interrogator shall prepend a *Challenge* command with a frame-sync (see 6.3.1.2.8). The CRC-16 that protects a *Challenge* is calculated over the first command-code bit to the last Message bit.

If a Tag supports the *Challenge* command then it shall implement the security (**S**) indicator (see 6.3.2.1.3).

The cryptographic suite specifies message formatting, what value or values the Tag precomputes, and the format in which the Tag stores the value(s). It specifies Tag behavior if a Tag cannot compute one or more values. It may contain additional information such as how Tag and Interrogator perform a subsequent authentication from values precomputed by a *Challenge*. It specifies the formatting of the computed result for both a successful and an unsuccessful *Challenge*. It may contain information about how Tag and Interrogator derive session keys for subsequent communications. It may include parameters, such as a key, that affect pre- and post-authenticated communications. See [Annex M](#) for the parameters specified by a cryptographic suite.

After executing a *Challenge* a Tag shall store its response (result or error code) in its ResponseBuffer. If IncRepLen=1 then the Tag also stores the length of the response (in bits) as shown in Figure 6.17. An Interrogator may subsequently read the response using a *ReadBuffer* command.

After executing and storing a response a Tag shall assert its **C** flag. A Tag shall not assert its **C** flag until after it has computed and stored the entire response. A Tag shall deassert its **C** flag upon (a) receiving a subsequent *Challenge*, or (b) exceeding the **C** flag persistence time in Table 6.20. As described above the ResponseBuffer contents may include a length field and may be a cryptographic response or an error code. A Tag does not permit an Interrogator to read its ResponseBuffer when **C**=0.

If the most recent *Challenge* received and executable by a Tag asserts immed, and if the Tag's **C** flag is asserted when it receives a subsequent *ACK*, then when replying to the *ACK* the Tag shall concatenate its ResponseBuffer contents to its EPC and backscatter the concatenated reply. See Table 6.17. See also Figure 6.23.

A *Challenge* may precede a *Query*. Tags that hear a *Challenge* and support the command, the CSI, and message compute their results simultaneously. An Interrogator may select on the **C** flag to preferentially inventory Tags that have successfully stored a response.

If an Interrogator sends a command while a Tag is processing a *Challenge* then the Tag may abort its processing (leaving **C**=0) and evaluate the command or, in environments with limited power availability, may undergo a power-on reset. This protocol recommends that Interrogators send CW for a sufficient period of time after sending a *Challenge* for all Tags to compute and store their result and assert their **C** flag.

If a Tag observes a properly formatted *Challenge* but there is a cryptographic error, and the cryptographic suite specifies that the error requires a security timeout, then the Tag shall return to **ready** and enforce a security timeout as specified in 6.3.2.5. If a Tag that supports security timeouts for a *Challenge* receives a *Challenge* during a timeout then it shall return to **ready** but not act on or otherwise execute any portion of the *Challenge*.

Table 6.31: *Challenge* Command

	Command	RFU	IncRepLen	Immed	CSI	Length	Message	CRC
# of bits	8	2	1	1	8	12	Variable	16
description	11010100	00	0: Omit <u>length</u> from reply 1: Include <u>length</u> in reply	0: Do not transmit result with EPC 1: Transmit result with EPC	<u>CSI</u>	<u>length</u> of <u>message</u>	<u>message</u> (depends on <u>CSI</u>)	CRC-16

6.3.2.12.2 Inventory commands

The inventory command set comprises *Query*, *QueryAdjust*, *QueryRep*, *ACK*, and *NAK*.

6.3.2.12.2.1 *Query* (mandatory)

Interrogators and Tags shall implement the *Query* command shown in Table 6.32. *Query* initiates and specifies an inventory round. *Query* includes the following fields:

- DR (TRcal divide ratio) sets the T=>R link frequency as described in 6.3.1.2.8 and Table 6.9.
- M (cycles per symbol) sets the T=>R data rate and modulation format as shown in Table 6.10.
- TRext chooses whether a Tag prepends the T=>R preamble with a pilot tone as described in 6.3.1.3.2.2 and 6.3.1.3.2.4. A Tag's reply to a command that uses a *delayed* or an *in-process* reply (see 6.3.1.6) always uses an extended preamble regardless of the TRext value.
- Sel chooses which Tags respond to the *Query* (see 6.3.2.12.1.1 and 6.3.2.10).
- Session chooses a session for the inventory round (see 6.3.2.10).
- Target selects whether Tags whose **inventoried** flag is *A* or *B* participate in the inventory round. Tags may change their inventoried flag from *A* to *B* (or vice versa) as a result of being singulated.
- Q sets the number of slots in the round (see 6.3.2.10).

An Interrogator shall prepend a *Query* with a preamble (see 6.3.1.2.8).

An Interrogator shall not encapsulate a *Query* in a *SecureComm* or *AuthComm* (see Table 6.28).

The CRC-5 that protects a *Query* is calculated over the first command-code bit to the last Q bit. If a Tag receives a *Query* with a CRC-5 error then it shall treat the command as invalid (see Table C.30).

Upon receiving a *Query*, Tags with matching Sel and Target shall pick a random value in the range (0, 2^Q-1), inclusive, and shall load this value into their slot counter. If a Tag, in response to the *Query*, loads its slot counter with zero, then its reply to a *Query* shall be as shown in Table 6.33 using the *immediate* reply type specified in 6.3.1.6.1; otherwise the Tag shall remain silent.

A *Query* may initiate an inventory round in a new session or in the prior session. If a Tag in the **acknowledged**, **open**, or **secured** states receives a *Query* whose session parameter matches the prior session it shall invert its **inventoried** flag (i.e. $A \rightarrow B$ or $B \rightarrow A$) for the session before it evaluates whether to transition to **ready**, **arbitrate**, or **reply**. If a Tag in the **acknowledged**, **open**, or **secured** states receives a *Query* whose session parameter does not match the prior session it shall leave its **inventoried** flag for the prior session unchanged when beginning the new round.

A Tag shall support all DR and M values specified in Table 6.9 and Table 6.10, respectively.

A Tag in any state other than **killed** shall execute a *Query* command, starting a new round in the specified session and transitioning to **ready**, **arbitrate**, or **reply**, as appropriate (see Figure 6.21). A Tag in the **killed** state shall ignore a *Query*.

Table 6.32: *Query* command

	Command	DR	M	TRext	Sel	Session	Target	Q	CRC
# of bits	4	1	2	1	2	2	1	4	5
description	1000	0: DR=8 1: DR=64/3	00: M=1 01: M=2 10: M=4 11: M=8	0: No pilot tone 1: Use pilot tone	00: All 01: All 10: ~SL 11: SL	00: S0 01: S1 10: S2 11: S3	0: A 1: B	0–15	CRC-5

Table 6.33: Tag reply to a *Query* command

	Reply
# of bits	16
description	RN16

6.3.2.12.2.2 *QueryAdjust* (mandatory)

Interrogators and Tags shall implement the *QueryAdjust* command shown in Table 6.34. *QueryAdjust* adjusts *Q* (i.e. the number of slots in an inventory round – see 6.3.2.10) without changing any other round parameters.

QueryAdjust includes the following fields:

- Session corroborates the session number for the inventory round (see 6.3.2.10 and 6.3.2.12.2.1). If a Tag receives a *QueryAdjust* whose session number is different from the session number in the *Query* that initiated the round it shall ignore the command.
- UpDn determines whether and how the Tag adjusts *Q*, as follows:
 - 110: Increment *Q* (i.e. $Q = Q + 1$).
 - 000: No change to *Q*.
 - 011: Decrement *Q* (i.e. $Q = Q - 1$).

If a Tag receives a *QueryAdjust* with an UpDn value different from those specified above then it shall treat the command as invalid (see Table C.30). If a Tag whose *Q* value is 15 receives a *QueryAdjust* with UpDn=110 then it shall change UpDn to 000 prior to executing the command; likewise, if a Tag whose *Q* value is 0 receives a *QueryAdjust* with UpDn=011 then it shall change UpDn to 000 prior to executing the command.

A Tag shall maintain a running count of the current *Q* value. The initial *Q* value is specified in the *Query* command that started the inventory round; one or more subsequent *QueryAdjust* commands may modify *Q*.

An Interrogator shall prepend a *QueryAdjust* with a frame-sync (see 6.3.1.2.8).

An Interrogator shall not encapsulate a *QueryAdjust* in a *SecureComm* or *AuthComm* (see Table 6.28).

Upon receiving a *QueryAdjust* Tags first update *Q*, then pick a random value in the range $(0, 2^Q - 1)$, inclusive, and load this value into their slot counter. If a Tag, in response to the *QueryAdjust*, loads its slot counter with zero, then its reply to a *QueryAdjust* shall be shown in Table 6.35 using the *immediate* reply type specified in 6.3.1.6.1; otherwise, the Tag shall remain silent. A Tag shall respond to a *QueryAdjust* only if it received a prior *Query*.

A Tag in any state except **ready** or **killed** shall execute a *QueryAdjust* command if, and only if, (i) the session parameter in the command matches the session parameter in the *Query* that started the round, and (ii) the Tag is not in the middle of a *Kill* or *Access* command sequence (see 6.3.2.12.3.4 or 6.3.2.12.3.6, respectively).

A Tag in the **acknowledged**, **open**, or **secured** state that receives a *QueryAdjust* whose session parameter matches the session parameter in the prior *Query*, and that is not in the middle of a *Kill* or *Access* command sequence (see 6.3.2.12.3.4 or 6.3.2.12.3.6, respectively), shall invert its **inventoried** flag (i.e. $A \rightarrow B$ or $B \rightarrow A$, as appropriate) for the current session and transition to **ready**.

Table 6.34: *QueryAdjust* command

	Command	Session	UpDn
# of bits	4	2	3
description	1001	00: S0 01: S1 10: S2 11: S3	110: $Q = Q + 1$ 000: No change to <i>Q</i> 011: $Q = Q - 1$

Table 6.35: Tag reply to a *QueryAdjust* command

	Reply
# of bits	16
description	RN16

6.3.2.12.2.3 *QueryRep* (mandatory)

Interrogators and Tags shall implement the *QueryRep* command shown in Table 6.36. *QueryRep* instructs Tags to decrement their slot counters and, if slot=0 after decrementing, to backscatter an RN16 to the Interrogator.

QueryRep includes the following field:

- Session corroborates the session number for the inventory round (see 6.3.2.10 and 6.3.2.12.2.1). If a Tag receives a *QueryRep* whose session number is different from the session number in the *Query* that initiated the round it shall ignore the command.

An Interrogator shall prepend a *QueryRep* with a frame-sync (see 6.3.1.2.8).

An Interrogator shall not encapsulate a *QueryRep* in a *SecureComm* or *AuthComm* (see Table 6.28).

If a Tag, in response to the *QueryRep*, decrements its slot counter and the decremented slot value is zero, then its reply to a *QueryRep* shall be as shown in Table 6.37 using the *immediate* reply type specified in 6.3.1.6.1; otherwise the Tag shall remain silent. A Tag shall respond to a *QueryRep* only if it received a prior *Query*.

A Tag in any state except **ready** or **killed** shall execute a *QueryRep* command if, and only if, (i) the session parameter in the command matches the session parameter in the *Query* that started the round, and (ii) the Tag is not in the middle of a *Kill* or *Access* command sequence (see 6.3.2.12.3.4 or 6.3.2.12.3.6, respectively).

A Tag in the **acknowledged**, **open**, or **secured** state that receives a *QueryRep* whose session parameter matches the session parameter in the prior *Query*, and that is not in the middle of a *Kill* or *Access* command sequence (see 6.3.2.12.3.4 or 6.3.2.12.3.6, respectively), shall invert its **inventoried** flag (i.e. $A \rightarrow B$ or $B \rightarrow A$, as appropriate) for the current session and transition to **ready**.

Table 6.36: *QueryRep* command

	Command	Session
# of bits	2	2
description	00	00: S0 01: S1 10: S2 11: S3

Table 6.37: Tag reply to a *QueryRep* command

	Reply
# of bits	16
description	RN16

6.3.2.12.2.4 **ACK**(mandatory)

Interrogators and Tags shall implement the **ACK** command shown in Table 6.38. An Interrogator sends an **ACK** to acknowledge a single Tag. **ACK** echoes the Tag's backscattered RN16.

If an Interrogator issues an **ACK** to a Tag in the **reply** or **acknowledged** state then the echoed RN16 shall be the RN16 that the Tag previously backscattered as it transitioned from the **arbitrate** state to the **reply** state. If an Interrogator issues an **ACK** to a Tag in the **open** or **secured** state then the echoed RN16 shall be the Tag's handle (see 6.3.2.12.3.1).

An Interrogator shall prepend an **ACK** with a frame-sync (see 6.3.1.2.8).

An Interrogator may encapsulate an **ACK** in a *SecureComm* or *AuthComm* (see Table 6.28).

The Tag reply to a successful **ACK** shall be as shown in Table 6.39, using the *immediate* reply type specified in 6.3.1.6.1. As described in 6.3.2.1.2 and shown in Table 6.17, the reply may be truncated or include a concatenated response. A Tag that receives an **ACK** with an incorrect RN16 or an incorrect handle (as appropriate) shall return to **arbitrate** without responding, unless the Tag is in **ready** or **killed**, in which case it shall ignore the **ACK** and remain in its current state.

If a Tag does not support XPC functionality then the maximum length of its backscattered EPC is 496 bits. If a Tag supports XPC functionality then the maximum length of its backscattered EPC is reduced by two words to accommodate the optional XPC_W1 and XPC_W2, so is 464 bits (see 6.3.2.1.2.2). In either case a Tag's reply to an **ACK** shall not exceed 528 bits for the PC + EPC + PacketCRC, optionally followed by a response field and its associated CRC-16 (see Table 6.17).

Table 6.38: *ACK* command

	Command	RN
# of bits	2	16
description	01	Echoed RN16 or <u>handle</u>

Table 6.39: Tag reply to a successful *ACK* command

	Reply
# of bits	21 to 33,328
description	See Table 6.17

6.3.2.12.2.5 *NAK* (mandatory)

Interrogators and Tags shall implement the *NAK* command shown in Table 6.40. A Tag that receives a *NAK* shall return to the **arbitrate** state without changing its **inventoried** flag, unless the Tag is in **ready** or **killed**, in which case it shall ignore the *NAK* and remain in its current state.

An Interrogator shall prepend a *NAK* with a frame-sync (see 6.3.1.2.8).

An Interrogator shall not encapsulate a *NAK* in a *SecureComm* or *AuthComm* (see Table 6.28).

A Tag shall not reply to a *NAK*.

Table 6.40: *NAK* command

	Command
# of bits	8
description	11000000

6.3.2.12.3 Access commands

The access command set comprises *Req_RN*, *Read*, *Write*, *Lock*, *Kill*, *Access*, *BlockWrite*, *BlockErase*, *BlockPermalock*, *Authenticate*, *ReadBuffer*, *SecureComm*, *AuthComm*, *KeyUpdate*, *Untraceable*, *FileOpen*, *FileList*, *FilePrivilege*, *FileSetup*, and *TagPrivilege*.

All access commands include the Tag's handle and a CRC-16. The CRC-16 is calculated over the first command-code bit to the last handle bit. A Tag in the **open** or **secured** state that receives an access command with an incorrect handle but a correct CRC-16 shall behave as specified in Table C.30.

6.3.2.12.3.1 *Req_RN*(mandatory)

Interrogators and Tags shall implement the *Req_RN* command shown in Table 6.41. *Req_RN* instructs a Tag to backscatter a new RN16. Both the Interrogator's command and the Tag's reply depend on the Tag's state:

- **Acknowledged** state: When issuing a *Req_RN* to a Tag in the **acknowledged** state an Interrogator shall include the Tag's last backscattered RN16 as a parameter in the *Req_RN*. The *Req_RN* is protected by a CRC-16 calculated over the command code and the RN16. If a Tag receives a *Req_RN* with a correct RN16 and a correct CRC-16 then it shall generate and store a new RN16 (denoted handle), backscatter this handle, and transition to the **open** or **secured** state. The choice of ending state depends on the Tag's access password, as follows:
 - Access password $\neq 0$: Tag transitions to **open** state.
 - Access password = 0: Tag transitions to **secured** state.

A Tag in the **acknowledged** state that receives a *Req_RN* with an incorrect RN16 but a correct CRC-16 shall ignore the *Req_RN* and remain in the **acknowledged** state.

- **Open** or **secured** state: When issuing a *Req_RN* to a Tag in the **open** or **secured** state an Interrogator shall include the Tag's handle as a parameter in the *Req_RN*. If a Tag receives the *Req_RN* with a correct handle and a correct CRC-16 then it shall generate and backscatter a new RN16, remaining in its current state (**open** or **secured**, as appropriate).

If an Interrogator wants to ensure that only one Tag is in the **acknowledged** state then it may issue a *Req_RN*, causing the Tag or Tags to each backscatter a handle and transition to the **open** or **secured** state (as appropriate). The Interrogator may then issue an *ACK* with handle as a parameter in the command. The Tag that receives the *ACK* with a correct handle replies as specified in Table 6.39, whereas those that receive it with an incorrect handle shall return to **arbitrate**. (Note: If a Tag receives an *ACK* with an incorrect handle it returns to **arbitrate**, whereas if it receives an access command with an incorrect handle it behaves as specified in Table C.30).

The first bit of the backscattered RN16 shall be denoted the MSB; the last bit shall be denoted the LSB.

An Interrogator shall prepend a *Req_RN* with a frame-sync (see 6.3.1.2.8).

An Interrogator may encapsulate a *Req_RN* in a *SecureComm* or *AuthComm* (see Table 6.28).

A Tag's reply to a *Req_RN* shall be as shown in Table 6.42, using the *immediate* reply type specified in 6.3.1.6.1. The RN16 or handle are protected by a CRC-16.

Table 6.41: *Req_RN* command

	Command	RN	CRC
# of bits	8	16	16
description	11000001	Prior RN16 or <u>handle</u>	CRC-16

Table 6.42: Tag reply to a *Req_RN* command

	RN	CRC
# of bits	16	16
description	<u>handle</u> or new RN16	CRC-16

6.3.2.12.3.2 Read (mandatory)

Interrogators and Tags shall implement the *Read* command shown in Table 6.44. A *Read* allows an Interrogator to read part or all of a Tag's Reserved memory, EPC memory, TID memory, or the currently open file in User memory. *Read* has the following fields:

- MemBank specifies whether the *Read* accesses Reserved, EPC, TID, or User memory. *Read* commands shall apply to a single memory bank. Successive *Reads* may apply to different banks.
- WordPtr specifies the starting word address for the memory read, where words are 16 bits in length. For example, WordPtr=00_h specifies the first 16-bit memory word, WordPtr=01_h specifies the second 16-bit memory word, etc. WordPtr uses EBV formatting (see [Annex A](#)).
- WordCount specifies the number of 16-bit words to read. If WordCount=00_h then a Tag shall backscatter the contents of the chosen memory bank or file starting at WordPtr and ending at the end of the memory bank or file, however:
 - if MemBank=01₂ then a Tag shall backscatter the memory contents specified in Table 6.43.
 - if MemBank=10₂, and part of TID memory is untraceably hidden (see 6.3.2.12.3.16), and the Interrogator has a deasserted Untraceable privilege, and the memory address specified by WordPtr is in the traceable part of TID memory, then a Tag may either (i) backscatter the traceable part of TID memory starting at WordPtr, or (ii) treat the command's parameters as unsupported (see Table C.30), depending on the Tag manufacturer's implementation.

Table 6.43: Tag *Read* reply when WordCount=00_h and MemBank=01₂

<u>WordPtr</u> Memory Address	Tag Implements XPC_W1?	Tag Implements XPC_W2?	What the Tag Backscatters
Within the StoredCRC, StoredPC, or the EPC specified by bits 10 _h –14 _h of the StoredPC	Don't care	Don't care	EPC memory starting at <u>WordPtr</u> and ending at the EPC length specified by StoredPC bits 10 _h –14 _h .
Within physical EPC memory but above the EPC specified by bits 10 _h –14 _h of the StoredPC	No	N/A. See note 1	EPC memory starting at <u>WordPtr</u> and ending at the end of physical EPC memory, unless the Interrogator has a deasserted <u>Untraceable</u> privilege and the reply would include untraceably hidden memory, in which case error code (see note 2).
	Yes	No	EPC memory starting at <u>WordPtr</u> and ending at the end of physical EPC memory, unless the Interrogator has a deasserted <u>Untraceable</u> privilege and the reply would include untraceably hidden memory, in which case error code (see note 2). Includes XPC_W1 if <u>WordPtr</u> is less than or equal to 210 _h , physical EPC memory extends to or above 210 _h , and no error code.
	Yes	Yes	EPC memory starting at <u>WordPtr</u> and ending at the end of physical EPC memory, unless the Interrogator has a deasserted <u>Untraceable</u> privilege and the reply would include untraceably hidden memory, in which case error code (see note 2). Includes XPC_W1 and XPC_W2 if <u>WordPtr</u> is less than or equal to 210 _h , physical EPC memory extends to or above 210 _h , and no error code. Includes XPC_W2 if <u>WordPtr</u> is equal to 220 _h and physical EPC memory extends to or above 220 _h .
210 _h . Above physical EPC memory	No	N/A. See note 1	Error code.
	Yes	No	XPC_W1.
	Yes	Yes	XPC_W1 and XPC_W2.
220 _h . Above physical EPC memory	No	N/A. See note 1	Error code.
	Yes	No	Error code.
	Yes	Yes	XPC_W2.
Not 210 _h or 220 _h . Above physical EPC memory.	Don't care	Don't care	Error code.

Note 1: If a Tag does not implement an XPC_W1 then it does not implement an XPC_W2. See 6.3.2.1.2.5.

Note 2: Untraceably hidden memory is not readable except by an Interrogator with an asserted Untraceable privilege. See 6.3.2.12.3.16.

An Interrogator shall prepend a *Read* with a frame-sync (see 6.3.1.2.8).

An unauthenticated Interrogator may, and an authenticated Interrogator shall, encapsulate a *Read* command in a *SecureComm* or *AuthComm* (see Table 6.28).

A Tag shall reply to a *Read* using the *immediate* reply type specified in 6.3.1.6.1. If all memory words specified in a *Read* exist, none are read-locked, all are traceable or the Interrogator has an asserted Untraceable privilege, and for User memory the Interrogator has read privileges to the currently open file (see 6.3.2.11.3), then a Tag's reply to a *Read* shall be as shown in Table 6.45 comprising a header (a 0-bit), the requested memory words, and the Tag's handle. The reply includes a CRC-16 calculated over the 0-bit, memory words, and handle. Otherwise the Tag shall not execute the *Read* and instead treat the command's parameters as unsupported (see Table C.30).

Table 6.44: *Read* command

	Command	MemBank	WordPtr	WordCount	RN	CRC
# of bits	8	2	EBV	8	16	16
description	11000010	00: Reserved 01: EPC 10: TID 11: User	Starting address pointer	Number of words to read	<u>handle</u>	CRC-16

Table 6.45: Tag reply to a successful *Read* command

	Header	Memory Words	RN	CRC
# of bits	1	Variable	16	16
description	0	Data	<u>handle</u>	CRC-16

6.3.2.12.3.3 *Write* (mandatory)

Interrogators and Tags shall implement the *Write* command shown in Table 6.46. *Write* allows an Interrogator to write a word in a Tag's Reserved memory, EPC memory, TID memory, or the currently open file in User memory. *Write* has the following fields:

- MemBank specifies whether the *Write* occurs in Reserved, EPC, TID, or User memory. *Write* commands shall apply to a single memory bank. Successive *Writes* may apply to different banks.
- WordPtr specifies the word address for the memory write, where words are 16 bits in length. For example, WordPtr=00_h specifies the first 16-bit memory word, WordPtr=01_h specifies the second 16-bit memory word, etc. WordPtr uses EBV formatting (see [Annex A](#)).
- Data contains a 16-bit word to be written. Before each and every *Write* the Interrogator shall first issue a *Req_RN* command; the Tag replies by backscattering a new RN16. The Interrogator shall cover code the data by EXORing it with this new RN16 prior to transmission.

A Tag shall only execute a *Write* in the **open** or **secured** state. If a Tag in the **open** or **secured** state receives a *Write* before which the immediately preceding command was not a *Req_RN* then it shall not execute the *Write* and instead treat the command as invalid (see Table C.30).

If an Interrogator attempts to write to the kill or access password, EPC or TID memory banks, or File_0 and these memory locations are permalocked; or to the kill or access password, EPC or TID memory banks, or File_0 and these memory locations are locked unwriteable and the Tag is in the **open** state; or to a permalocked block in File_N, N≥0 of User memory; or to memory that is untraceably hidden and the Interrogator has a deasserted Untraceable privilege; or to a file for which the Interrogator does not have sufficient privileges; then the Tag shall not execute the *Write* and instead treat the command's parameters as unsupported (see Table C.30).

An Interrogator shall prepend a *Write* with a frame-sync (see 6.3.1.2.8).

An Interrogator shall not encapsulate a *Write* in a *SecureComm* or *AuthComm* (see Table 6.28).

Upon receiving an executable *Write* a Tag shall write the commanded data into memory.

A Tag shall reply to a *Write* using the *delayed* reply specified in 6.3.1.6.2.

Table 6.46: *Write* command

	Command	MemBank	WordPtr	Data	RN	CRC
# of bits	8	2	EBV	16	16	16
description	11000011	00: Reserved 01: EPC 10: TID 11: User	Address pointer	RN16 ⊗ word to be written	<u>handle</u>	CRC-16

6.3.2.12.3.4 *Kill*(mandatory)

Interrogators and Tags shall implement the *Kill* command shown in Table 6.47. *Kill* allows an Interrogator to permanently disable a Tag. To kill a Tag, an Interrogator shall follow the kill procedure shown in Figure 6.24. A Tag shall implement the password-based kill sequence shown in the left-side branch of the kill procedure in Figure 6.24. A Tag that implements Interrogator or mutual authentication and *SecureComm* or *AuthComm* may also implement the authenticated-kill sequence shown in the right-side branch of the kill procedure in Figure 6.24. *Kill* has the following fields:

- Password specifies half of the kill password EXORed with an RN16.

A *Kill* contains 3 RFU bits. An Interrogator shall set these bits to 000₂. A Tag shall ignore these bits. Future protocols may use these bits to expand the functionality of the *Kill* command.

An Interrogator shall prepend an unencapsulated *Kill* command with a frame-sync (see 6.3.1.2.8).

An Interrogator may encapsulate a *Kill* in a *SecureComm* or *AuthComm* (see Table 6.28).

Password-based kill (mandatory)

A Tag may execute a password-based kill from the **open** or **secured** state. A Tag is not required to authenticate an Interrogator for a password-based kill. To perform the kill, an Interrogator issues two successive *Kill* commands, the first containing the 16 MSBs of the Tag's kill password EXORed with an RN16, and the second containing the 16 LSBs of the Tag's kill password EXORed with a different RN16. Each EXOR operation shall be performed MSB first (i.e. the MSB of each half-password shall be EXORed with the MSB of its respective RN16). Just prior to issuing each *Kill* command the Interrogator first issues a *Req_RN* to obtain a new RN16.

A Tag shall be capable of successively accepting two 16-bit subportions of the 32-bit kill password. An Interrogator shall not intersperse commands other than a *Req_RN* between the two successive *Kill* commands. If a Tag, after receiving a first *Kill*, receives any valid command other than *Req_RN* before the second *Kill* then it shall not execute the command and instead treat it as improper (see Table C.30), unless the intervening command is a *Query*, in which case the Tag shall execute the *Query* and invert its **inventoried** flag if the session parameter in the *Query* matches that in the prior session.

A Tag with a zero-valued kill password shall disallow itself from being killed by a password-based kill operation. A Tag with a zero-valued kill password shall respond to a password-based kill by not executing the kill operation and backscattering an error code, remaining in its current state. See Figure 6.24.

A Tag shall reply to a first *Kill* using the *immediate* reply specified in 6.3.1.6.1. The Tag's first reply shall be as shown in Table 6.48. The reply shall use the TRExt value specified in the *Query* command that initiated the round.

A Tag shall reply to the second *Kill* using the *delayed* reply specified in 6.3.1.6.2. If the kill succeeds then the Tag, after sending the final reply shown in Table 6.13, shall render itself silent and shall not respond to an Interrogator thereafter. If the kill does not succeed then the Interrogator may issue a *Req_RN* containing the Tag's handle to verify that the Tag is in the Interrogator's field, and may again attempt the multi-step kill procedure in Figure 6.24.

If a Tag observes a properly formatted password-based *Kill*-command sequence but the kill fails (as will happen if the Interrogator sends an incorrect kill password) then the Tag shall return to **arbitrate** and may enforce a security timeout as specified in 6.3.2.5. If a Tag that supports security timeouts for a password-based *Kill*-command sequence receives such a sequence during a timeout then it shall behave as though it is not killable, backscatter an error code (see [Annex I](#)), and remain in its current state.

Authenticated kill (optional)

A Tag may execute an authenticated kill from the **secured** state. A Tag shall authenticate an Interrogator via an Interrogator or mutual authentication prior to executing an authenticated kill. To perform an authenticated kill an Interrogator issues a single *Kill* command encapsulated in a *SecureComm* or *AuthComm*. The Interrogator may use any 16-bit value in the password field of the *Kill* command because a Tag shall ignore the kill password for an authenticated kill. An Interrogator is not required to issue a *Req_RN* prior to sending an encapsulated *Kill*.

A Tag shall only execute an authenticated kill if the Interrogator possesses an asserted AuthKill privilege (see Table 6.23) and the Tag is in the **secured** state. A Tag shall reply to an authenticated kill using an in-process reply (as required by a *SecureComm* or *AuthComm*), but with SenRep=1 regardless of the SenRep value actually specified in the *SecureComm* or *AuthComm*. If the kill succeeds then the Tag, after sending the final reply shown in Table 6.13, shall transition to the **killed** state and not respond to an Interrogator thereafter. If the kill fails then the Tag shall remain in its current state and backscatter an error code (see [Annex I](#)), unless the Tag is in the **open** state, the Interrogator is not authenticated, or the Interrogator does not have an asserted AuthKill privilege (see

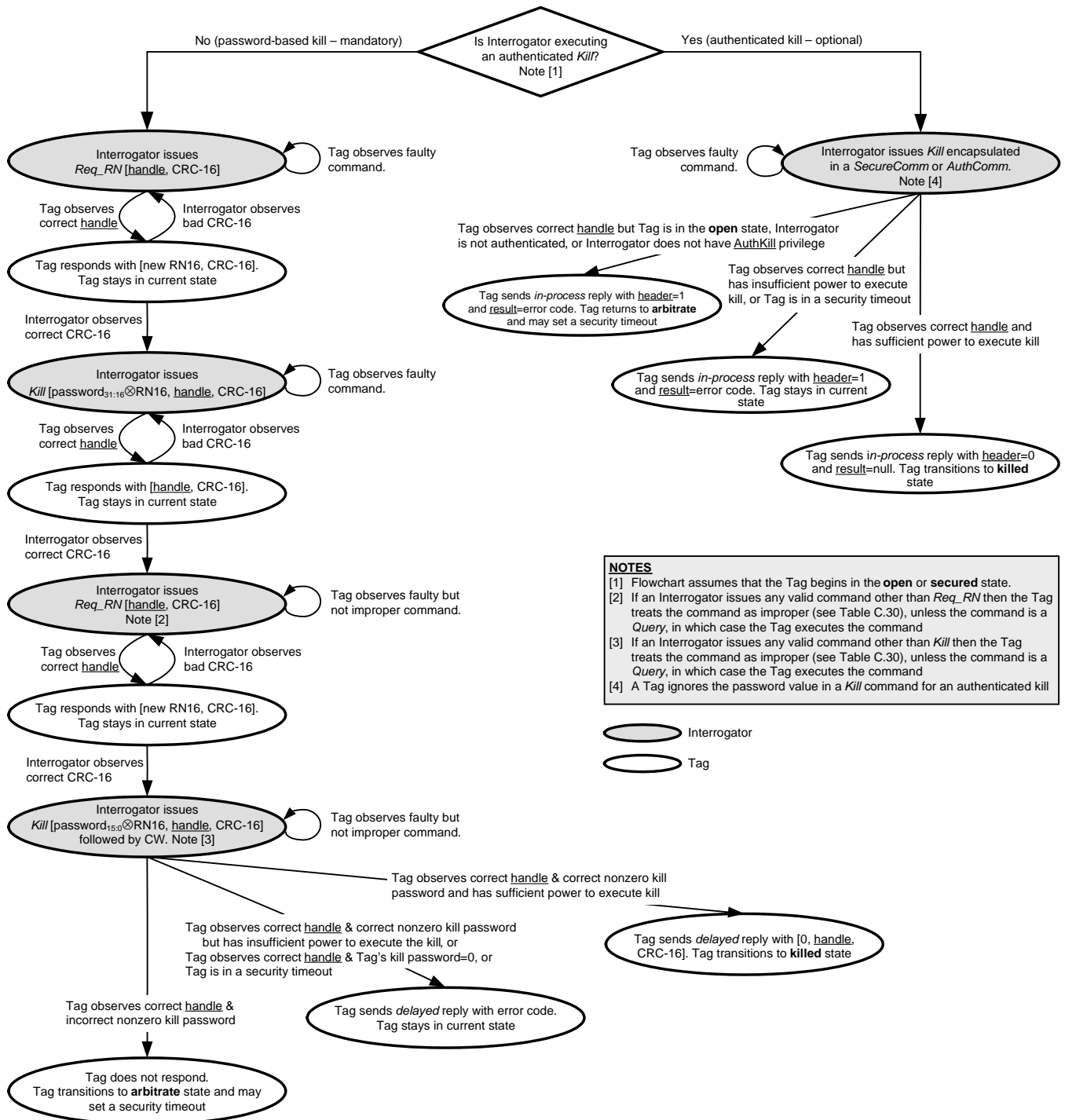
Table 6.23), in which case the Tag shall return to **arbitrate** and may enforce a security timeout as specified in 6.3.2.5. If a Tag that supports security timeouts for an authenticated *Kill* command receives an authenticated *Kill* command during a timeout then it shall behave as though it is not killable, backscatter an error code (see [Annex I](#)), and remain in its current state.

Table 6.47: *Kill* command

	Command	Password	RFU	RN	CRC
# of bits	8	16	3	16	16
description	11000100	Password-based kill: ($\frac{1}{2}$ kill password) \otimes RN16 Authenticated kill: any 16-bit value	000 ₂	<u>handle</u>	CRC-16

Table 6.48: Tag reply to the first *Kill* command

	RN	CRC
# of bits	16	16
description	<u>handle</u>	CRC-16



NOTES

[1] Flowchart assumes that the Tag begins in the **open** or **secured** state.

[2] If an Interrogator issues any valid command other than *Req_RN* then the Tag treats the command as improper (see Table C.30), unless the command is a *Query*, in which case the Tag executes the command

[3] If an Interrogator issues any valid command other than *Kill* then the Tag treats the command as improper (see Table C.30), unless the command is a *Query*, in which case the Tag executes the command

[4] A Tag ignores the password value in a *Kill* command for an authenticated kill

Interrogator
Tag

Figure 6.24: Kill procedure

6.3.2.12.3.5 *Lock* (mandatory)

Interrogators and Tags shall implement the *Lock* command shown in Table 6.49 and Figure 6.25. *Lock* allows an Interrogator to:

- Lock the kill and/or access passwords, thereby preventing or allowing subsequent reads and/or writes of those passwords,
- Lock the EPC and TID memory banks, thereby preventing or allowing subsequent writes to those banks,
- Lock File_0 of User memory, thereby preventing or allowing subsequent writes to File_0, and
- Make the lock status for the passwords, EPC memory, TID memory, and/or File_0 permanent.

Lock contains a 20-bit payload defined as follows:

- The first 10 payload bits are Mask bits. A Tag shall interpret these bit values as follows:
 - Mask=0: Ignore the associated Action field and retain the current lock setting.
 - Mask=1: Implement the associated Action field and overwrite the current lock setting.
- The last 10 payload bits are Action bits. A Tag shall interpret these bit values as follows:
 - Action=0: Deassert lock for the associated memory location.
 - Action=1: Assert lock or permalock for the associated memory location.

The functionality of the various Action fields is described in Table 6.50.

The payload of a *Lock* command shall always be 20 bits in length.

If an Interrogator issues a *Lock* whose Mask and Action fields attempt to change the lock status of a nonexistent memory bank, nonexistent File_0, or nonexistent password then a Tag shall not execute the *Lock* and instead treat the command's parameters as unsupported (see Table C.30).

Lock differs from *BlockPermalock* in that *Lock* reversibly or permanently locks the kill and/or access password, the EPC memory bank, the TID memory bank, and/or File_0 of User memory in a writeable or unwriteable state, whereas *BlockPermalock* permanently locks individual blocks of File_N, $N \geq 0$ of User memory in an unwriteable state. Table 6.55 specifies how a Tag reacts to a *Lock* targeting File_0 that follows a prior *BlockPermalock* (with Read/Lock=1), or vice versa.

Permalock bits, once asserted, cannot be deasserted. If a Tag receives a *Lock* whose payload attempts to deassert a previously asserted permalock bit then the Tag shall not execute the *Lock* and instead treat the command's parameters as unsupported (see Table C.30). If a Tag receives a *Lock* whose payload attempts to reassert a previously asserted permalock bit then the Tag shall ignore this particular Action field and implement the remainder of the *Lock* payload.

An *Untraceable* command may change the values of the **L** and **U** bits in EPC memory regardless of the lock or permalock status of the EPC memory bank. See 6.3.2.12.3.16.

A Tag manufacturer may choose where a Tag stores its lock bits and may choose a readable portion of memory (if desired). Regardless of the location, a field-deployed Tag shall not permit an Interrogator to change its lock bits except by means of a *Lock* command.

A Tag shall implement memory locking and the *Lock* command. However, a Tag need not support all the Action fields in Figure 6.25, depending on whether a Tag implements the memory location associated with the Action field and that memory location is lockable and/or unlockable. If a Tag receives a *Lock* it cannot execute because one or more memory locations do not exist, or one or more of the Action fields attempt to change a permalocked value, or one or more of the memory locations are either not lockable or not unlockable, then the Tag shall not execute the *Lock* and instead treat the command's parameters as unsupported (see Table C.30). The only exception to this general rule is for a Tag that (a) does not support File_N, $N > 0$ and (b) whose only lock functionality is to permanently lock **all** memory (i.e. all memory banks and all passwords) at once; such a Tag shall execute a *Lock* whose payload is FFFF_h, and shall backscatter an error code for any payload other than FFFF_h.

A Tag in the **secured** state shall permit an Interrogator to write or erase memory locations with (pwd-write=1 AND permalock=0) or (pwd-read/write=1 AND permalock=0) without first issuing a *Lock* to change these fields.

An Interrogator shall prepend a *Lock* with a frame-sync (see 6.3.1.2.8).

An unauthenticated Interrogator may, and an authenticated Interrogator shall, encapsulate a *Lock* command in a *SecureComm* or *AuthComm* (see Table 6.28).

Upon receiving an executable *Lock* a Tag shall perform the commanded lock operation. A Tag shall reply to a *Lock* using the *delayed* reply specified in 6.3.1.6.2.

Table 6.49: *Lock* command

	Command	Payload	RN	CRC
# of bits	8	20	16	16
description	11000101	<u>Mask</u> and <u>Action</u> Fields	<u>handle</u>	CRC-16

Lock-Command Payload

19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Kill	Access	EPC	TID	File_0	Kill	Access	EPC	TID	File_0										
Mask	Mask	Mask	Mask	Mask	Action	Action	Action	Action	Action										

Masks and Associated Action Fields

	Kill pwd		Access pwd		EPC memory		TID memory		File_0 memory	
	19	18	17	16	15	14	13	12	11	10
<i>Mask</i>	skip/ write	skip/ write	skip/ write	skip/ write	skip/ write	skip/ write	skip/ write	skip/ write	skip/ write	skip/ write
<i>Action</i>	9	8	7	6	5	4	3	2	1	0
	pwd read/ write	perma lock	pwd read/ write	perma lock	pwd write	perma lock	pwd write	perma lock	pwd write	perma lock

Figure 6.25: *Lock* payload and usage

Table 6.50: *Lock* Action-field functionality

pwd-write	permalock	Description
0	0	Associated memory bank/file is writeable from either the open or secured states.
0	1	Associated memory bank/file is permanently writeable from either the open or secured states and may never be locked.
1	0	Associated memory bank/file is writeable from the secured state but not from the open state.
1	1	Associated memory bank/file is not writeable from any state.
pwd-read/write	permalock	Description
0	0	Associated password location is readable and writeable from either the open or secured states.
0	1	Associated password location is permanently readable and writeable from either the open or secured states and may never be locked.
1	0	Associated password location is readable and writeable from the secured state but not from the open state.
1	1	Associated password location is not readable or writeable from any state.

6.3.2.12.3.6 Access (optional)

Interrogators and Tags may implement an *Access* command; if they do, they shall implement it as shown in Table 6.51. *Access* allows an Interrogator to transition a Tag from the **open** to the **secured** state or, if the Tag is already in the **secured** state, to remain in **secured**. *Access* has the following fields:

- Password specifies half of the access password EXORed with an RN16.

To access a Tag, an Interrogator shall follow the multi-step procedure outlined in Figure 6.26. Briefly, an Interrogator issues two *Access* commands, the first containing the 16 MSBs of the Tag's access password EXORed with an RN16, and the second containing the 16 LSBs of the Tag's access password EXORed with a different RN16. Each EXOR operation shall be performed MSB first (i.e. the MSB of each half-password shall be EXORed with the MSB of its respective RN16). Just prior to issuing each *Access* the Interrogator first issues a *Req_RN* to obtain a new RN16.

A Tag shall be capable of successively accepting two 16-bit subportions of the 32-bit access password. An Interrogator shall not intersperse commands other than a *Req_RN* between the two successive *Access* commands. If a Tag, after receiving a first *Access*, receives any valid command other than *Req_RN* before the second *Access* then it shall not execute the command and instead treat it as improper (see Table C.30), unless the intervening command is a *Query*, in which case the Tag shall execute the *Query* and invert its **inventoried** flag if the session parameter in the *Query* matches that in the prior session.

An Interrogator shall prepend an *Access* with a frame-sync (see 6.3.1.2.8).

An Interrogator shall not encapsulate an *Access* in a *SecureComm* or *AuthComm* (see Table 6.28).

A Tag shall reply to an *Access* using the *immediate* reply specified in 6.3.1.6.1. The reply shall be as shown in Table 6.52. If the *Access* is the first in the sequence then the Tag backscatters its handle to acknowledge that it received the command. If the *Access* is the second in the sequence and the received 32-bit access password is correct then the Tag backscatters its handle to acknowledge that it has executed the command successfully and has transitioned to the **secured** state; otherwise the Tag does not reply and returns to **arbitrate**. The Tag reply includes a CRC-16 calculated over the handle.

If a Tag observes a properly formatted *Access* sequence but the Interrogator sends an incorrect access password then the Tag shall return to **arbitrate** and may enforce a security timeout as specified in 6.3.2.5. If a Tag that supports security timeouts for an *Access* command sequence receives such a sequence during a timeout then it shall behave as though Tag access was disallowed, backscatter an error code (see [Annex I](#)), and remain in its current state.

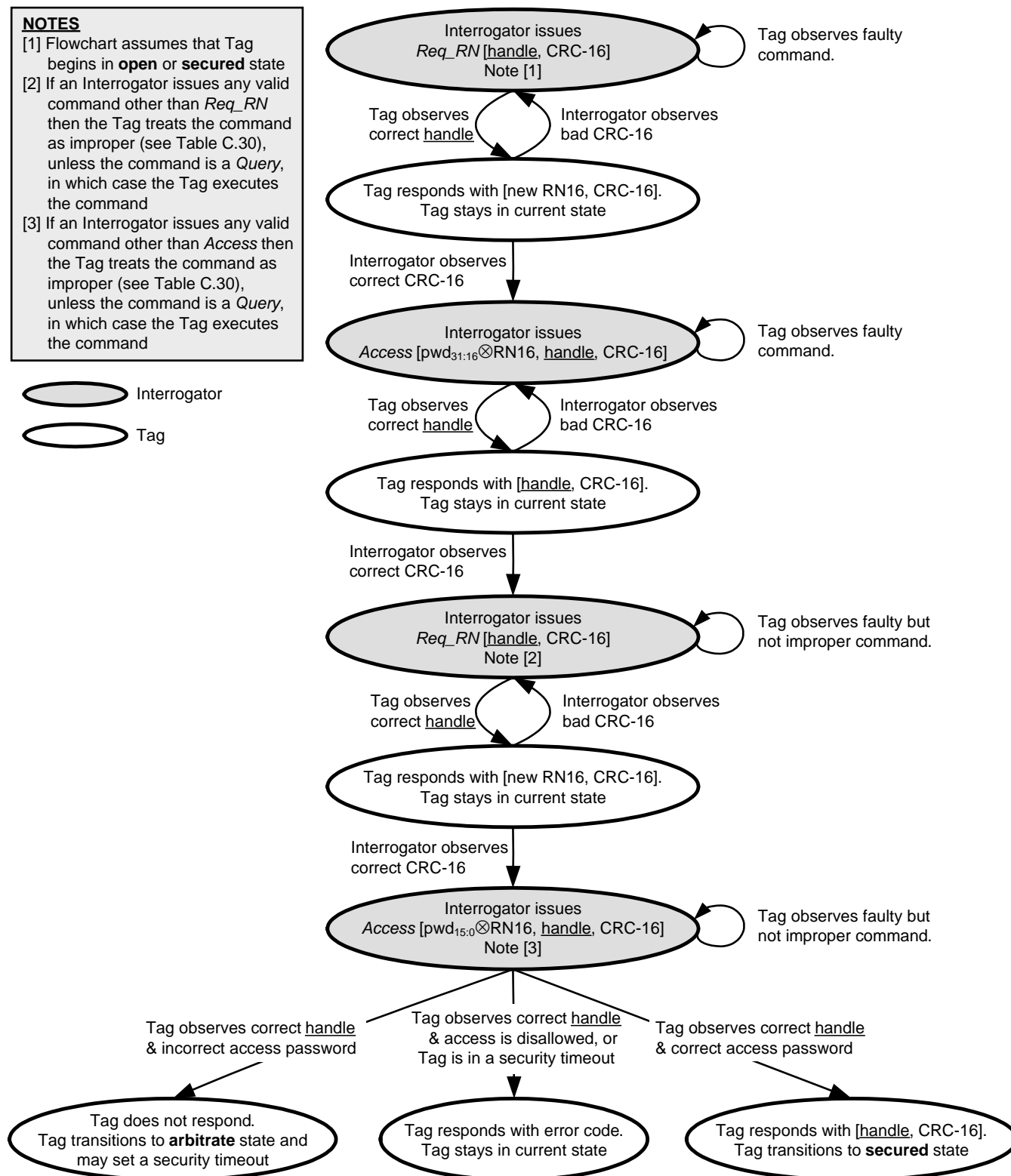
Table 6.51: *Access* command

	Command	Password	RN	CRC
# of bits	8	16	16	16
description	11000110	(½ access password) ⊗ RN16	<u>handle</u>	CRC-16

Table 6.52: Tag reply to an *Access* command

	RN	CRC
# of bits	16	16
description	<u>handle</u>	CRC-16

- [1] Flowchart assumes that Tag begins in **open** or **secured** state
- [2] If an Interrogator issues any valid command other than *Req_RN* then the Tag treats the command as improper (see Table C.30), unless the command is a *Query*, in which case the Tag executes the command
- [3] If an Interrogator issues any valid command other than *Access* then the Tag treats the command as improper (see Table C.30), unless the command is a *Query*, in which case the Tag executes the command



6.3.2.12.3.7 *BlockWrite* (optional)

Interrogators and Tags may implement a *BlockWrite* command; if they do, they shall implement it as shown in Table 6.53. *BlockWrite* allows an Interrogator to write multiple words in a Tag's Reserved memory, EPC memory, TID memory, or the currently open file in User memory. *BlockWrite* has the following fields:

- MemBank specifies whether the *BlockWrite* occurs in Reserved, EPC, TID, or User memory. *BlockWrite* commands shall apply to a single memory bank. Successive *BlockWrites* may apply to different banks.
- WordPtr specifies the starting word address for the memory write, where words are 16 bits in length. For example, WordPtr=00_h specifies the first 16-bit memory word, WordPtr=01_h specifies the second 16-bit memory word, etc. WordPtr uses EBV formatting (see [Annex A](#)).
- WordCount specifies the number of 16-bit words to be written. If WordCount=00_h then a Tag shall treat the *BlockWrite* as invalid. If WordCount=01_h then a Tag shall write a single data word.
- Data contains the 16-bit words to be written, and shall be 16×WordCount bits in length. Unlike a *Write*, the data in a *BlockWrite* are not cover-coded, and an Interrogator need not issue a *Req_RN* before issuing a *BlockWrite*.

A Tag shall only execute a *BlockWrite* in the **open** or **secured** state.

If an Interrogator attempts to write to the kill or access password, EPC or TID memory banks, or File_0 and these memory locations are permalocked; or to the kill or access password, EPC or TID memory banks, or File_0 and these memory locations are locked unwriteable and the Tag is in the **open** state; or to memory that is untraceably hidden and the Interrogator has a deasserted Untraceable privilege; or to a file for which the Interrogator does not have sufficient privileges; or if WordPtr and WordCount include one or more permalocked blocks in File_N, N≥0 of User memory; then the Tag shall not execute the *BlockWrite* and instead treat the command's parameters as unsupported (see Table C.30).

An Interrogator shall prepend a *BlockWrite* with a frame-sync (see 6.3.1.2.8).

An unauthenticated Interrogator may, and an authenticated Interrogator shall, encapsulate a *BlockWrite* in a *SecureComm* or *AuthComm* (see Table 6.28).

Upon receiving an executable *BlockWrite* a Tag shall write the commanded data into memory.

A Tag shall reply to a *BlockWrite* using the *delayed* reply specified in 6.3.1.6.2.

Table 6.53: *BlockWrite* command

	Command	MemBank	WordPtr	WordCount	Data	RN	CRC
# of bits	8	2	EBV	8	Variable	16	16
description	11000111	00: Reserved 01: EPC 10: TID 11: User	Starting address pointer	Number of words to write	Data to be written	<u>handle</u>	CRC-16

6.3.2.12.3.8 *BlockErase* (optional)

Interrogators and Tags may implement a *BlockErase* command; if they do, they shall implement it as shown in Table 6.54. *BlockErase* allows an Interrogator to erase multiple words in a Tag's Reserved memory, EPC memory, TID memory, or the currently open file in User memory. *BlockErase* has the following fields:

- MemBank specifies whether the *BlockErase* occurs in Reserved, EPC, TID, or User memory. *BlockErase* commands shall apply to a single memory bank. Successive *BlockErases* may apply to different banks.
- WordPtr specifies the starting word address for the memory erase, where words are 16 bits in length. For example, WordPtr=00_h specifies the first 16-bit memory word, WordPtr=01_h specifies the second 16-bit memory word, etc. WordPtr uses EBV formatting (see [Annex A](#)).
- WordCount specifies the number of 16-bit words to be erased. If WordCount=00_h then a Tag shall treat the *BlockErase* as invalid. If WordCount=01_h then a Tag shall erase a single data word.

A Tag shall only execute a *BlockErase* in the **open** or **secured** state.

If an Interrogator attempts to erase the kill or access password, EPC or TID memory banks, or File_0 and these memory locations are permalocked; or the kill or access password, EPC or TID memory banks, or File_0 and these memory locations are locked unwriteable and the Tag is in the **open** state; or to memory that is untraceably hidden and the Interrogator has a deasserted Untraceable privilege; or a file for which the Interrogator does not have sufficient privileges; or if WordPtr and WordCount include one or more permalocked blocks in File_N, N≥0 of User memory; then the Tag shall not execute the *BlockErase* and instead treat the command's parameters as unsupported (see Table C.30).

An Interrogator shall prepend a *BlockErase* with a frame-sync (see 6.3.1.2.8).

An unauthenticated Interrogator may, and an authenticated Interrogator shall, encapsulate a *BlockErase* in a *SecureComm* or *AuthComm* (see Table 6.28).

Upon receiving an executable *BlockErase* command a Tag shall erase the commanded memory words.

A Tag shall reply to a *BlockErase* using the *delayed* reply specified in 6.3.1.6.2.

Table 6.54: *BlockErase* command

	Command	MemBank	WordPtr	WordCount	RN	CRC
# of bits	8	2	EBV	8	16	16
description	11001000	00: Reserved 01: EPC 10: TID 11: User	Starting address pointer	Number of words to erase	<u>handle</u>	

6.3.2.12.3.9 *BlockPermalock* (optional)

Interrogators and Tags may implement a *BlockPermalock* command; if they do, they shall implement it as shown in Table 6.56. *BlockPermalock* allows an Interrogator to:

- Permalock one or more memory blocks in the currently open file of a Tag's User memory, or
- Read the permalock status of the memory blocks in the currently open file of a Tag's User memory.

A *BlockPermalock* may permalock between zero and 4080 memory blocks. The block size, which is predefined by the Tag manufacturer, is fixed at between one and 1024 words, is the same for all files, and is the same for block permalocking and file allocation. The memory blocks specified by a *BlockPermalock* need not be contiguous.

A Tag shall only execute a *BlockPermalock* in the **secured** state.

A *BlockPermalock* differs from a *Lock* in that *BlockPermalock* permanently locks individual blocks of File_N, N≥0 of User memory in an unwriteable state whereas *Lock* reversibly or permanently locks the kill and/or access password, the EPC memory bank, the TID memory bank, and/or File_0 of User memory in a writeable or unwriteable state. Table 6.55 specifies how a Tag shall behave upon receiving a *BlockPermalock* targeting File_0 that follows a prior *Lock*, or vice versa (assuming Read/Lock=1).

A *BlockPermalock* has the following fields:

- MemBank specifies whether the *BlockPermalock* applies to EPC, TID, or User memory. *BlockPermalock* commands shall apply to a single memory bank. Successive *BlockPermalocks* may apply to different memory banks. A Tag shall only execute a *BlockPermalock* command if MemBank=11 (User memory); if a Tag receives a *BlockPermalock* with MemBank<>11 then it shall not execute the *BlockPermalock* and instead treat the command's parameters as unsupported (see Table C.30). Future protocols may use these other MemBank values to expand the functionality of the *BlockPermalock* command.
- Read/Lock specifies whether a Tag backscatters the permalock status of, or permalocks, one or more blocks within the memory bank specified by MemBank. A Tag shall interpret the Read/Lock bit as follows:
 - Read/Lock=0: A Tag shall backscatter the permalock status of blocks in the specified memory bank, starting from the memory block located at BlockPtr and ending at the memory block located at BlockPtr+(16×BlockRange)−1. A Tag shall backscatter a "0" if the memory block corresponding to that bit is not permalocked and a "1" if the block is permalocked. An Interrogator omits Mask from the *BlockPermalock* when Read/Lock=0.

Table 6.55: Precedence for *Lock* and *BlockPermalock* targeting File_0

First Command		Second Command		Tag Action and Response to 2 nd Command
<i>Lock</i>	<u>pwd-write</u>	<u>permalock</u>	<i>BlockPermalock</i> (<u>Read/Lock</u> =1)	
	0	0		Permalock the blocks indicated by <u>Mask</u> ; respond as described in this section 6.3.2.12.3.9
	0	1		Do not execute the <i>BlockPermalock</i> ; respond with an error code (Table C.30, unsupported parameters)
	1	0		Permalock the blocks indicated by <u>Mask</u> ; respond as described in this section 6.3.2.12.3.9
	1	1		Permalock the blocks indicated by <u>Mask</u> ; respond as described in this section 6.3.2.12.3.9
<i>BlockPermalock</i> (<u>Read/Lock</u> =1)		<u>pwd-write</u>	<u>permalock</u>	
		0	0	Implement the <i>Lock</i> , but do not un-permalock any blocks that were previously permalocked; respond as described in 6.3.2.12.3.5
		0	1	Implement the <i>Lock</i> , but do not un-permalock any blocks that were previously permalocked; respond as described in 6.3.2.12.3.5
		1	0	Implement the <i>Lock</i> , but do not un-permalock any blocks that were previously permalocked; respond as described in 6.3.2.12.3.5
		1	1	Implement the <i>Lock</i> ; respond as described in 6.3.2.12.3.5

- Read/Lock=1: A Tag shall permalock those blocks in the specified memory bank that are specified by Mask, starting at BlockPtr and ending at BlockPtr+(16×BlockRange)−1.
- BlockPtr specifies the starting address for Mask, in units of 16 blocks. For example, BlockPtr=00_h indicates block 0, BlockPtr=01_h indicates block 16, BlockPtr=02_h indicates block 32. BlockPtr uses EBV formatting (see [Annex A](#)).
- BlockRange specifies the range of Mask, starting at BlockPtr and ending (16×BlockRange)−1 blocks later. If BlockRange=00_h then a Tag shall not execute the *BlockPermalock* and instead treat the command's parameters as unsupported (see Table C.30).
- Mask specifies which memory blocks a Tag permalocks. Mask depends on the Read/Lock bit as follows:
 - Read/Lock=0: The Interrogator shall omit Mask from the *BlockPermalock*.
 - Read/Lock=1: The Interrogator shall include a Mask of length 16×BlockRange bits in the *BlockPermalock*. The Mask bits shall be ordered from lower-order block to higher (i.e. if BlockPtr=00_h then the leading Mask bit refers to block 0). The Tag shall interpret each bit of Mask as follows:
 - Mask bit=0: Retain the current permalock setting for the corresponding memory block.
 - Mask bit=1: Permalock the corresponding memory block. If a block is already permalocked then a Tag shall retain the current permalock setting. A memory block, once permalocked, cannot be un-permalocked.

The following example illustrates the usage of Read/Lock, BlockPtr, BlockRange, and Mask: If Read/Lock=1, BlockPtr=01_h, and BlockRange=01_h then the Tag operates on sixteen blocks starting at block 16 and ending at block 31, permalocking those blocks whose corresponding bits are asserted in Mask.

A *BlockPermalock* contains 8 RFU bits. An Interrogator shall set these bits to 00_h. A Tag in the **secured** state that receives a *BlockPermalock* with nonzero RFU bits shall not execute the *BlockPermalock* and instead treat the command's parameters as unsupported (see Table C.30). Future protocols may use these RFU bits to expand the *BlockPermalock* command's functionality.

If a Tag receives a *BlockPermalock* that it cannot execute because User memory does not exist, or User memory is untraceably hidden and the Interrogator has a deasserted Untraceable privilege, or in which one of the asserted Mask bits references a non-existent memory block, or because the Interrogator has insufficient file privileges (see 6.3.2.11.3) then the Tag shall not execute the *BlockPermalock* and instead treat the command's parameters as unsupported (see Table C.30). A Tag shall treat as invalid a *BlockPermalock* in which Read/Lock=0 but Mask is not omitted, or a *BlockPermalock* in which Read/Lock=1 but Mask has a length not equal to 16×BlockRange bits (see Table C.30).

Certain Tags, depending on the Tag manufacturer's implementation, may be unable to execute a *BlockPermalock* with certain BlockPtr and BlockRange values, in which case the Tag shall not execute the *BlockPermalock* and instead treat the command's parameters as unsupported (see Table C.30). Because a Tag contains information in its TID memory that an Interrogator can use to identify the optional features that the Tag supports (see 6.3.2.1.3), this protocol recommends that an Interrogator read a Tag's TID memory prior to issuing a *BlockPermalock*.

If an Interrogator issues a *BlockPermalock* in which BlockPtr and BlockRange specify one or more nonexistent blocks, but Mask only asserts permalocking on existent blocks, then the Tag shall execute the *BlockPermalock*.

An Interrogator shall prepend a *BlockPermalock* with a frame-sync (see 6.3.1.2.8).

An unauthenticated Interrogator may, and an authenticated Interrogator shall, encapsulate a *BlockPermalock* in a *SecureComm* or *AuthComm* (see Table 6.28).

Upon receiving an executable *BlockPermalock* a Tag shall perform the requested operation, unless the Tag does not support block permalocking in which case it shall treat the command as invalid (see Table C.30).

If Read/Lock=0 then a Tag shall reply to a *BlockPermalock* using the *immediate* reply type specified in 6.3.1.6.1. If the Tag is able to execute the *BlockPermalock* then its reply shall be as shown in Table 6.57 comprising a header (a 0-bit), the requested permalock bits, and the Tag's handle. The reply includes a CRC-16 calculated over the 0-bit, permalock bits, and handle. If the Tag is unable to execute the *BlockPermalock* then it shall backscatter an error code (see Table C.30, unsupported parameters) rather than the reply shown in Table 6.57. The Tag's reply when Read/Lock=0 shall use the preamble specified by the TRExt value in the *Query* that initiated the inventory round.

If Read/Lock=1 then a Tag shall reply to a *BlockPermalock* using the *delayed* reply specified in 6.3.1.6.2.

Table 6.56: *BlockPermalock* command

	Command	RFU	Read/Lock	MemBank	BlockPtr	BlockRange	Mask	RN	CRC
# of bits	8	8	1	2	EBV	8	Variable	16	16
description	11001001	00 _h	0: Read 1: Permalock	00: RFU 01: EPC 10: TID 11: User	<u>Mask</u> starting address, specified in units of 16 blocks	<u>Mask</u> range, specified in units of 16 blocks	0: Retain current permalock setting 1: Assert permalock	<u>handle</u>	CRC-16

Table 6.57: Tag reply to a successful *BlockPermalock* command with Read/Lock=0

	Header	Data	RN	CRC
# of bits	1	Variable	16	16
description	0	Permalock bits	<u>handle</u>	CRC-16

6.3.2.12.3.10 *Authenticate* (optional)

Interrogators and Tags may implement the *Authenticate* command; if they do, they shall implement it as shown in Table 6.58. *Authenticate* allows an Interrogator to perform Tag, Interrogator, or mutual authentication. The generic nature of the *Authenticate* command allows it to support a variety of cryptographic suites. The CSI specified in an *Authenticate* selects one cryptographic suite from among those supported by the Tag. The number of *Authenticate* commands required to implement an authentication depends on the authentication type and on the chosen cryptographic suite. A Tag only executes an *Authenticate* in the **open** or **secured** state. *Authenticate* has the following fields:

- SenRep specifies whether a Tag backscatters its response or stores the response in its ResponseBuffer.
- IncRepLen specifies whether a Tag omits or includes length in its reply. If IncRepLen=0 then a Tag omits length from its reply; if IncRepLen=1 then the Tag includes length in its reply.
- CSI selects the cryptographic suite that Tag and Interrogator use for the authentication as well as for all subsequent communications (until the Interrogator initiates another authentication with a different CSI or the Tag leaves the **open** or **secured** state).
- Length is the message length in bits.
- Message includes parameters for the authentication.

An *Authenticate* contains 2 RFU bits. An Interrogator shall set these bits to 00₂. A Tag in the **open** or **secured** states that receives an *Authenticate* with nonzero RFU bits shall not execute the *Authenticate* and instead treat the command's parameters as unsupported (see Table C.30). Future protocols may use these RFU bits to expand the *Authenticate* command's functionality.

An Interrogator shall prepend an *Authenticate* with a frame-sync (see 6.3.1.2.8).

An Interrogator shall not encapsulate an *Authenticate* in a *SecureComm* or *AuthComm* (see Table 6.28).

If a Tag supports the *Authenticate* command then it shall implement the security (**S**) indicator (see 6.3.2.1.3).

The cryptographic suite specifies message formatting, the number of steps in an authentication, whether an authentication implements wait states, the behavior if Tag or Interrogator cannot complete a computation, and the behavior in the event of an incorrect cryptographic response. It specifies the formatting of the Tag's response for both a successful and an unsuccessful authentication. It may include parameters, such as a key, that affect pre- and post-authenticated communications. It may contain information about how Tag and Interrogator derive session keys for subsequent communications. See [Annex M](#) for the parameters specified by a cryptographic suite.

An *Authenticate* command shall use the *in-process* reply specified in 6.3.1.6.3. The parameters that a Tag includes in its response are specified by the cryptographic suite. See [Annex M](#).

If a Tag receives an *Authenticate* specifying an unsupported CSI, an improperly formatted or not-executable message, or an improper cryptographic parameter then the Tag shall not execute the *Authenticate* and instead treat the command's parameters as unsupported (see Table C.30). If a Tag in the **secured** state receives an *Authenticate* that begins a new authentication, such as if the *Authenticate* contains a changed CSI, then the Tag shall transition to the **open** state, discontinue using and reset the current cryptographic engine, and begin the new authentication.

If a Tag receives a properly formatted *Authenticate* but there is a cryptographic error, and the cryptographic suite specifies that the error requires a security timeout, then the Tag shall set a security timeout as specified in 6.3.2.5. If a Tag that supports security timeouts for the *Authenticate* command receives an *Authenticate* during a timeout then it shall reject the command, backscatter an error code (see [Annex I](#)), and remain in its current state.

Table 6.58: *Authenticate* command

	Command	RFU	SenRep	IncRepLen	CSI	Length	Message	RN	CRC
# of bits	8	2	1	1	8	12	Variable	16	16
description	11010101	00	0: store 1: send	0: Omit <u>length</u> from reply 1: Include <u>length</u> in reply	<u>CSI</u>	<u>length of message</u>	<u>message</u> (depends on <u>CSI</u>)	<u>handle</u>	CRC-16

6.3.2.12.3.11 *AuthComm* (optional)

Interrogators and Tags may implement the *AuthComm* command; if they do, they shall implement it as shown in Table 6.59. *AuthComm* allows authenticated communications from R=>T by encapsulating another command and typically also a MAC in the *AuthComm*'s message field. Table 6.28 shows the commands that an *AuthComm* may encapsulate. The generic nature of an *AuthComm* allows it to support a wide variety of cryptographic suites. An *AuthComm* shall always be preceded by a Tag, Interrogator, or mutual authentication via an *Authenticate* or a *Challenge*. The cryptographic suite indicated by the CSI in the *Authenticate* or *Challenge* that preceded the *AuthComm* specifies message and reply formatting. A Tag may include a MAC in its reply, again as specified by the cryptographic suite. A Tag only executes an *AuthComm* in the **open** or **secured** state. *AuthComm* has the following fields:

- IncRepLen specifies whether the Tag omits or includes length in its reply. If IncRepLen=0 then the Tag omits length from its reply; if IncRepLen=1 then the Tag includes length in its reply.
- Message includes the encapsulated command and other parameters (such as a MAC) as specified by the cryptographic suite. An Interrogator shall remove the command's preamble, handle, and CRC before encapsulating it in an *AuthComm*. The encapsulated command shall not be encrypted or obscured.

An *AuthComm* contains 2 RFU bits. An Interrogator shall set these bits to 00₂. A Tag in the **open** or **secured** states that receives an *AuthComm* with nonzero RFU bits shall not execute the *AuthComm* and instead treat the command's parameters as unsupported (see Table C.30). Future protocols may use these RFU bits to expand the *AuthComm* command's functionality.

A Tag in the **open** or **secured** states that receives an *AuthComm* encapsulating a disallowed command, an unsupported command, or a command that does not support encapsulation (see Table 6.28) shall not execute the *AuthComm* and instead treat the command's parameters as unsupported (see Table C.30).

An Interrogator shall prepend an *AuthComm* with a frame-sync (see 6.3.1.2.8).

A Tag shall only accept an *AuthComm* after a successful cryptographic authentication. Because an *Access* command sequence is not a cryptographic authentication, a Tag that most recently entered the **secured** state via a successful *Access* command sequence shall not execute an *AuthComm* and instead treat the command's parameters as unsupported (see Table C.30).

When processing an *AuthComm* a Tag shall first perform the functions/analysis/state-change/error-handling for the *AuthComm* itself and then, if the *AuthComm* is successful, the functions/analysis/state-change/error-handling for the command encapsulated in the *AuthComm*'s message field. In some instances, such as when an *AuthComm* encapsulates an authenticated *Kill*, the Tag may change state in response to the encapsulated command even though it did not change state in response to the *AuthComm* itself.

A Tag shall reply to an *AuthComm* using the *in-process* reply specified in 6.3.1.6.3. The cryptographic suite shall specify the parameters that a Tag includes in its response, including at least the reply for the encapsulated command minus preamble, handle, and CRC. For example, if the encapsulated command is a *Read* then the reply includes at least the read data or an error code as appropriate for a *Read*. Unlike other commands that use an *in-process* reply, *AuthComm* does not include a SenRep field because a Tag shall always send (i.e. never store) its reply to an *AuthComm*.

An *AuthComm* may exhibit behavior different from other commands because an *AuthComm* itself may succeed or fail or the encapsulated command, such as a *Lock*, may succeed or fail. Done and header in the reply of Table 6.14 indicate success or failure of the *AuthComm*. Response in the reply of Table 6.14 indicates success or failure of the encapsulated command. For example, suppose a Tag receives an *AuthComm* with IncRepLen=1 encapsulating a command whose reply type is *delayed* (such as a *Lock*). Upon successfully completing the *Lock* the Tag's reply will be as shown in Table 6.14 with done=1 and header=0, indicating that the *AuthComm* executed successfully, and length=0002_h and result=0, indicating that the *Lock* completed successfully. Note that this example presumes that the Tag was in the **secured** state; if the Tag was in the **open** state then the *AuthComm* would succeed but the reply to the *Lock* would be an error code.

If a Tag receives a properly formatted *AuthComm* but there is a cryptographic error, and the cryptographic suite specifies that the error requires a security timeout, then the Tag shall set a security timeout as specified in 6.3.2.5. If a Tag that supports security timeouts for the *AuthComm* command and receives an *AuthComm* during a timeout then it shall reject the command, backscatter an error code (see [Annex I](#)), and remain in its current state.

Table 6.59: *AuthComm* command

	Command	RFU	IncRepLen	Message	RN	CRC
# of bits	8	2	1	Variable	16	16
description	11010111	00 ₂	0: Omit <u>length</u> from reply 1: Include <u>length</u> in reply	<u>message</u>	<u>handle</u>	CRC-16

6.3.2.12.3.12 *SecureComm* (optional)

Interrogators and Tags may implement the *SecureComm* command; if they do, they shall implement it as shown in Table 6.60. *SecureComm* allows encrypted communications from R=>T by encapsulating another, encrypted command in the *SecureComm*'s message field. Table 6.28 shows the commands that a *SecureComm* may encapsulate. The generic nature of a *SecureComm* allows it to support a wide variety of cryptographic suites. A *SecureComm* shall always be preceded by a Tag, Interrogator, or mutual authentication via an *Authenticate* or a *Challenge*. The cryptographic suite indicated by the CSI in the *Authenticate* or *Challenge* that preceded the *SecureComm* specifies message and reply formatting. A Tag may encrypt and/or include a MAC in its reply, again as specified by the cryptographic suite. A Tag only executes a *SecureComm* in the **open** or **secured** state. *SecureComm* has the following fields:

- SenRep specifies whether a Tag backscatters its response or stores the response in its ResponseBuffer.
- IncRepLen specifies whether the Tag omits or includes length in its reply. If IncRepLen=0 then the Tag omits length from its reply; if IncRepLen=1 then the Tag includes length in its reply.
- Length is the message length, in bits.
- Message includes the encapsulated command and other parameters (such as a MAC) as specified by the cryptographic suite. An Interrogator shall remove the command's preamble, handle, and CRC before encapsulating it in a *SecureComm*. The encapsulated command shall be encrypted.

A *SecureComm* contains 2 RFU bits. An Interrogator shall set these bits to 00₂. A Tag in the **open** or **secured** states that receives a *SecureComm* with nonzero RFU bits shall not execute the *SecureComm* and instead treat the command's parameters as unsupported (see Table C.30). Future protocols may use these RFU bits to expand the *SecureComm* command's functionality.

A Tag in the **open** or **secured** states that receives a *SecureComm* encapsulating a disallowed command, an unsupported command, or a command that does not support encapsulation (see Table 6.28) shall not execute the *SecureComm* and instead treat the command's parameters as unsupported (see Table C.30).

An Interrogator shall prepend a *SecureComm* with a frame-sync (see 6.3.1.2.8).

A Tag shall only accept a *SecureComm* after a successful cryptographic authentication. Because an *Access* command sequence is not a cryptographic authentication, a Tag that most recently entered the **secured** state via a successful *Access* command sequence shall not execute a *SecureComm* and instead treat the command's parameters as unsupported (see Table C.30).

When processing a *SecureComm* a Tag shall first perform the functions/analysis/state-change/error-handling for the *SecureComm* itself and then, if the *SecureComm* is successful, the functions/analysis/state-change/error-handling for the command encapsulated in the *SecureComm*'s message field. In some instances, such as when a *SecureComm* encapsulates an authenticated *Kill*, the Tag may change state in response to the encapsulated command even though it did not change state in response to the *SecureComm* itself.

A Tag shall reply to a *SecureComm* using the *in-process* reply specified in 6.3.1.6.3. The cryptographic suite shall specify the parameters that a Tag includes in its response, including at least the reply for the encapsulated command minus preamble, handle, and CRC. For example, if the encapsulated command is a *Read* then the reply includes at least the read data or an error code as appropriate for a *Read*.

A *SecureComm* may exhibit behavior different from other commands because a *SecureComm* itself may succeed or fail or the encapsulated command, such as a *Lock*, may succeed or fail. Done and header in the reply of Table 6.14 indicate success or failure of the *SecureComm*. Response in the reply of Table 6.14 indicates success or failure of the encapsulated command. For example, suppose a Tag receives a *SecureComm* with IncRepLen=1 and SenRep=1 encapsulating a command whose reply type is *delayed* (such as a *Lock*). Upon successfully completing the *Lock* the Tag's reply will be as in Table 6.14 with done=1 and header=0, indicating the *SecureComm* executed successfully, and length=0002_h and result=0, indicating that the *Lock* completed successfully. Alternatively, if SenRep=0 then the reply will be as shown in Table 6.14 with done=1 and header=0, indicating the *SecureComm* executed successfully, and length=0002_h and result=null, indicating that the *Lock* completed successfully and result (O₂) is in the ResponseBuffer. In this latter case the Tag asserts **C** in XPC_W1 to indicate that the ResponseBuffer contains a computed result. This example presumes that the Tag was in the **secured** state; if it was in the **open** state then the *SecureComm* would succeed but the reply to the *Lock* would be an error code.

If a Tag receives a properly formatted *SecureComm* but there is a cryptographic error, and the cryptographic suite specifies that the error requires a security timeout, then the Tag shall set a security timeout as specified in 6.3.2.5. If a Tag that supports security timeouts for the *SecureComm* command receives a *SecureComm* during a timeout then it shall reject the command, backscatter an error code (see [Annex I](#)), and remain in its current state.

Table 6.60: *SecureComm* command

	Command	RFU	SenRep	IncRepLen	Length	Message	RN	CRC
# of bits	8	2	1	1	12	Variable	16	16
description	11010110	00	0: store 1: send	0: Omit <u>length</u> from reply 1: Include <u>length</u> in reply	<u>length of message</u>	<u>message</u>	<u>handle</u>	CRC-16

6.3.2.12.3.13 *KeyUpdate* (optional)

Interrogators and Tags may implement the *KeyUpdate* command; if they do, they shall implement it as shown in Table 6.61. *KeyUpdate* allows an Interrogator to write or overwrite a key stored in a Tag. The generic nature of a *KeyUpdate* allows it to support a wide variety of cryptographic suites. A *KeyUpdate* shall always be preceded by an Interrogator or mutual authentication via an *Authenticate*. The cryptographic suite indicated by the CSI in the *Authenticate* that preceded the *KeyUpdate* specifies message and reply formatting. A Tag only executes a *KeyUpdate* in the **secured** state. *KeyUpdate* has the following fields:

- SenRep specifies whether a Tag backscatters its response or stores the response in its ResponseBuffer.
- IncRepLen specifies whether the Tag omits or includes length in its reply. If IncRepLen=0 then the Tag omits length from its reply; if IncRepLen=1 then the Tag includes length in its reply.
- Length is the message length, in bits.
- KeyID specifies the key to be written or updated.
- Message is or contains the key. Message may contain other parameters (such as a MAC) as specified by the cryptographic suite. Message may be encrypted.

A *KeyUpdate* contains 2 RFU bits. An Interrogator shall set these bits to 00₂. A Tag in the **secured** state that receives a *KeyUpdate* with nonzero RFU bits shall not execute the *KeyUpdate* and instead treat the command's parameters as unsupported (see Table C.30). Future protocols may use these RFU bits to expand the *KeyUpdate* command's functionality.

An Interrogator may encapsulate a *KeyUpdate* in a *SecureComm* or an *AuthComm* (see Table 6.28). If a cryptographic suite requires that *KeyUpdate* be encapsulated in a *SecureComm* then message in the *KeyUpdate* need not be encrypted. If a cryptographic suite allows sending a *KeyUpdate* in an *AuthComm* or without encapsulation then message in the *KeyUpdate* shall be encrypted.

A Tag in the **secured** state shall only write a key if (a) the Interrogator authenticated itself as a crypto superuser and KeyID is assigned to the same cryptographic suite as that specified by CSI in the *Authenticate* command that preceded the *KeyUpdate*, or (b) KeyID is the same as that used by the Interrogator to authenticate itself. In all other instances the Tag shall not execute the *KeyUpdate* and instead treat the command's parameters as unsupported (see Table C.30). See 6.3.2.11.2 for a description of Tag privileges and the crypto superuser privilege.

Upon receiving an executable *KeyUpdate* a Tag shall overwrite its old key with the new key. If the Tag does not write the new key successfully then it shall revert to the prior stored key. A Tag may meet this latter requirement by, for example, double-buffering the write operation.

An Interrogator shall prepend an unencapsulated *KeyUpdate* with a frame-sync (see 6.3.1.2.8).

A Tag shall only accept a *KeyUpdate* after a successful cryptographic authentication. Because an *Access* command sequence is not a cryptographic authentication, a Tag that most recently entered the **secured** state via a successful *Access* command sequence shall not execute a *KeyUpdate* and instead treat the command's parameters as unsupported (see Table C.30).

A Tag shall reply to a *KeyUpdate* using the *in-process* reply specified in 6.3.1.6.3. The cryptographic suite shall specify the parameters that a Tag includes in its response.

If a Tag receives a properly formatted *KeyUpdate* but there is a cryptographic error, and the cryptographic suite specifies that the error requires a security timeout, then the Tag shall set a security timeout as specified in 6.3.2.5. If a Tag that supports security timeouts for the *KeyUpdate* command receives a *KeyUpdate* during a timeout then it shall reject the command, backscatter an error code (see [Annex I](#)), and remain in its current state.

Table 6.61: *KeyUpdate* command

	Command	RFU	SenRep	IncRepLen	KeyID	Length	Message	RN	CRC
# of bits	16	2	1	1	8	12	Variable	16	16
description	11100010 00000010	00	0: store 1: send	0: Omit <u>length</u> from reply 1: Include <u>length</u> in reply	<u>KeyID</u>	<u>length of message</u>	<u>message</u>	<u>handle</u>	CRC-16

6.3.2.12.3.14 *TagPrivilege* (optional)

Interrogators and Tags may implement the *TagPrivilege* command; if they do, they shall implement it as shown in Table 6.62. *TagPrivilege* allows an Interrogator to read or modify the Tag privileges in Table 6.22 or Table 6.23 for the access password or for a key, respectively. A Tag only executes a *TagPrivilege* in the **secured** state. *TagPrivilege* has the following fields:

- SenRep specifies whether a Tag backscatters its response or stores the response in its ResponseBuffer.
- IncRepLen specifies whether the Tag omits or includes length in its reply. If IncRepLen=0 then the Tag omits length from its reply; if IncRepLen=1 then the Tag includes length in its reply.
- Action specifies whether the Interrogator is reading privileges or modifying them. Action=0 indicates read; Action=1 indicates modify.
- Target specifies whether the Interrogator is targeting the access password or a key. If Target=0 then the Tag reads or modifies the access-password privileges; if Target=1 then the Tag reads or modifies the Tag privileges for the key indicated by KeyID.
- KeyID specifies the key for the privileges being read or written.
- Privilege specifies values for each of the 16 Tag privileges in Table 6.22 or Table 6.23 when an Interrogator is modifying a privilege (i.e. when Action=1).

A *TagPrivilege* contains 2 RFU bits. An Interrogator shall set these bits to 00₂. A Tag in the **secured** state that receives a *TagPrivilege* containing nonzero RFU bits shall not execute the *TagPrivilege* and instead treat the command's parameters as unsupported (see Table C.30). Future protocols may use these RFU bits to expand the *TagPrivilege* command's functionality.

An unauthenticated Interrogator may issue a *TagPrivilege*; if it does then it shall issue the *TagPrivilege* without encapsulation and with Target=0 (i.e. specifying the access password).

An authenticated Interrogator shall encapsulate a *TagPrivilege* in a *SecureComm* or *AuthComm* (see Table 6.28). If a Tag in the **secured** state receives an unencapsulated *TagPrivilege* from an authenticated Interrogator then it shall not execute the *TagPrivilege* and instead treat the command's parameters as unsupported (see Table C.30).

A Tag in the **secured** state shall only read or modify the access-password privileges if the Interrogator supplied the correct access password and is not attempting to assert a deasserted privilege. In all other instances the Tag shall not execute the *TagPrivilege* and instead treat the command's parameters as unsupported (see Table C.30).

A Tag in the **secured** state shall only read or modify a key's privileges if (a) the Interrogator authenticated itself as a crypto superuser and KeyID is assigned to the same cryptographic suite as that specified by CSI in the *Authenticate* command that preceded the *TagPrivilege*, or (b) KeyID is the same as that used by the Interrogator to authenticate itself and the Interrogator is not attempting to assert a deasserted privilege.

If an Interrogator specifies Action=0 in a *TagPrivilege* then it may use any value for privilege. A Tag shall ignore privilege when Action=0.

If an Interrogator specifies Target=0 in a *TagPrivilege* then it may use any value for the KeyID. If Tag receives a *TagPrivilege* with Target=0 then it shall ignore the value that the Interrogator supplies for KeyID.

Upon receiving an executable *TagPrivilege* with Action=1 a Tag shall overwrite the old privileges with the new privileges. If the Tag does not write the new privileges successfully then it shall revert to the prior stored privileges. A Tag may meet this latter requirement by, for example, double-buffering the write operation.

A Tag in the **secured** state that receives a *TagPrivilege* which attempts to assert one or more RFU privilege bits or to change an unchangeable privilege value shall not execute the *TagPrivilege* and instead treat the command's parameters as unsupported (see Table C.30).

An Interrogator shall prepend an unencapsulated *TagPrivilege* with a frame-sync (see 6.3.1.2.8).

A Tag shall reply to a *TagPrivilege* using the *in-process* reply specified in 6.3.1.6.3. The Tag's response shall be as shown in Table 6.63 for Action=0 or Action=1. The response includes Target, the Interrogator-supplied KeyID, and the current privileges (newly written if Action=1 and the Tag wrote the new privileges successfully).

Table 6.62: *TagPrivilege* command

	Command	RFU	SenRep	IncRepLen	Action	Target	KeyID	Privileges	RN	CRC
# of bits	16	2	1	1	1	1	8	16	16	16
description	11100010 00000011	00	0: store 1: send	0: Omit <u>length</u> from reply 1: Include <u>length</u> in reply	0: read 1: modify	0: access pwd 1: key	<u>KeyID</u>	<u>privilege</u>	<u>handle</u>	CRC-16

Table 6.63: Tag reply to a successful *TagPrivilege* command

	Target	KeyID	Privileges
# of bits	1	8	16
description	0: access pwd 1: key	<u>KeyID</u>	<u>privilege</u>

6.3.2.12.3.15 *ReadBuffer* (optional)

Interrogators and Tags may implement the *ReadBuffer* command; if they do, they shall implement it as shown in Table 6.64. *ReadBuffer* allows an Interrogator to read data stored in a Tag's ResponseBuffer. A Tag only executes a *ReadBuffer* in the **open** or **secured** state and only if the Tag's **C** flag is asserted. *ReadBuffer* has the following fields:

- WordPtr specifies the starting word address for the read. For example, WordPtr=000_h specifies the first 16-bit memory word, WordPtr=001_h specifies the second 16-bit memory word, etc.
- BitCount specifies the number of bits to read. If BitCount=000_h then a Tag shall backscatter the contents of the ResponseBuffer starting at WordPtr and ending at the end of the allocated ResponseBuffer.

A *ReadBuffer* contains 2 RFU bits. An Interrogator shall set these bits to 00₂. A Tag in the **open** or **secured** states that receives a *ReadBuffer* with nonzero RFU bits shall not execute the *ReadBuffer* and instead treat the command's parameters as unsupported (see Table C.30). Future protocols may use these RFU bits to expand the *ReadBuffer* command's functionality.

An Interrogator may encapsulate a *ReadBuffer* in an *AuthComm* but shall not encapsulate it in a *SecureComm* (see Table 6.28).

If a Tag implements a ResponseBuffer then that Tag shall implement the *ReadBuffer* command.

An Interrogator shall prepend an unencapsulated *ReadBuffer* with a frame-sync (see 6.3.1.2.8).

A Tag shall reply to a *ReadBuffer* using the *immediate* reply specified in 6.3.1.6.1. If **C**=1 and the memory bits specified in the *ReadBuffer* exist then the Tag's reply shall be as shown in Table 6.65 including a header (a 0-bit), the data bits, and the Tag's handle. The reply includes a CRC-16 calculated over the 0-bit, data bits, and handle. If one or more of the memory bits specified in the *ReadBuffer* do not exist, or if the **C** flag in XPC_W1 is zero-valued, then the Tag shall not execute the *ReadBuffer* and instead backscatter an error code (see Table C.30, unsupported parameters) within time T₁ in Table 6.16 rather than the reply shown in Table 6.65.

Table 6.64: *ReadBuffer* command

	Command	RFU	WordPtr	BitCount	RN	CRC
# of bits	8	2	12	12	16	16
description	11010010	00	Starting address pointer	Number of bits to read	<u>handle</u>	CRC-16

Table 6.65: Tag reply to a successful *ReadBuffer* command

	Header	Data Bits	RN	CRC
# of bits	1	Variable	16	16
description	0	<u>data</u>	<u>handle</u>	CRC-16

6.3.2.12.3.16 *Untraceable* (optional)

Interrogators and Tags may implement the *Untraceable* command; if they do, they shall implement it as shown in Table 6.66. *Untraceable* allows an Interrogator with an asserted *Untraceable* privilege to instruct a Tag to (a) alter the **L** and **U** bits in EPC memory, (b) hide memory from Interrogators with a deasserted *Untraceable* privilege, and/or (c) reduce its operating range for all Interrogators. The memory that a Tag may hide includes words of EPC memory, the Tag serialization in TID memory, all of TID memory, and/or User memory (File_0 and above). *Untraceable* and traceable Tags behave identically from a state-machine and command-response perspective; the difference between them is (a) the memory the Tag exposes to an Interrogator with a deasserted *Untraceable* privilege and/or (b) the Tag's operating range. A Tag only executes an *Untraceable* in the **secured** state. *Untraceable* has the following fields:

- **U** specifies a value for the **U** bit in XPC_W1 (see 6.3.2.1.2.2). Upon receiving an *Untraceable* command a Tag that supports the **U** bit shall overwrite bit 21C_h of XPC_W1 with the provided **U** value regardless of the lock or permalock status of EPC memory. If the Tag does not support the **U** bit then the Tag shall ignore the provided **U** value but continue to process the remainder of the *Untraceable*.
- **EPC** includes a **show/hide** bit (MSB) and 5 **length** bits (5 LSBs). These fields operate independently.
 - **Show/hide** specifies whether a Tag untraceably hides part of EPC memory. If **show/hide**=0₂ then a Tag exposes EPC memory. If **show/hide**=1₂ then a Tag untraceably hides EPC memory above that set by its EPC length field (i.e. StoredPC bits 10_h – 14_h) to bit 20F_h (inclusive).
 - **Length** specifies a new EPC length field (**L** bits). Upon receiving an *Untraceable* command a Tag shall overwrite its EPC length field (StoredPC bits 10_h – 14_h) with the provided **length** bits regardless of the lock or permalock status of EPC memory. In response to subsequent *ACKs* the Tag backscatters an EPC whose length is set by the new **length** bits.
- **TID** specifies the TID memory that a Tag untraceably hides. If **TID**=00₂ then a Tag exposes TID memory. If **TID**=01₂ and a Tag's allocation class identifier (see 6.3.2.1.3) is E0_h then the Tag untraceably hides TID memory above 10_h, inclusive; if the Tag's allocation class identifier is E2_h then the Tag untraceably hides TID memory above 20_h, inclusive. If **TID**=10₂ then the Tag untraceably hides all of TID memory. **TID**=11₂ is RFU.
- **User** specifies whether a Tag untraceably hides User memory. If **User**=0₂ then the Tag exposes User memory. If **User**=1₂ then the Tag untraceably hides User memory (i.e. hides File_0 and above).
- **Range** specifies a Tag's operating range. If **range**=00₂ then the Tag persistently enables normal operating range. If **range**=10₂ then the Tag persistently enables reduced operating range. If **range**=01₂ then the Tag temporarily toggles its operating range (if normal then to reduced; if reduced then to normal) but reverts to its prior persistent operating range when the Tag loses power. Temporary toggling allows an Interrogator to confirm that a Tag is still readable before committing range-reduced untraceability to the Tag's non-volatile memory (by sending a subsequent *Untraceable* with **range**=10₂). **Range**=11₂ is RFU. A Tag shall execute a range change prior to replying to the *Untraceable*. The range-reduction details, including its magnitude and the commands to which it applies, are manufacturer-defined. If a Tag does not support range reduction then it shall ignore **range** but continue to process the remainder of the *Untraceable*.

An *Untraceable* contains 2 RFU bits. An Interrogator shall set these bits to 00₂. A Tag in the **secured** state that receives an *Untraceable* with nonzero RFU bits, **TID**=11₂, or **range**=11₂ shall not execute the *Untraceable* and instead treat the command's parameters as unsupported (see Table C.30). Future protocols may use these RFU bits to expand the *Untraceable* command's functionality.

If a Tag in the **secured** state receives an *Untraceable* from an Interrogator with an asserted *Untraceable* privilege then it shall execute the command; if the Interrogator has a deasserted *Untraceable* privilege then the Tag shall not execute the command and instead treat the command's parameters as unsupported (see Table C.30).

An unauthenticated Interrogator may issue an *Untraceable* without encapsulation. An authenticated Interrogator shall encapsulate an *Untraceable* in a *SecureComm* or *AuthComm* (see Table 6.28). If a Tag in the **secured** state receives an unencapsulated *Untraceable* from an authenticated Interrogator then it shall not execute the *Untraceable* and instead treat the command's parameters as unsupported (see Table C.30).

Untraceable commands shall be atomic, meaning that a Tag, upon receiving an executable *Untraceable*, shall discard its prior memory and range settings and implement the new ones.

If an *Untraceable* command modifies a Tag's EPC length field and the Tag computes its StoredCRC at powerup then the StoredCRC is likely to be incorrect until the Interrogator power-cycles the Tag. See 6.3.2.1.2.1.

If a Tag supports only $XI=0_2$ then the length bits in an *Untraceable* may have any 5-bit value. If the Tag supports $XI=1_2$ then the maximum length-bit value is 11101_2 . A Tag that supports $XI=1_2$ shall not execute an *Untraceable* that specifies length bits greater than 11101_2 and shall instead treat the command's parameters as unsupported (see Table C.30). Regardless of these absolute bounds on length, if an *Untraceable* specifies a length value that a Tag does not support then the Tag shall not execute the *Untraceable* and instead treat the command's parameters as unsupported (see Table C.30).

A Tag that is operating with reduced range shall do so for all commands regardless of whether an Interrogator has an asserted or a deasserted Untraceable privilege.

A Tag shall execute supported access commands that operate on untraceably hidden memory if the commanding Interrogator has an asserted Untraceable privilege, but shall not execute these commands if the Interrogator has a deasserted Untraceable privilege. In the latter case a Tag shall behave as though untraceably hidden memory does not exist and treat the commands' parameters as unsupported (see Table C.30). As an example, suppose that a Tag's User memory is untraceably hidden. The Tag may execute a *FileOpen* from an Interrogator with an asserted Untraceable privilege but not from an Interrogator with a deasserted Untraceable privilege.

A Tag that is untraceably hiding EPC memory shall not include any of the untraceably hidden EPC memory bits when replying to an *ACK*.

This protocol recommends that an Interrogator permalock the EPC memory bank prior to untraceably hiding part or all of EPC memory. Absent such permalocking, an Interrogator without the Untraceable privilege may subsequently alter the Tag's EPC length field and expose untraceably hidden memory.

A Tag treats as not-matching a *Select* command whose Mask includes untraceably hidden memory.

If a Tag computes its **UMI** then the untraceability status of User memory does not change the **UMI** value.

An Interrogator shall prepend an unencapsulated *Untraceable* with a frame-sync (see 6.3.1.2.8).

This protocol allows a Tag manufacturer to implement irreversible untraceability whereby a memory region, once untraceably hidden, cannot be re-exposed and/or the Tag's operating range, once reduced, cannot be restored to normal. The details of this irreversible untraceability, including whether a Tag with irreversibly hidden memory will still alter its operating range, and vice versa, shall be Tag-manufacturer defined.

This protocol allows a Tag manufacturer to configure a Tag to only execute an *Untraceable* at short range. This protocol also allows a Tag manufacturer to configure such a Tag with a zero-valued access password and an asserted Untraceable privilege for the access password, in which case the short-range feature provides the only protection against illicit use of the *Untraceable* command.

A Tag shall reply to an *Untraceable* using the *delayed* reply specified in 6.3.1.6.2. Upon receiving an executable *Untraceable* a Tag shall perform the specified actions. If a Tag receives an *Untraceable* whose fields it supports but nonetheless cannot execute, such as if the *Untraceable* instructs the Tag to expose an irreversibly hidden portion of Tag memory or the Interrogator has a deasserted Untraceable privilege, then the Tag shall not execute the *Untraceable* and instead treat the command's parameters as unsupported (see Table C.30).

Table 6.66: *Untraceable* command

	Command	RFU	U	EPC	TID	User	Range	RN	CRC
# of bits	16	2	1	6	2	1	2	16	16
description	11100010 00000000	00	0: Deassert U in XPC_W1 1: Assert U in XPC_W1	MSB (show/hide): 0: show memory above EPC 1: hide memory above EPC 5 LSBs (length): New EPC length field (new L bits)	00: hide none 01: hide some 10: hide all 11: RFU	0: view 1: hide	00: normal 01: toggle temporarily 10: reduced 11: RFU	<u>handle</u>	CRC-16

6.3.2.12.3.17 *FileOpen* (optional)

Interrogators and Tags may implement the *FileOpen* command; if they do, they shall implement it as shown in Table 6.67. *FileOpen* allows an Interrogator to instruct a Tag to close the currently open file and open a new file. A Tag only executes a *FileOpen* in the **open** or **secured** state. *FileOpen* has the following fields:

- FileNum specifies the file to be opened.

A *FileOpen* contains 2 RFU bits. An Interrogator shall set these bits to 00₂. A Tag in the **open** or **secured** states that receives a *FileOpen* with nonzero RFU bits or that specifies FileNum=11111111₂ (RFU FileNum) shall not execute the *FileOpen* and instead treat the command's parameters as unsupported (see Table C.30). Future protocols may use these RFU bits to expand the *FileOpen* command's functionality

An authenticated Interrogator shall encapsulate a *FileOpen* in a *SecureComm* or *AuthComm* (see Table 6.28). If a Tag in the **secured** state receives an unencapsulated *FileOpen* from an authenticated Interrogator then it shall not execute the *FileOpen* and instead treat the command's parameters as unsupported (see Table C.30).

An unauthenticated Interrogator may issue a *FileOpen* without encapsulation to open files accessible from a Tag (a) in the **open** state, or (b) in the **secured** state by an Interrogator that supplied the access password.

If an Interrogator or a Tag support File_N, N>0 then that Interrogator or Tag shall implement a *FileOpen*.

If an Interrogator issues a *FileOpen* specifying a File_N, N>0 for which the Interrogator has a 0000₂ file privilege value then the Tag will open the file, but the Interrogator will not be able to read any data in or otherwise modify the file (see Table 6.24 and Table 6.25).

An Interrogator shall prepend an unencapsulated *FileOpen* with a frame-sync (see 6.3.1.2.8).

If a Tag supports the *FileOpen* command then it shall implement the file (F) indicator (see 6.3.2.1.3).

A Tag shall reply to a *FileOpen* using the *immediate* reply specified in 6.3.1.6.1. If the Tag has an allocated file at FileNum then it shall close the currently open file, open the specified file, and reply as shown in Table 6.68. The reply includes a header (a 0-bit), FileNum, FileType, FileSize, BlockSize, IntPriv, LastFile, and the Tag's handle. FileNum, FileType, FileSize, BlockSize are defined in 6.3.2.11.3. IntPriv is the Interrogator's 4-bit privilege to the file (see Table 6.24 and Table 6.25). LastFile indicates whether the just-opened file has the largest assigned FileNum; if a Tag has a FileNum larger than that of the just-opened file then it shall set LastFile to 0, otherwise it shall set LastFile to 1. The reply includes a CRC-16 calculated over the 0-bit to the last handle bit. If a Tag receives a *FileOpen* specifying the currently open file then it shall leave the file open and reply as specified in Table 6.68. If a Tag receives a *FileOpen* but does not have an allocated file at FileNum, or if User memory is untraceably hidden and the Interrogator has a deasserted Untraceable privilege, or if the Tag is otherwise unable to execute the *FileOpen*, then the Tag shall not execute the *FileOpen* and instead treat the command's parameters as unsupported (see Table C.30), reverting to the currently open file (or to no file if the Tag doesn't have any allocated files or if User memory is untraceably hidden and the Interrogator has a deasserted Untraceable privilege).

Table 6.67: *FileOpen* command

	Command	RFU	FileNum	RN	CRC
# of bits	8	2	10	16	16
description	11010011	00	Which file to open	<u>handle</u>	CRC-16

Table 6.68: Tag reply to a successful *FileOpen* command

	Header	FileNum	FileType	FileSize	BlockSize	IntPriv	LastFile	RN	CRC
# of bits	1	10	8	10	10	4	1	16	16
description	0	Open file	<u>FileType</u>	File size in blocks	Block size in words	Interrogator's file privilege	0: Not max <u>FileNum</u> 1: Max <u>FileNum</u>	<u>handle</u>	CRC-16

6.3.2.12.3.18 *FileList* (optional)

Interrogators and Tags may implement the *FileList* command; if they do, they shall implement it as shown in Table 6.69. *FileList* allows an Interrogator to obtain information about a Tag's files and the Interrogator's privileges to those files. A Tag only executes a *FileList* in the **open** or **secured** state. *FileList* has the following fields:

- SenRep specifies whether a Tag backscatters its response or stores the response in its ResponseBuffer.
- IncRepLen specifies whether the Tag omits or includes length in its reply. If IncRepLen=0 then the Tag omits length from its reply; if IncRepLen=1 then the Tag includes length in its reply.
- FileNum identifies the starting file for which the Interrogator is requesting information, inclusive.
- AddlFiles identifies the number of additional files for which the Interrogator is requesting information. For example, if FileNum=4 and AddlFiles=2 then the Tag shall provide information for File_4 and for the next two higher-numbered files (which may be File_5 and File_6 if the Tag manufacturer assigned file numbers sequentially or may be other files if the numbering is not sequential).

A *FileList* contains 2 RFU bits. An Interrogator shall set these bits to 00₂. A Tag in the **open** or **secured** states that receives a *FileList* with nonzero RFU bits or that specifies FileNum=11111111₂ (RFU FileNum) shall not execute the *FileList* and instead treat the command's parameters as unsupported (see Table C.30). Future protocols may use these RFU bits to expand the *FileList* command's functionality.

An authenticated Interrogator shall encapsulate a *FileList* in a *SecureComm* or *AuthComm* (see Table 6.28). If a Tag in the **secured** state receives an unencapsulated *FileList* from an authenticated Interrogator then it shall not execute the *FileList* and instead treat the command's parameters as unsupported (see Table C.30).

An unauthenticated Interrogator may issue a *FileList* without encapsulation to a Tag in the **open** or **secured** state.

An Interrogator shall not specify AddlFiles=FF_h. If a Tag receives a *FileList* with AddlFiles=FF_h then the Tag shall behave as though it had received a *FileList* with AddlFiles=FD_h.

An Interrogator shall prepend an unencapsulated *FileList* with a frame-sync (see 6.3.1.2.8).

A Tag shall reply to a *FileList* using the *in-process* reply specified in 6.3.1.6.3. A Tag's response shall be as shown in Table 6.70 and includes a message for each file for which the Interrogator requested information. The response includes the number of messages, the message contents (10-bit FileNum, 8-bit FileType, 10-bit FileSize, 4-bit IntPriv), the BlockSize, and the free memory available for file resizing (AvailFileSize). IntPriv is the Interrogator's 4-bit privilege to the file (see Table 6.24 and Table 6.25). If a Tag is *static* then AvailFileSize shall be zero. If a Tag has more than 1022 blocks of free memory then AvailFileSize shall be 11111111₂. If a Tag receives a *FileList* with an unsupported FileNum, or AddlFiles exceeds the number of files above FileNum, or User memory is untraceably hidden and the Interrogator has a deasserted Untraceable privilege, or the Tag is otherwise unable to execute the *FileList*, then the Tag shall not execute the *FileList* and instead treat the command's parameters as unsupported (see Table C.30).

Table 6.69: *FileList* command

	Command	RFU	SenRep	IncRepLen	FileNum	AddlFiles	RN16	CRC
# of bits	16	2	1	1	10	8	16	16
Description	11100010 00000001	00	0: store 1: send	0: Omit <u>length</u> from reply 1: Include <u>length</u> in reply	First file number	Total number of additional files	<u>handle</u>	CRC-16

Table 6.70: Tag reply to a successful *FileList* command

	NumMessages	Message 1	...	Message N	BlockSize	AvailFileSize
# of bits	8	32	...	32	10	10
description	Number of mes- sages in this reply	[FileNum, FileType, FileSize, IntPriv]	...	[FileNum, FileType, FileSize, IntPriv]	Block size in words	Allocateable memory in blocks

6.3.2.12.3.19 *FilePrivilege* (optional)

Interrogators and Tags may implement the *FilePrivilege* command; if they do, they shall implement it as shown in Table 6.72. *FilePrivilege* allows an Interrogator to read or modify file privileges (Table 6.24 or Table 6.25) for the currently open file. A Tag only executes a *FilePrivilege* in the **secured** state. *FilePrivilege* has the following fields:

- SenRep specifies whether a Tag backscatters its response or stores the response in its ResponseBuffer.
- IncRepLen specifies whether the Tag omits or includes length in its reply. If IncRepLen=0 then the Tag omits length from its reply; if IncRepLen=1 then the Tag includes length in its reply.
- Action specifies whether the Interrogator is reading or modifying a privilege for the currently open file, and if modifying whether the change applies to the **open** state, access password, a single key, or all keys.
- KeyID specifies a key.
- Privilege specifies the file privilege. See Table 6.24 and Table 6.25.

A *FilePrivilege* contains 2 RFU bits. An Interrogator shall set these bits to 00₂. A Tag in the **secured** state that receives a *FilePrivilege* with nonzero RFU bits shall not execute the *FilePrivilege* and instead treat the command's parameters as unsupported (see Table C.30). Future protocols may use these RFU bits to expand the *FilePrivilege* command's functionality.

An authenticated Interrogator shall encapsulate a *FilePrivilege* in a *SecureComm* or *AuthComm* (see Table 6.28). If a Tag in the **secured** state receives an unencapsulated *FilePrivilege* from an authenticated Interrogator then it shall not execute the *FilePrivilege* and instead treat the command's parameters as unsupported (see Table C.30).

An unauthenticated Interrogator may issue a *FilePrivilege* to a Tag in the **secured** state without encapsulation.

A Tag shall execute a *TagPrivilege* according to Table 6.71 which specifies, for each Action value, the privilege assignment that the Tag makes (if any), the fields in the *FilePrivilege* that the Tag ignores, the required Tag or file privilege to perform the requested operation, and the reply that the Tag backscatters. An Interrogator may set an ignored field in a *FilePrivilege* to any value.

As shown in Table 6.71, a Tag permits an Interrogator that is a file superuser to modify a file privilege for the **open** state, access password, or any key regardless of the cryptographic suite to which the key is assigned, for the currently open file. Table 6.71 also shows that a Tag permits an Interrogator that is not a file superuser to decrement the file privilege for the access password or key that it used to most recently enter the **secured** state if the

Table 6.71: Action field behavior for a *FilePrivilege*

Action	Privilege a Tag Assigns to the Currently Open File	Tag Ignores	Required Privilege	Tag Reply to the <i>FilePrivilege</i>	Reference
000 ₂	–	<u>KeyID</u> and <u>privilege</u>	Any	<u>FileNum</u> and the open -state file <u>privilege</u>	Table 6.73, <u>Action</u> =000 ₂ or 001 ₂
001 ₂	<u>privilege</u> to the open state for <u>FileNum</u>	<u>KeyID</u>	File superuser	–	
010 ₂	–	<u>KeyID</u> and <u>privilege</u>	Any	<u>FileNum</u> and the access-password file <u>privilege</u>	Table 6.73, <u>Action</u> =010 ₂ or 011 ₂
011 ₂	<u>privilege</u> to the access password for <u>FileNum</u>	<u>KeyID</u>	<ul style="list-style-type: none"> File superuser to assign <u>privilege</u> for the access password <u>DecFilePriv</u> to decrement <u>privilege</u> for supplied access password 	–	
100 ₂	–	<u>privilege</u>	Any	<u>FileNum</u> , <u>KeyID</u> , and <u>KeyID</u> 's file <u>privilege</u>	Table 6.73, <u>Action</u> =100 ₂ or 101 ₂
101 ₂	<u>privilege</u> to <u>KeyID</u> for <u>FileNum</u>	–	<ul style="list-style-type: none"> File superuser to assign <u>privilege</u> for any <u>Key_N</u> <u>DecFilePriv</u> to decrement <u>privilege</u> for supplied key 	–	
110 ₂	–	<u>KeyID</u> and <u>privilege</u>	Any	<u>FileNum</u> , <u>NumKeys</u> , and a <u>KeyID/privilege</u> pair for each key	Table 6.73, <u>Action</u> =110 ₂ or 111 ₂
111 ₂	<u>privilege</u> to all <u>KeyID</u> for <u>FileNum</u>	<u>KeyID</u>	File superuser	–	

access password or key has an asserted DecFilePriv, but only for the currently open file and not for the **open** state or for any other password or key. Finally, Table 6.71 shows that a Tag permits any Interrogator to read the privileges for the currently open file, for the **open** state, access password, or for any key.

Upon receiving an executable *FilePrivilege* with Action=001₂, 011₂, 101₂, or 111₂ a Tag shall overwrite the current file privilege(s) with the new privilege. If the Tag does not write the new privilege successfully then it shall revert to the prior stored privilege. A Tag may meet this latter requirement by, for example, double-buffering the write operation. Note that, if Action=111₂ then a Tag may complete the write operation for some keys but not for others, in which case an Interrogator can read the privilege values and, if necessary, re-issue a *FilePrivilege*.

An Interrogator shall prepend an unencapsulated *FilePrivilege* with a frame-sync (see 6.3.1.2.8).

A Tag's response to the *FilePrivilege*, for incorporation into the *in-process* reply specified in 6.3.1.6.3, shall be as shown in Table 6.73.

If a Tag receives a *FilePrivilege* that it cannot execute because the access password or key the Interrogator supplied has insufficient privileges, or the *FilePrivilege* contains an unsupported KeyID, or privilege is an RFU value, or User memory is untraceably hidden and the Interrogator has a deasserted Untraceable privilege, or the Tag is otherwise unable to execute the *FilePrivilege*, then the Tag shall not execute the *FilePrivilege* and instead treat the command's parameters as unsupported (see Table C.30).

Table 6.72: *FilePrivilege* command

	Command	RFU	SenRep	IncRepLen	Action	KeyID	Privilege	RN	CRC
# of bits	16	2	1	1	3	8	4	16	16
description	11100010 00000100	00	0: store 1: send	0: Omit <u>length</u> from reply 1: Include <u>length</u> in reply	000: Read open state 001: Modify open state 010: Read access pwd 011: Modify access pwd 100: Read <u>KeyID</u> 101: Modify <u>KeyID</u> 110: Read all keys 111: Modify all keys	<u>KeyID</u>	<u>privilege</u>	<u>handle</u>	CRC-16

Table 6.73: Tag reply to a successful *FilePrivilege* with indicated Action fields

Action=000₂ or 001₂

	FileNum	Privilege
# of bits	10	4
description	Currently open file	open state <u>privilege</u>

Action=010₂ or 011₂

	FileNum	Privilege
# of bits	10	4
description	Currently open file	access password <u>privilege</u>

Action=100₂ or 101₂

	FileNum	KeyID	Privilege
# of bits	10	8	4
description	Currently open file	<u>KeyID</u>	<u>KeyID</u> <u>privilege</u>

Action=110₂ or 111₂

	FileNum	NumKeys	Key_0 / Privilege_0 pair	...	Key_N / Privilege_N pair
# of bits	10	8	12	...	12
description	Currently open file	Number of keys	Key_0 Privilege_0	...	Key_N Privilege_N

6.3.2.12.3.20 *FileSetup* (optional)

Interrogators and Tags may implement the *FileSetup* command; if they do, they shall implement it as shown in Table 6.74. *FileSetup* allows an Interrogator to resize the currently open file, change its FileType, or both. A Tag only executes a *FileSetup* in the **secured** state. *FileSetup* has the following fields:

- SenRep specifies whether a Tag backscatters its response or stores the response in its ResponseBuffer.
- IncRepLen specifies whether the Tag omits or includes length in its reply. If IncRepLen=0 then the Tag omits length from its reply; if IncRepLen=1 then the Tag includes length in its reply.
- FileType specifies the new file type.
- FileSize specifies the requested file size in blocks.

A *FileSetup* contains 2 RFU bits. An Interrogator shall set these bits to 00₂. A Tag in the **secured** state that receives a *FileSetup* with nonzero RFU bits shall not execute the *FileSetup* and instead treat the command's parameters as unsupported (see Table C.30). Future protocols may use these RFU bits to expand the *FileSetup* command's functionality.

A Tag shall only execute a *FileSetup* issued by an Interrogator with a file superuser privilege (see 6.3.2.11.3).

An authenticated Interrogator shall encapsulate a *FileSetup* in a *SecureComm* or *AuthComm* (see Table 6.28). If a Tag in the **secured** state receives an unencapsulated *FileSetup* from an authenticated Interrogator then it shall not execute the *FileSetup* and instead treat the command's parameters as unsupported (see Table C.30).

An unauthenticated Interrogator may issue a *FileSetup* to a Tag in the **secured** state without encapsulation.

A *static* Tag that supports the *FileSetup* command shall permit an Interrogator with the file superuser privilege to modify a file's type but never its size. A *static* Tag shall write the FileType in a *FileSetup* as the file's new type and shall ignore FileSize. An Interrogator may set FileSize to any value when communicating with a *static* Tag.

A *dynamic* Tag shall permit an Interrogator with the file superuser privilege to modify a file's type and size. Table 6.26 specifies the conditions under which a *dynamic* Tag may be able to resize a file. When increasing a file's size a *dynamic* Tag shall only allocate "free" memory (i.e. memory not currently allocated to another file) to the resized file. When reducing a file's size a *dynamic* Tag may or may not, depending on the Tag manufacturer's implementation, erase the excised memory. Consequently, this protocol recommends that Interrogators, before reducing a file's size, erase that portion of the file that will be excised by the resizing. Whether a *dynamic* Tag is able to recover memory freed by resizing a file's size downward depends on the Tag manufacturer's implementation and is not specified by this protocol.

Regardless of whether a Tag is *static* or *dynamic*, after executing a *FileSetup* a Tag's response shall include both FileType and FileSize (even if the Tag made no changes to either one). See Table 6.75.

An Interrogator shall prepend an unencapsulated *FileSetup* with a frame-sync (see 6.3.1.2.8).

A Tag's response to the *FileSetup*, for incorporation into the *in-process* reply specified in 6.3.1.6.3, shall be as shown in Table 6.75. The response includes the FileNum, FileType, and FileSize. If a Tag receives a *FileSetup* that it cannot execute because the access password or key that the Interrogator most recently supplied does not have a file superuser privilege, or User memory is untraceably hidden and the Interrogator has a deasserted Untraceable privilege, or the Tag is otherwise unable to execute the *FileSetup*, then the Tag shall not execute the *FileSetup* and instead treat the command's parameters as unsupported (see Table C.30).

There are many reasons why a *dynamic* Tag may be unable to execute a *FileSetup* including (a) the Tag does not have free memory to increase the file size, (b) the Tag has free memory but is unable to allocate it to the file, (c) the file has a permalocked block, and (d) many others. If a *dynamic* Tag is unable to execute the FileSize in the *FileSetup* command then it shall not execute any portion of the *FileSetup* (i.e. it shall not change the FileType) and instead treat the command's parameters as unsupported (see Table C.30).

Table 6.74: *FileSetup* command

	Command	RFU	SenRep	IncRepLen	FileType	FileSize	RN16	CRC
# of bits	16	2	1	1	8	10	16	16
description	11100010 00000101	00	0: store 1: send	0: Omit <u>length</u> from reply 1: Include <u>length</u> in reply	<u>FileType</u>	Requested file size, in blocks	<u>handle</u>	CRC-16

Table 6.75: Tag reply to a successful *FileSetup* command¹

	FileNum	FileType	FileSize
# of bits	10	8	10
description	Currently open file	<u>FileType</u>	Current file size, in blocks

¹ see also Table 6.26

7. Intellectual property rights policy and disclaimer

GS1, under its IP Policy, seeks to avoid uncertainty regarding intellectual property claims by requiring the participants in the Work Group that developed this Generation-2 UHF RFID V2.0.0 Protocol to agree to grant to GS1 members a royalty-free license or a RAND license to Necessary Claims, as that term is defined in the GS1/EPCglobal IP Policy. Furthermore, attention is drawn to the possibility that an implementation of one or more features of this Protocol may be the subject of a patent or other intellectual property right that does not involve a Necessary Claim. Any such patent or other intellectual property right is not subject to the licensing obligations of GS1. Moreover, the agreement to grant licenses provided under the GS1/EPCglobal IP Policy does not include IP rights and any claims of third parties who were not participants in the Work Group.

Accordingly, GS1 recommends that any organization developing an implementation designed to be in conformance with this Protocol should determine whether there are any patents that may encompass a specific implementation that the organization is developing in compliance with the Protocol and whether a license under any patent rights identified herein, or any patent rights of third parties, or any other intellectual property right is needed. Such a determination of a need for licensing should be made in view of the details of the specific system designed by the organization in consultation with their own patent counsel.

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<u>U.S Patent No.</u>	<u>U.S. Patent Application No.</u>
7,145,482	13/481,141
8,188,839	10/597,725
6,784,787	
6,480,143	
5,680,459	
5,519,381	
5,726,630	
7,987,405	

Annex A

(normative)

Extensible bit vectors (EBV)

An *extensible bit vector* (EBV) is a data structure with an extensible data range.

An EBV is an array of blocks. Each block contains a single extension bit followed by a specific number of data bits. If B represents the total number of bits in one block, then a block contains $B - 1$ data bits. Although a general EBV may contain blocks of varying lengths, Tags and Interrogators manufactured according to this protocol shall use blocks of length 8 bits (EBV-8).

The data value represented by an EBV is simply the bit string formed by the data bits as read from left-to-right, ignoring the extension bits.

Tags and Interrogators shall use the EBV-8 word format specified in Table A.1.

Table A.1: EBV-8 word format

	0	0	0000000				
	1	0	0000001				
$2^7 - 1$	127	0	1111111				
2^7	128	1	0000001	0	0000000		
$2^{14} - 1$	16383	1	1111111	0	1111111		
2^{14}	16384	1	0000001	1	0000000	0	0000000

Because each block has 7 available data bits, an EBV-8 can represent numeric values between 0 and 127 with a single block. To represent the value 128, set the extension bit to 1 in the first block, and append a second block to the EBV-8. In this manner, an EBV-8 can represent arbitrarily large data values.

This protocol uses EBV-8 values to represent memory addresses and mask lengths.

Annex B

(normative)

State-transition tables

State-transition tables B.1 to B.7 shall define a Tag's response to Interrogator commands. The term “handle” used in the state-transition tables is defined in 6.3.2.6.5; error codes are defined in Table I.2; “slot” is the slot-counter output shown in Figure 6.21 and detailed in [Annex J](#); and “–” in the “Action” column means that a Tag neither executes the command nor backscatters a reply.

B.1 Present state: Ready

Table B.1: Ready state-transition table

Command	Condition	Action	Next State
<i>Query</i> ¹	slot=0; matching inventoried & SL flags	backscatter new RN16	reply
	slot<>0; matching inventoried & SL flags	–	arbitrate
	otherwise	–	ready
<i>QueryRep</i>	all	–	ready
<i>QueryAdjust</i>	all	–	ready
<i>ACK</i>	all	–	ready
<i>NAK</i>	all	–	ready
<i>Req_RN</i>	all	–	ready
<i>Select</i>	correct parameters	assert or deassert SL , or set inventoried to <i>A</i> or <i>B</i>	ready
	incorrect parameters	–	ready
<i>Read</i>	all	–	ready
<i>Write</i>	all	–	ready
<i>Kill</i>	all	–	ready
<i>Lock</i>	all	–	ready
<i>Access</i>	all	–	ready
<i>BlockWrite</i>	all	–	ready
<i>BlockErase</i>	all	–	ready
<i>BlockPermalock</i>	all	–	ready
<i>Challenge</i>	supported security timeout, unsupported CSI , not-executable <u>message</u> , nonzero RFU bits	set C =0	ready
	supported CSI & executable <u>message</u>	store <u>result</u> , set C =1	ready
<i>Authenticate</i>	all	–	ready
<i>AuthComm</i>	all	–	ready
<i>SecureComm</i>	all	–	ready
<i>ReadBuffer</i>	all	–	ready
<i>KeyUpdate</i>	all	–	ready
<i>Untraceable</i>	all	–	ready
<i>FileSetup</i>	all	–	ready
<i>FileOpen</i>	all	–	ready
<i>FilePrivilege</i>	all	–	ready
<i>TagPrivilege</i>	all	–	ready
<i>FileList</i>	all	–	ready
Faulty	invalid ²	–	ready

1: *Query* starts a new round and may change the session. *Query* also instructs a Tag to load a new random value into its slot counter.

2: “Invalid” shall mean a command not recognizable by the Tag such as (1) an erroneous command (example: a command with an incorrect length field), (2) a command with a CRC error, or (3) an unsupported command.

B.2 Present state: Arbitrate

Table B.2: Arbitrate state-transition table

Command	Condition	Action	Next State
Query ^{1,2}	slot=0; matching inventoried & SL flags	backscatter new RN16	reply
	slot<>0; matching inventoried & SL flags	–	arbitrate
	otherwise	–	ready
QueryRep	<u>session</u> matches inventory round & slot=0 after decrementing slot counter	decrement slot counter; backscatter new RN16	reply
	<u>session</u> matches inventory round & slot<>0 after decrementing slot counter	decrement slot counter	arbitrate
	<u>session</u> does not match inventory round	–	arbitrate
QueryAdjust ²	<u>session</u> matches inventory round & slot=0	backscatter new RN16	reply
	<u>session</u> matches inventory round & slot<>0	–	arbitrate
	<u>session</u> does not match inventory round	–	arbitrate
ACK	all	–	arbitrate
NAK	all	–	arbitrate
Req_RN	all	–	arbitrate
Select	correct parameters	assert or deassert SL , or set inventoried to <i>A</i> or <i>B</i>	ready
	incorrect parameters	–	arbitrate
Read	all	–	arbitrate
Write	all	–	arbitrate
Kill	all	–	arbitrate
Lock	all	–	arbitrate
Access	all	–	arbitrate
BlockWrite	all	–	arbitrate
BlockErase	all	–	arbitrate
BlockPermalock	all	–	arbitrate
Challenge	supported security timeout, unsupported <u>CSI</u> , not-executable <u>message</u> , nonzero RFU bits	set C =0	ready
	supported <u>CSI</u> & executable <u>message</u>	store <u>result</u> , set C =1	ready
Authenticate	all	–	arbitrate
AuthComm	all	–	arbitrate
SecureComm	all	–	arbitrate
ReadBuffer	all	–	arbitrate
KeyUpdate	all	–	arbitrate
Untraceable	all	–	arbitrate
FileSetup	all	–	arbitrate
FileOpen	all	–	arbitrate
FilePrivilege	all	–	arbitrate
TagPrivilege	all	–	arbitrate
FileList	all	–	arbitrate
Faulty	invalid ³	–	arbitrate

1: Query starts a new round and may change the session.

2: Query and QueryAdjust instruct a Tag to load a new random value into its slot counter.

3: "Invalid" shall mean a command not recognizable by the Tag such as (1) an erroneous command (example: a command with an incorrect length field), (2) a command with a CRC error, or (3) an unsupported command.

B.3 Present state: Reply

Table B.3: Reply state-transition table

Command	Condition	Action	Next State
Query ^{1,2}	slot=0; matching inventoried & SL flags	backscatter new RN16	reply
	slot<>0; matching inventoried & SL flags	–	arbitrate
	otherwise	–	ready
QueryRep	<u>session</u> matches inventory round	–	arbitrate
	<u>session</u> does not match inventory round	–	reply
QueryAdjust ²	<u>session</u> matches inventory round & slot=0	backscatter new RN16	reply
	<u>session</u> matches inventory round & slot<>0	–	arbitrate
	<u>session</u> does not match inventory round	–	reply
ACK	correct RN16	See Table 6.17	acknowledged
	incorrect RN16	–	arbitrate
NAK	all	–	arbitrate
Req_RN	all	–	arbitrate
Select	correct parameters	assert or deassert SL , or set inventoried to A or B	ready
	incorrect parameters	–	reply
Read	all	–	arbitrate
Write	all	–	arbitrate
Kill	all	–	arbitrate
Lock	all	–	arbitrate
Access	all	–	arbitrate
BlockWrite	all	–	arbitrate
BlockErase	all	–	arbitrate
BlockPermalock	all	–	arbitrate
Challenge	supported security timeout, unsupported <u>CSI</u> , not-executable <u>message</u> , nonzero RFU bits	set C =0	ready
	supported <u>CSI</u> & executable <u>message</u>	store <u>result</u> , set C =1	ready
Authenticate	all	–	arbitrate
AuthComm	all	–	arbitrate
SecureComm	all	–	arbitrate
ReadBuffer	all	–	arbitrate
KeyUpdate	all	–	arbitrate
Untraceable	all	–	arbitrate
FileSetup	all	–	arbitrate
FileOpen	all	–	arbitrate
FilePrivilege	all	–	arbitrate
TagPrivilege	all	–	arbitrate
FileList	all	–	arbitrate
T ₂ timeout	See Figure 6.18 and Table 6.16	–	arbitrate
Faulty	invalid ³	–	reply

1: Query starts a new round and may change the session.

2: Query and QueryAdjust instruct a Tag to load a new random value into its slot counter.

3: “Invalid” shall mean a command not recognizable by the Tag such as (1) an erroneous command (example: a command with an incorrect length field), (2) a command with a CRC error, or (3) an unsupported command.

B.4 Present state: Acknowledged

Table B.4: Acknowledged state-transition table

Command	Condition	Action	Next State
Query ¹	slot=0; matching inventoried ² & SL flags	backscatter new RN16; transition inventoried ² from $A \rightarrow B$ or $B \rightarrow A$ if and only if new <u>session</u> matches prior <u>session</u>	reply
	slot<>0; matching inventoried ² & SL flags	transition inventoried ² from $A \rightarrow B$ or $B \rightarrow A$ if and only if new <u>session</u> matches prior <u>session</u>	arbitrate
	otherwise	transition inventoried from $A \rightarrow B$ or $B \rightarrow A$ if and only if new <u>session</u> matches prior <u>session</u>	ready
QueryRep	<u>session</u> matches inventory round	transition inventoried from $A \rightarrow B$ or $B \rightarrow A$	ready
	<u>session</u> does not match inventory round	–	acknowledged
QueryAdjust	<u>session</u> matches inventory round	transition inventoried from $A \rightarrow B$ or $B \rightarrow A$	ready
	<u>session</u> does not match inventory round	–	acknowledged
ACK	correct RN16	See Table 6.17	acknowledged
	incorrect RN16	–	arbitrate
NAK	all	–	arbitrate
Req_RN	correct RN16 & access password<>0	backscatter <u>handle</u>	open
	correct RN16 & access password=0	backscatter <u>handle</u>	secured
	incorrect RN16	–	acknowledged
Select	correct parameters	assert or deassert SL , or set inventoried to A or B	ready
	incorrect parameters	–	acknowledged
Read	all	–	arbitrate
Write	all	–	arbitrate
Kill	all	–	arbitrate
Lock	all	–	arbitrate
Access	all	–	arbitrate
BlockWrite	all	–	arbitrate
BlockErase	all	–	arbitrate
BlockPermalock	all	–	arbitrate
Challenge	supported security timeout, unsupported <u>CSL</u> , not-executable <u>message</u> , nonzero RFU bits	set C =0	ready
	supported <u>CSL</u> & executable <u>message</u>	store <u>result</u> , set C =1	ready
Authenticate	all	–	arbitrate
AuthComm	all	–	arbitrate
SecureComm	all	–	arbitrate
ReadBuffer	all	–	arbitrate
KeyUpdate	all	–	arbitrate
Untraceable	all	–	arbitrate
FileSetup	all	–	arbitrate
FileOpen	all	–	arbitrate
FilePrivilege	all	–	arbitrate
TagPrivilege	all	–	arbitrate
FileList	all	–	arbitrate
T ₂ timeout	See Figure 6.18 and Table 6.16	–	arbitrate
Faulty	invalid ³	–	acknowledged

1: Query starts a new round and may change the session. Query also instructs a Tag to load a new random value into its slot counter.

2: As described in 6.3.2.10, a Tag transitions its **inventoried** flag prior to evaluating the condition.

3: "Invalid" shall mean a command not recognizable by the Tag such as (1) an erroneous command (example: a command with an incorrect length field), (2) a command with a CRC error, or (3) an unsupported command.

B.5 Present state: Open

Table B.5: Open state-transition table

Command	Condition	Action	Next State
Query ¹	slot=0; matching inventoried ² & SL flags	backscatter new RN16; transition inventoried ² from $A \rightarrow B$ or $B \rightarrow A$ if and only if new <u>session</u> matches prior <u>session</u>	reply
	slot<>0; matching inventoried ² & SL flags	transition inventoried ² from $A \rightarrow B$ or $B \rightarrow A$ if and only if new <u>session</u> matches prior <u>session</u>	arbitrate
	otherwise	transition inventoried from $A \rightarrow B$ or $B \rightarrow A$ if and only if new <u>session</u> matches prior <u>session</u>	ready
QueryRep	<u>session</u> matches inventory round	transition inventoried from $A \rightarrow B$ or $B \rightarrow A$	ready
	<u>session</u> does not match inventory round	–	open
QueryAdjust	<u>session</u> matches inventory round	transition inventoried from $A \rightarrow B$ or $B \rightarrow A$	ready
	<u>session</u> does not match inventory round	–	open
ACK	correct <u>handle</u>	See Table 6.17	open
	incorrect <u>handle</u>	–	arbitrate
NAK	all	–	arbitrate
Req_RN	all	backscatter new RN16	open
Select	correct parameters	assert or deassert SL , or set inventoried to A or B	ready
	incorrect parameters	–	open
Read	all	backscatter data	open
Write	all	backscatter <u>header</u> when done	open
Kill (see also Figure 6.24)	supported security timeout	backscatter error code	open
	password-based kill & correct nonzero kill password	backscatter <u>header</u> when done	killed
	password-based kill & incorrect nonzero kill password	may set security timeout	arbitrate
	password-based kill & kill password=0	backscatter error code	open
	authenticated kill	backscatter error code; may set security timeout	arbitrate
Lock	all	–	open
Access (see also Figure 6.26)	supported security timeout	backscatter error code	open
	correct access password	backscatter <u>handle</u>	secured
	incorrect access password	may set security timeout	arbitrate
BlockWrite	all	backscatter <u>header</u> when done	open
BlockErase	all	backscatter <u>header</u> when done	open
BlockPermalock	all	–	open
Challenge	supported security timeout, unsupported <u>CSI</u> , not-executable <u>message</u> , nonzero RFU bits	set C =0	ready
	supported <u>CSI</u> and executable <u>message</u>	store <u>result</u> , set C =1	ready
Authenticate	supported security timeout	backscatter error code	open
	executable & <u>senrep</u> =0	store <u>result</u> ; set C =1, backscatter <u>response</u> when done	open or secured ³
	executable & <u>senrep</u> =1	backscatter <u>response</u> when done	open or secured ³
	crypto error	see crypto suite	arbitrate
	new authentication	reset crypto engine	open

Command	Condition	Action	Next State
AuthComm	supported security timeout	backscatter error code	open
	prior Tag authentication & executable	backscatter <u>response</u> when done	see encapsulated command
	no prior Tag authentication	backscatter error code	open
	crypto error	see crypto suite	arbitrate
SecureComm	supported security timeout	backscatter error code	open
	prior Tag authentication, executable, & <u>senrep</u> =0	store <u>result</u> ; set C =1, backscatter <u>response</u> when done	see encapsulated command
	prior Tag authentication, executable, & <u>senrep</u> =1	backscatter <u>response</u> when done	see encapsulated command
	no prior Tag authentication	backscatter error code	open
	crypto error	see crypto suite	arbitrate
ReadBuffer	C =1	backscatter data	open
	C =0	backscatter error code	open
KeyUpdate	all	–	open
Untraceable	all	–	open
FileSetup	all	–	open
FileOpen	executable	close current file; open requested file; backscatter file info	open
FilePrivilege	all	–	open
TagPrivilege	all	–	open
FileList	executable & <u>senrep</u> =0	store <u>result</u> ; set C =1, backscatter <u>response</u> when done	open
	executable & <u>senrep</u> =1	backscatter <u>response</u> when done	open
Faulty	unsupported parameters ⁴	backscatter error code	open
	incorrect <u>handle</u> ⁵	none unless specified by crypto suite	open
	improper ⁶	–	arbitrate
	invalid ⁷	none unless specified by crypto suite	open

1: *Query* starts a new round and may change the session. *Query* also instructs a Tag to load a new random value into its slot counter.

2: As described in 6.3.2.10, a Tag transitions its **inventoried** flag prior to evaluating the condition.

3: See cryptographic suite

4: "Unsupported parameters" shall mean an access command with a correct handle and CRC and that is recognizable by the Tag but contains or specifies (1) a nonzero or incorrect RFU value, (2) an unsupported CSI, (3) an encapsulated command that is unsupported or disallowed, (4) an unsupported or incorrect memory bank, memory location, address range, or FileNum, (5) a hidden or locked memory bank or location, (6) an unsupported file or files, (7) a command that requires encapsulation but is nonetheless unencapsulated (see Table 6.28), (8) a *delayed* or *in-process* reply and the specified operation causes the Tag to encounter an error, (9) an operation for which the Interrogator has insufficient privileges, (10) an unsupported cryptographic parameter, or (11) other parameters not supported by the Tag.

5: "Incorrect handle" shall mean an access command with a correct CRC and that is recognizable by the Tag but has an incorrect handle. The cryptographic suite indicated by CSI in the prior *Challenge* or *Authenticate* command may specify that a Tag reset its cryptographic engine upon receiving a security command with an incorrect handle.

6: "Improper" shall mean a command (except *Req_RN* or *Query*) that is recognizable by the Tag but is interspersed between successive *Kill* or *Access* commands in a password-based kill or access command sequence, respectively (see Figure 6.24 and Figure 6.26).

7: "Invalid" shall mean a command not recognizable by the Tag such as (1) an erroneous command (example: a command with an incorrect length field or a *BlockWrite/BlockErase* with a zero-valued WordCount), (2) a command with a CRC error, (3) an unsupported command, or (4) a *Write* command for which the immediately preceding command was not a *Req_RN*. The cryptographic suite indicated by CSI in the prior *Challenge* or *Authenticate* command may specify that a Tag reset its cryptographic engine upon receiving an invalid command.

B.6 Present state: Secured

Table B.6: Secured state-transition table

Command	Condition	Action	Next State
Query ¹	slot=0; matching inventoried ² & SL flags	backscatter new RN16; transition inventoried ² from $A \rightarrow B$ or $B \rightarrow A$ if and only if new <u>session</u> matches prior <u>session</u>	reply
	slot<>0; matching inventoried ² & SL flags	transition inventoried ² from $A \rightarrow B$ or $B \rightarrow A$ if and only if new <u>session</u> matches prior <u>session</u>	arbitrate
	otherwise	transition inventoried from $A \rightarrow B$ or $B \rightarrow A$ if and only if new <u>session</u> matches prior <u>session</u>	ready
QueryRep	<u>session</u> matches inventory round	transition inventoried from $A \rightarrow B$ or $B \rightarrow A$	ready
	<u>session</u> does not match inventory round	–	secured
QueryAdjust	<u>session</u> matches inventory round	transition inventoried from $A \rightarrow B$ or $B \rightarrow A$	ready
	<u>session</u> does not match inventory round	–	secured
ACK	correct <u>handle</u>	See Table 6.17	secured
	incorrect <u>handle</u>	–	arbitrate
NAK	all	–	arbitrate
Req_RN	all	backscatter new RN16	secured
Select	correct parameters	assert or deassert SL , or set inventoried to A or B	ready
	incorrect parameters	–	secured
Read	all	backscatter data	secured
Write	all	backscatter <u>header</u> when done	secured
Kill (see also Figure 6.24)	supported security timeout	backscatter error code	secured
	password-based kill & correct nonzero kill password	backscatter <u>header</u> when done	killed
	password-based kill & incorrect nonzero kill password	may set security timeout	arbitrate
	password-based kill & kill password=0	backscatter error code	secured
	authenticated kill with prior Interrogator authentication & <u>AuthKill</u> privilege	backscatter <u>response</u> when done	killed
	authenticated kill but no prior Interrogator authentication or no <u>AuthKill</u> privilege	backscatter error code; may set security timeout	arbitrate
Lock	all	backscatter <u>header</u> when done	secured
Access (see also Figure 6.26)	supported security timeout	backscatter error code	secured
	correct access password	backscatter <u>handle</u>	secured
	incorrect access password	may set security timeout	arbitrate
BlockWrite	all	backscatter <u>header</u> when done	secured
BlockErase	all	backscatter <u>header</u> when done	secured
BlockPermalock	<u>Read/Lock</u> =0	backscatter permalock bits	secured
	<u>Read/Lock</u> =1	backscatter <u>header</u> when done	secured
Challenge	supported security timeout, unsupported <u>CSI</u> , not-executable <u>message</u> , nonzero RFU bits	set C =0	ready
	supported <u>CSI</u> and executable <u>message</u>	store <u>result</u> , set C =1	ready
Authenticate	supported security timeout	backscatter error code	secured
	executable & <u>senrep</u> =0	store <u>result</u> ; set C =1, backscatter <u>response</u> when done	secured
	executable & <u>senrep</u> =1	backscatter <u>response</u> when done	secured
	crypto error	see crypto suite	arbitrate
	new authentication	reset crypto engine	open
AuthComm	supported security timeout	backscatter error code	secured
	prior Interrogator authentication & executable	backscatter <u>response</u> when done	see encapsulated command
	no prior Interrogator authentication	backscatter error code	secured
	crypto error	see crypto suite	arbitrate

Command	Condition	Action	Next State
SecureComm	supported security timeout	backscatter error code	secured
	prior Interrogator authentication, executable, & <u>senrep</u> =0	store <u>result</u> ; set C =1, backscatter <u>response</u> when done	see encapsulated command
	prior Interrogator authentication, executable, & <u>senrep</u> =1	backscatter <u>response</u> when done	see encapsulated command
	no prior Interrogator authentication	backscatter error code	secured
	crypto error	see crypto suite	arbitrate
ReadBuffer	C =1	backscatter data	secured
	C =0	backscatter error code	secured
KeyUpdate	supported security timeout	backscatter error code	secured
	prior Interrogator authentication, executable, & <u>senrep</u> =0	store <u>result</u> ; set C =1, backscatter <u>response</u> when done	secured
	prior Interrogator authentication, executable, & <u>senrep</u> =1	backscatter <u>response</u> when done	secured
	no prior Interrogator authentication	backscatter error code	secured
	crypto error	see crypto suite	arbitrate
Untraceable	executable	backscatter <u>header</u> when done	secured
FileSetup	executable & <u>senrep</u> =0	store <u>result</u> ; set C =1, backscatter <u>response</u> when done	secured
	executable & <u>senrep</u> =1	backscatter <u>response</u> when done	secured
FileOpen	executable	close current file; open requested file; backscatter file info	secured
FilePrivilege	executable & <u>senrep</u> =0	store <u>result</u> ; set C =1, backscatter <u>response</u> when done	secured
	executable & <u>senrep</u> =1	backscatter <u>response</u> when done	secured
TagPrivilege	executable & <u>senrep</u> =0	store <u>result</u> ; set C =1, backscatter <u>response</u> when done	secured
	executable & <u>senrep</u> =1	backscatter <u>response</u> when done	secured
FileList	executable & <u>senrep</u> =0	store <u>result</u> ; set C =1, backscatter <u>response</u> when done	secured
	executable & <u>senrep</u> =1	backscatter <u>response</u> when done	secured
Faulty	unsupported parameters ³	backscatter error code	secured
	incorrect <u>handle</u> ⁴	none unless specified by crypto suite	secured or open ⁴
	improper ⁵	—	arbitrate
	invalid ⁶	none unless specified by crypto suite	secured or open ⁶

1: *Query* starts a new round and may change the session. *Query* also instructs a Tag to load a new random value into its slot counter.

2: As described in 6.3.2.10, a Tag transitions its **inventoried** flag prior to evaluating the condition.

3: "Unsupported parameters" shall mean an access command with a correct handle and CRC and that is recognizable by the Tag but contains or specifies (1) a nonzero or incorrect RFU value, (2) an unsupported CSI; (3) an encapsulated command that is unsupported or disallowed, (4) an unsupported or incorrect memory bank, memory location, address range, lock payload, blockpermalock payload, KeyID, or FileNum, (5) a hidden or locked memory bank or location, (6) an unsupported file or files, (7) insufficient or unallocateable memory, (8) an unencrypted message that requires encryption, (9) a command that requires encapsulation but is nonetheless unencapsulated (see Table 6.28), (10) a *delayed* or *in-process* reply and the specified operation causes the Tag to encounter an error, (11) an RFU privilege value, (12) an operation for which the Interrogator has insufficient privileges, (13) an unsupported cryptographic parameter, or (14) other parameters not supported by the Tag.

4: "Incorrect handle" shall mean an access command with a correct CRC and that is recognizable by the Tag but has an incorrect handle. The default next state is **secured**, but the cryptographic suite indicated by CSI in the prior *Challenge* or *Authenticate* command may specify that a Tag reset its crypto engine and transition to the **open** state upon receiving a security command with an incorrect handle.

5: "Improper" shall mean a command (except *Req_RN* or *Query*) that is recognizable by the Tag but is interspersed between successive *Kill* or *Access* commands in a password-based kill or access command sequence, respectively (see Figure 6.24 and Figure 6.26).

6: "Invalid" shall mean a command not recognizable by the Tag such as (1) an erroneous command (example: a command with an incorrect length field or a *BlockWrite/BlockErase* with a zero-valued WordCount), (2) a command with a CRC error, (3) an unsupported command, or (4) a *Write* command for which the immediately preceding command was not a *Req_RN*. The default next state is **secured**, but the cryptographic suite indicated by CSI in the prior *Challenge* or *Authenticate* command may specify that a Tag reset its cryptographic engine and transition to the **open** state upon receiving an invalid command.

B.7 Present state: Killed

Table B.7: Killed state-transition table

Command	Condition	Action	Next State
<i>Query</i>	all	–	killed
<i>QueryRep</i>	all	–	killed
<i>QueryAdjust</i>	all	–	killed
<i>ACK</i>	all	–	killed
<i>NAK</i>	all	–	killed
<i>Req_RN</i>	all	–	killed
<i>Select</i>	all	–	killed
<i>Read</i>	all	–	killed
<i>Write</i>	all	–	killed
<i>Kill</i>	all	–	killed
<i>Lock</i>	all	–	killed
<i>Access</i>	all	–	killed
<i>BlockWrite</i>	all	–	killed
<i>BlockErase</i>	all	–	killed
<i>BlockPermalock</i>	all	–	killed
<i>Challenge</i>	all	–	killed
<i>Authenticate</i>	all	–	killed
<i>AuthComm</i>	all	–	killed
<i>SecureComm</i>	all	–	killed
<i>ReadBuffer</i>	all	–	killed
<i>KeyUpdate</i>	all	–	killed
<i>Untraceable</i>	all	–	killed
<i>FileSetup</i>	all	–	killed
<i>FileOpen</i>	all	–	killed
<i>FilePrivilege</i>	all	–	killed
<i>TagPrivilege</i>	all	–	killed
<i>FileList</i>	all	–	killed
Faulty	all	–	killed

Annex C

(normative)

Command-Response Tables

Command-response tables C.1 to C.30 shall define a Tag's response to Interrogator commands. The term "handle" used in the command-response tables is defined in 6.3.2.6.5; error codes are defined in Table I.2; "slot" is the slot-counter output shown in Figure 6.21 and detailed in [Annex J](#); "–" in the "Response" column means that a Tag neither executes the command nor backscatters a reply.

C.1 Command response: Power-up

Table C.1: Power-up command-response table

Starting State	Condition	Response	Next State
ready, arbitrate, reply, acknowledged, open, secured	power-up	–	ready
killed	all	–	killed

C.2 Command response: *Query*

Table C.2: *Query*¹ command-response table

Starting State	Condition	Response	Next State
ready, arbitrate, reply	slot=0; matching inventoried & SL flags	backscatter new RN16	reply
	slot<>0; matching inventoried & SL flags	–	arbitrate
	otherwise	–	ready
acknowledged, open, secured	slot=0; matching inventoried ² & SL flags	backscatter new RN16; transition inventoried ² from $A \rightarrow B$ or $B \rightarrow A$ if and only if new <u>session</u> matches prior <u>session</u>	reply
	slot<>0; matching inventoried ² & SL flags	transition inventoried ² from $A \rightarrow B$ or $B \rightarrow A$ if and only if new <u>session</u> matches prior <u>session</u>	arbitrate
	otherwise	transition inventoried from $A \rightarrow B$ or $B \rightarrow A$ if and only if new <u>session</u> matches prior <u>session</u>	ready
killed	all	–	killed

1: *Query* (in any state other than **killed**) starts a new round and may change the session; *Query* also instructs a Tag to load a new random value into its slot counter.

2: As described in 6.3.2.10, a Tag transitions its **inventoried** flag prior to evaluating the condition.

C.3 Command response: *QueryRep*

Table C.3: *QueryRep* command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate	<u>session</u> matches inventory round & slot=0 after decrementing slot counter	decrement slot counter; backscatter new RN16	reply
	<u>session</u> matches inventory round & slot<>0 after decrementing slot counter	decrement slot counter	arbitrate
	<u>session</u> does not match inventory round	–	arbitrate
reply	<u>session</u> matches inventory round	–	arbitrate
	<u>session</u> does not match inventory round	–	reply
acknowledged	<u>session</u> matches inventory round	transition inventoried from $A \rightarrow B$ or $B \rightarrow A$	ready
	<u>session</u> does not match inventory round	–	acknowledged
open	<u>session</u> matches inventory round	transition inventoried from $A \rightarrow B$ or $B \rightarrow A$	ready
	<u>session</u> does not match inventory round	–	open
secured	<u>session</u> matches inventory round	transition inventoried from $A \rightarrow B$ or $B \rightarrow A$	ready
	<u>session</u> does not match inventory round	–	secured
killed	all	–	killed

C.4 Command response: *QueryAdjust*

Table C.4: *QueryAdjust*¹ command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate	<u>session</u> matches inventory round & slot=0	backscatter new RN16	reply
	<u>session</u> matches inventory round & slot<>0	–	arbitrate
	<u>session</u> does not match inventory round	–	arbitrate
reply	<u>session</u> matches inventory round & slot=0	backscatter new RN16	reply
	<u>session</u> matches inventory round & slot<>0	–	arbitrate
	<u>session</u> does not match inventory round	–	reply
acknowledged	<u>session</u> matches inventory round	transition inventoried from $A \rightarrow B$ or $B \rightarrow A$	ready
	<u>session</u> does not match inventory round	–	acknowledged
open	<u>session</u> matches inventory round	transition inventoried from $A \rightarrow B$ or $B \rightarrow A$	ready
	<u>session</u> does not match inventory round	–	open
secured	<u>session</u> matches inventory round	transition inventoried from $A \rightarrow B$ or $B \rightarrow A$	ready
	<u>session</u> does not match inventory round	–	secured
killed	all	–	ready

1: *QueryAdjust*, in the **arbitrate** or **reply** states, instructs a Tag to load a new random value into its slot counter.

C.5 Command response: *ACK*

Table C.5: *ACK* command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate	all	–	arbitrate
reply, acknowledged	correct RN16	see Table 6.17	acknowledged
	incorrect RN16	–	arbitrate
open	correct <u>handle</u>	see Table 6.17	open
	incorrect <u>handle</u>	–	arbitrate
secured	correct <u>handle</u>	see Table 6.17	secured
	incorrect <u>handle</u>	–	arbitrate
killed	all	–	killed

C.6 Command response: *NAK*

Table C.6: *NAK* command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate, reply, acknowledged, open, secured	all	–	arbitrate
killed	all	–	killed

C.7 Command response: *Req_RN*

Table C.7: *Req_RN* command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate, reply	all	–	arbitrate
acknowledged	correct RN16 & access password<>0	backscatter <u>handle</u>	open
	correct RN16 & access password=0	backscatter <u>handle</u>	secured
	incorrect RN16	–	acknowledged
open ¹	all	backscatter new RN16	open
secured ¹	all	backscatter new RN16	secured
killed	all	–	killed

1: See Table C.30 for the Tag response to an incorrect handle.

C.8 Command response: *Select*

Table C.8: *Select* command-response table

Starting State	Condition	Response	Next State
ready	correct parameters	assert or deassert SL , or set inventoried to <i>A</i> or <i>B</i>	ready
	incorrect parameters	–	ready
arbitrate	correct parameters	assert or deassert SL , or set inventoried to <i>A</i> or <i>B</i>	ready
	incorrect parameters	–	arbitrate
reply	correct parameters	assert or deassert SL , or set inventoried to <i>A</i> or <i>B</i>	ready
	incorrect parameters	–	reply
acknowledged	correct parameters	assert or deassert SL , or set inventoried to <i>A</i> or <i>B</i>	ready
	incorrect parameters	–	acknowledged
open	correct parameters	assert or deassert SL , or set inventoried to <i>A</i> or <i>B</i>	ready
	incorrect parameters	–	open
secured	correct parameters	assert or deassert SL , or set inventoried to <i>A</i> or <i>B</i>	ready
	incorrect parameters	–	secured
killed	all	–	killed

C.9 Command response: *Read*

Table C.9: *Read* command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate, reply, acknowledged	all	–	arbitrate
open ¹	all	backscatter data	open
secured ¹	all	backscatter data	secured
killed	all	–	killed

1: See Table C.30 for the Tag response to an incorrect handle or unsupported parameters.

C.10 Command response: *Write*

Table C.10: *Write* command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate, reply, acknowledged	all	–	arbitrate
open ¹	all	backscatter <u>header</u> when done	open
secured ¹	all	backscatter <u>header</u> when done	secured
killed	all	–	killed

1: See Table C.30 for the Tag response to an incorrect handle, unsupported parameters, or an improper command.

C.11 Command response: *Kill*

Table C.11: *Kill*¹ command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate, reply, acknowledged	all	–	arbitrate
open ²	supported security timeout	backscatter error code	open
	password-based kill & correct nonzero kill password	backscatter <u>header</u> when done	killed
	password-based kill & incorrect nonzero kill password	may set security timeout	arbitrate
	password-based kill & kill password=0	backscatter error code	open
	authenticated kill	backscatter error code; may set security timeout	arbitrate
secured ²	supported security timeout	backscatter error code	secured
	password-based kill & correct nonzero kill password	backscatter <u>header</u> when done	killed
	password-based kill & incorrect nonzero kill password	may set security timeout	arbitrate
	password-based kill & kill password=0	backscatter error code	secured
	authenticated kill with prior Interrogator authentication & <u>AuthKill</u> privilege	backscatter <u>response</u> when done	killed
	authenticated kill but no prior Interrogator authentication or no <u>AuthKill</u> privilege	backscatter error code; may set security timeout	arbitrate
killed	all	–	killed

1: See also Figure 6.24.

2: See Table C.30 for the Tag response to an incorrect handle, unsupported parameters, or an improper command.

C.12 Command response: *Lock*

Table C.12: *Lock* command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate, reply, acknowledged	all	–	arbitrate
open	all	–	open
secured ¹	all	backscatter <u>header</u> when done	secured
killed	all	–	killed

1: See Table C.30 for the Tag response to an incorrect handle or unsupported parameters.

C.13 Command response: *Access*

Table C.13: *Access*¹ command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate, reply, acknowledged	all	–	arbitrate
open ²	supported security timeout	backscatter error code	open
	correct access password	backscatter <u>handle</u>	secured
	incorrect access password	may set security timeout	arbitrate
secured ²	supported security timeout	backscatter error code	secured
	correct access password	backscatter <u>handle</u>	secured
	incorrect access password	may set security timeout	arbitrate
killed	all	–	killed

1: See also Figure 6.26.

2: See Table C.30 for the Tag response to an incorrect handle or an improper command.

C.14 Command response: *BlockWrite*

Table C.14: *BlockWrite* command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate, reply, acknowledged	all	–	arbitrate
open ¹	all	backscatter <u>header</u> when done	open
secured ¹	all	backscatter <u>header</u> when done	secured
killed	all	–	killed

1: See Table C.30 for the Tag response to an incorrect handle or unsupported parameters.

C.15 Command response: *BlockErase*

Table C.15: *BlockErase* command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate, reply, acknowledged	all	–	arbitrate
open ¹	all	backscatter <u>header</u> when done	open
secured ¹	all	backscatter <u>header</u> when done	secured
killed	all	–	killed

1: See Table C.30 for the Tag response to an incorrect handle or unsupported parameters.

C.16 Command response: *BlockPermalock*

Table C.16: *BlockPermalock* command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate, reply, acknowledged	all	–	arbitrate
open	all	–	open
secured ¹	<u>Read/Lock</u> =0	backscatter permalock bits	secured
	<u>Read/Lock</u> =1	backscatter <u>header</u> when done	secured
killed	all	–	killed

1: See Table C.30 for the Tag response to an incorrect handle or unsupported parameters.

C.17 Command response: *Challenge*

Table C.17: *Challenge* command-response table

Starting State	Condition	Response	Next State
ready, arbitrate, reply, acknowledged, open, secured	supported security timeout, unsupported <u>CSI</u> , not-executable <u>message</u> , nonzero RFU bits	set C =0	ready
	supported <u>CSI</u> and executable <u>message</u>	store <u>result</u> , set C =1	ready
killed	all	–	killed

C.18 Command response: *Authenticate*

Table C.18: *Authenticate* command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate, reply, acknowledged	all	–	arbitrate
open ¹	supported security timeout	backscatter error code	open
	executable & <u>senrep</u> =0	store <u>result</u> ; set C =1, backscatter <u>response</u> when done	open or secured ²
	executable & <u>senrep</u> =1	backscatter <u>response</u> when done	open or secured ²
	crypto error	see crypto suite	arbitrate
	new authentication	reset crypto engine	open
secured ¹	supported security timeout	backscatter error code	secured
	executable & <u>senrep</u> =0	store <u>result</u> ; set C =1, backscatter <u>response</u> when done	secured
	executable & <u>senrep</u> =1	backscatter <u>response</u> when done	secured
	crypto error	see crypto suite	arbitrate
	new authentication	reset crypto engine	open
killed	all	–	killed

1: See Table C.30 for the Tag response to an incorrect handle or unsupported parameters.

2: See cryptographic suite.

C.19 Command response: *AuthComm*

Table C.19: *AuthComm* command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate, reply, acknowledged	all	–	arbitrate
open ¹	supported security timeout	backscatter error code	open
	prior Tag authentication & executable	backscatter <u>response</u> when done	see encapsulated command
	no prior Tag authentication	backscatter error code	open
	crypto error	see crypto suite	arbitrate
secured ¹	supported security timeout	backscatter error code	secured
	prior Interrogator authentication & executable	backscatter <u>response</u> when done	see encapsulated command
	no prior Interrogator authentication	backscatter error code	secured
	crypto error	see crypto suite	arbitrate
killed	all	–	killed

1: See Table C.30 for the Tag response to an incorrect handle or unsupported parameters.

C.20 Command response: *SecureComm*

Table C.20: *SecureComm* command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate, reply, acknowledged	all	–	arbitrate
open ¹	supported security timeout	backscatter error code	open
	prior Tag authentication, executable, & <u>senrep</u> =0	store <u>result</u> ; set C =1, backscatter <u>response</u> when done	see encapsulated command
	prior Tag authentication, executable, & <u>senrep</u> =1	backscatter <u>response</u> when done	see encapsulated command
	no prior Tag authentication	backscatter error code	open
	crypto error	see crypto suite	arbitrate
secured ¹	supported security timeout	backscatter error code	secured
	prior Interrogator authentication, executable, & <u>senrep</u> =0	store <u>result</u> ; set C =1, backscatter <u>response</u> when done	see encapsulated command
	prior Interrogator authentication, executable, & <u>senrep</u> =1	backscatter <u>response</u> when done	see encapsulated command
	no prior Interrogator authentication	backscatter error code	secured
	crypto error	see crypto suite	arbitrate
killed	all	–	killed

1: See Table C.30 for the Tag response to an incorrect handle or unsupported parameters.

C.21 Command response: *ReadBuffer*

Table C.21: *ReadBuffer* command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate, reply, acknowledged	all	–	arbitrate
open ¹	C=1	backscatter data	open
	C=0	backscatter error code	open
secured ¹	C=1	backscatter data	secured
	C=0	backscatter error code	secured
killed	all	–	killed

1: See Table C.30 for the Tag response to an incorrect handle or unsupported parameters.

C.22 Command response: *KeyUpdate*

Table C.22: *KeyUpdate* command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate, reply, acknowledged	all	–	arbitrate
open	all	–	open
secured ¹	supported security timeout	backscatter error code	secured
	prior Interrogator authentication, executable, & <u>senrep</u> =0	store <u>result</u> ; set C=1, backscatter <u>response</u> when done	secured
	prior Interrogator authentication, executable, & <u>senrep</u> =1	backscatter <u>response</u> when done	secured
	no prior Interrogator authentication	backscatter error code	secured
	crypto error	see crypto suite	arbitrate
killed	all	–	killed

1: See Table C.30 for the Tag response to an incorrect handle or unsupported parameters.

C.23 Command response: *Untraceable*

Table C.23: *Untraceable* command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate, reply, acknowledged	all	–	arbitrate
open	all	–	open
secured ¹	executable	backscatter <u>header</u> when done	secured
killed	all	–	killed

1: See Table C.30 for the Tag response to an incorrect handle or unsupported parameters.

C.24 Command response: *FileSetup*

Table C.24: *FileSetup* command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate, reply, acknowledged	all	–	arbitrate
open	all	–	open
secured ¹	executable & <u>senrep</u> =0	store <u>result</u> ; set C =1, backscatter <u>response</u> when done	secured
	executable & <u>senrep</u> =1	backscatter <u>response</u> when done	secured
killed	all	–	killed

1: See Table C.30 for the Tag response to an incorrect handle or unsupported parameters.

C.25 Command response: *FileOpen*

Table C.25: *FileOpen* command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate, reply, acknowledged	all	–	arbitrate
open ¹	executable	close current file; open requested file; backscatter file info	open
secured ¹	executable	close current file; open requested file; backscatter file info	secured
killed	all	–	killed

1: See Table C.30 for the Tag response to an incorrect handle or unsupported parameters.

C.26 Command response: *FilePrivilege*

Table C.26: *FilePrivilege* command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate, reply, acknowledged	all	–	arbitrate
open	all	–	open
secured ¹	executable & <u>senrep</u> =0	store <u>result</u> ; set C =1, backscatter <u>response</u> when done	secured
	executable & <u>senrep</u> =1	backscatter <u>response</u> when done	secured
killed	all	–	killed

1: See Table C.30 for the Tag response to an incorrect handle or unsupported parameters.

C.27 Command response: *TagPrivilege*

Table C.27: *TagPrivilege* command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate, reply, acknowledged	all	–	arbitrate
open	all	–	open
secured ¹	executable & <u>senrep</u> =0	store <u>result</u> ; set C =1, backscatter <u>response</u> when done	secured
	executable & <u>senrep</u> =1	backscatter <u>response</u> when done	secured
killed	all	–	killed

1: See Table C.30 for the Tag response to an incorrect handle or unsupported parameters.

C.28 Command response: *FileList*

Table C.28: *FileList* command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate, reply, acknowledged	all	–	arbitrate
open ¹	executable & <u>senrep</u> =0	store <u>result</u> ; set C =1, backscatter <u>response</u> when done	open
	executable & <u>senrep</u> =1	backscatter <u>response</u> when done	open
secured ¹	executable & <u>senrep</u> =0	store <u>result</u> ; set C =1, backscatter <u>response</u> when done	secured
	executable & <u>senrep</u> =1	backscatter <u>response</u> when done	secured
killed	all	–	killed

1: See Table C.30 for the Tag response to an incorrect handle or unsupported parameters.

C.29 Command response: T_2 timeout

Table C.29: T_2 timeout command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate	all	–	arbitrate
reply, acknowledged	See Figure 6.18 and Table 6.16	–	arbitrate
open	all	–	open
secured	all	–	secured
killed	all	–	killed

C.30 Command response: Faulty command

Table C.30: Faulty command-response table

Starting State	Condition	Response	Next State
ready	invalid ¹	–	ready
arbitrate	invalid ¹	–	arbitrate
reply	invalid ¹	–	reply
acknowledged	invalid ¹	–	acknowledged
open	unsupported parameters ²	backscatter error code	open
	incorrect <u>handle</u> ⁴	none unless specified by crypto suite	open
	improper ⁶	–	arbitrate
	invalid ⁷	none unless specified by crypto suite	open
secured	unsupported parameters ³	backscatter error code	secured
	incorrect <u>handle</u> ⁵	none unless specified by crypto suite	secured or open ⁹
	improper ⁶	–	arbitrate
	invalid ⁸	none unless specified by crypto suite	secured or open ⁹
killed	all	–	killed

1: "Invalid" shall mean a command not recognizable by the Tag such as (1) an erroneous command (example: a command with an incorrect length field), (2) a command with a CRC error, or (3) an unsupported command.

2: "Unsupported parameters" shall mean an access command with a correct handle and CRC and that is recognizable by the Tag but contains or specifies (1) a nonzero or incorrect RFU value, (2) an unsupported CSI; (3) an encapsulated command that is unsupported or disallowed, (4) an unsupported or incorrect memory bank, memory location, address range, or FileNum, (5) a hidden or locked memory bank or location, (6) an unsupported file or files, (7) a command that requires encapsulation but is nonetheless unencapsulated (see Table 6.28), (8) a *delayed* or *in-process* reply and the specified operation causes the Tag to encounter an error, (9) an operation for which the Interrogator has insufficient privileges, (10) an unsupported cryptographic parameter, or (11) other parameters not supported by the Tag.

3: "Unsupported parameters" shall mean an access command with a correct handle and CRC and that is recognizable by the Tag but contains or specifies (1) a nonzero or incorrect RFU value, (2) an unsupported CSI; (3) an encapsulated command that is unsupported or disallowed, (4) an unsupported or incorrect memory bank, memory location, address range, lock payload, blockpermalock payload, KeyID, or FileNum, (5) a hidden or locked memory bank or location, (6) an unsupported file or files, (7) insufficient or unallocatable memory, (8) an unencrypted message that requires encryption, (9) a command that requires encapsulation but is nonetheless unencapsulated (see Table 6.28), (10) a *delayed* or *in-process* reply and the specified operation causes the Tag to encounter an error, (11) an RFU privilege value, (12) an operation for which the Interrogator has insufficient privileges, (13) an unsupported cryptographic parameter, or (14) other parameters not supported by the Tag.

4: "Incorrect handle" shall mean an access command with a correct CRC and that is recognizable by the Tag but has an incorrect handle. The cryptographic suite indicated by CSI in the prior *Challenge* or *Authenticate* command may specify that a Tag reset its cryptographic engine upon receiving a security command with an incorrect handle.

5: "Incorrect handle" shall mean an access command with a correct CRC and that is recognizable by the Tag but has an incorrect handle. The default next state is **secured**, but the cryptographic suite indicated by CSI in the prior *Challenge* or *Authenticate* command may specify that a Tag reset its crypto engine and transition to the **open** state upon receiving a security command with an incorrect handle.

6: "Improper" shall mean a command (except *Req_RN* or *Query*) that is recognizable by the Tag but is interspersed between successive *Kill* or *Access* commands in a password-based kill or access command sequence, respectively (see Figure 6.24 and Figure 6.26).

7: "Invalid" shall mean a command not recognizable by the Tag such as (1) an erroneous command (example: a command with an incorrect length field or a *BlockWrite/BlockErase* with a zero-valued WordCount), (2) a command with a CRC error, (3) an unsupported command, or (4) a *Write* command for which the immediately preceding command was not a *Req_RN*. The cryptographic suite indicated by CSI in the prior *Challenge* or *Authenticate* command may specify that a Tag reset its cryptographic engine upon receiving an invalid command.

8: "Invalid" shall mean a command not recognizable by the Tag such as (1) an erroneous command (example: a command with an incorrect length field or a *BlockWrite/BlockErase* with a zero-valued WordCount), (2) a command with a CRC error, (3) an unsupported command, or (4) a *Write* command for which the immediately preceding command was not a *Req_RN*. The default next state is **secured**, but the cryptographic suite indicated by CSI in the prior *Challenge* or *Authenticate* command may specify that a Tag reset its cryptographic engine and transition to the **open** state upon receiving an invalid command.

9: See cryptographic suite.

Annex D

(informative)

Example slot-count (Q) selection algorithm

D.1 Example algorithm an Interrogator might use to choose Q

Figure D.1 shows an algorithm an Interrogator might use for setting the slot-count parameter Q in a *Query* command. Q_{fp} is a floating-point representation of Q ; an Interrogator rounds Q_{fp} to an integer value and substitutes this integer value for Q in the *Query*. Typical values for Δ are $0.1 < \Delta < 0.5$. An Interrogator typically uses small values of Δ when Q is large, and larger values of Δ when Q is small.

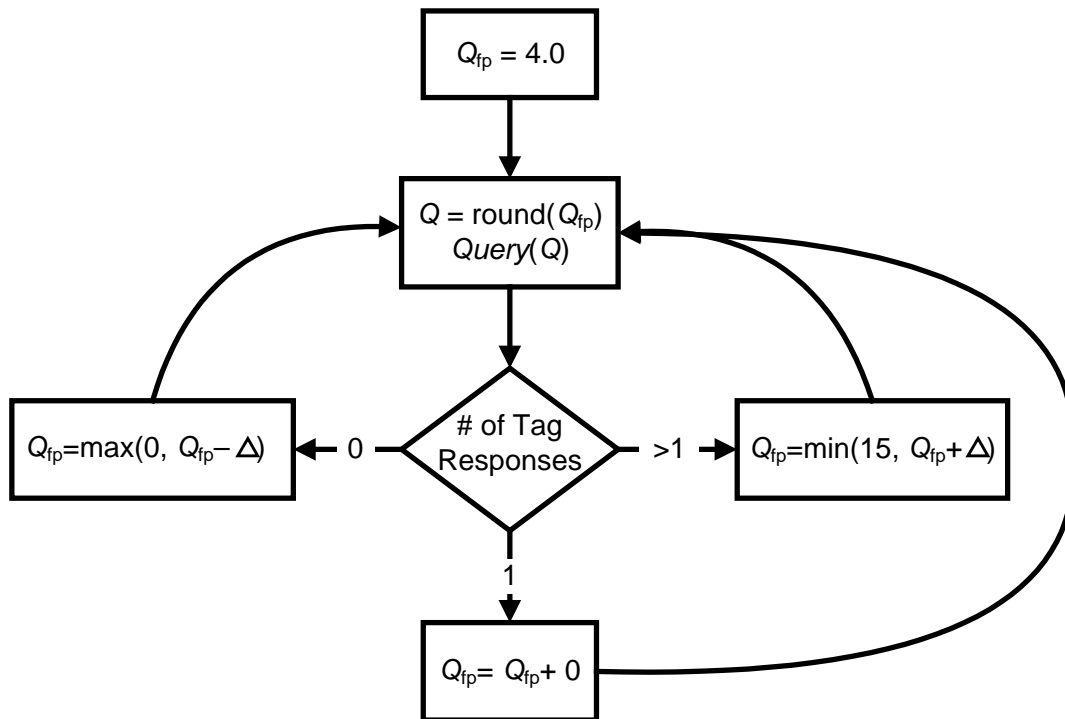


Figure D.1: Example algorithm for choosing the slot-count parameter Q

Annex E

(informative)

Example Tag inventory and access

E.1 Example inventory and access of a single Tag

Figure E.1 shows the steps by which an Interrogator inventories and accesses a single Tag.

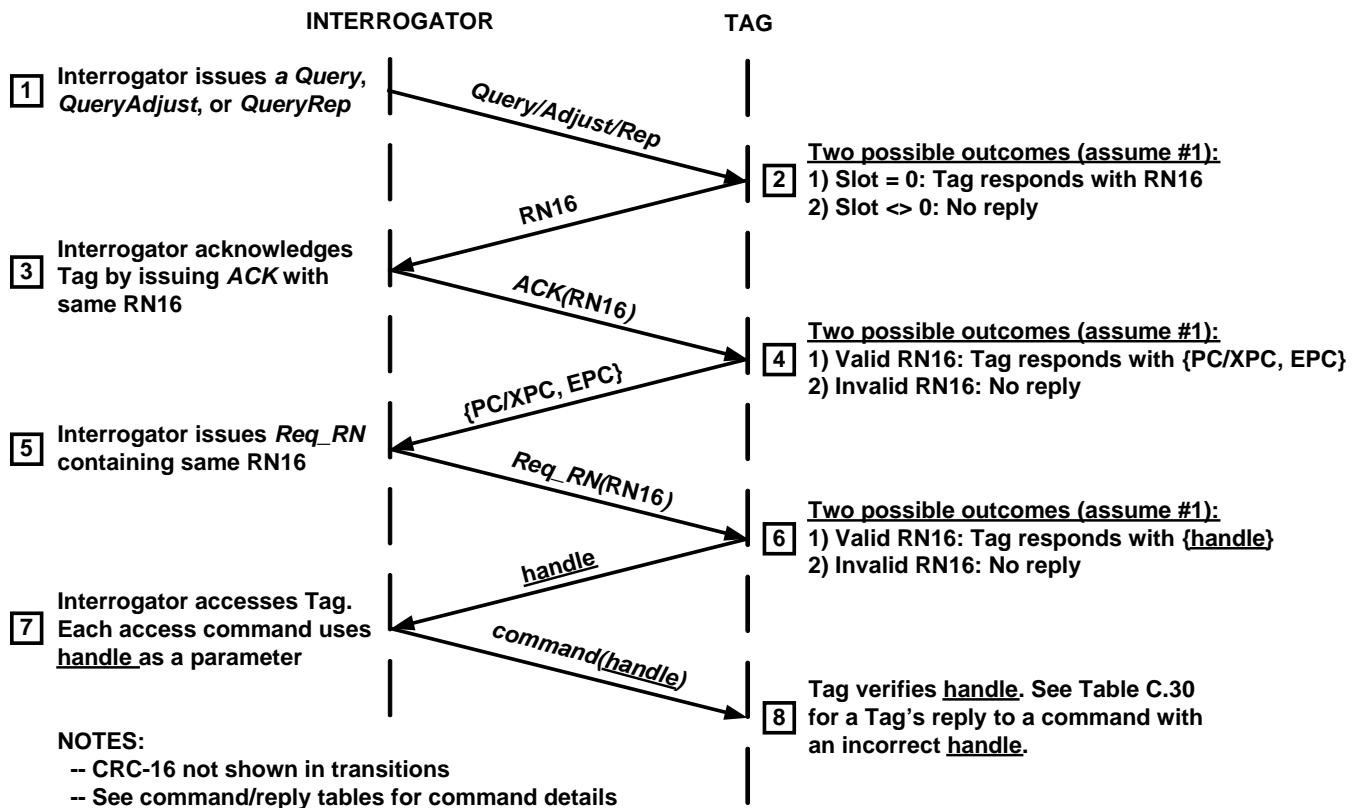


Figure E.1: Example of Tag inventory and access

Annex F

(informative)

Calculation of 5-bit and 16-bit cyclic redundancy checks

F.1 Example CRC-5 encoder/decoder

An exemplary schematic diagram for a CRC-5 encoder/decoder is shown in Figure F.1, using the polynomial and preset defined in Table 6.12.

To calculate a CRC-5, first preload the entire CRC register (i.e. Q[4:0], Q4 being the MSB and Q0 the LSB) with the value 01001₂ (see Table F.1), then clock the data bits to be encoded into the input labeled DATA, MSB first. After clocking in all the data bits, Q[4:0] holds the CRC-5 value.

To check a CRC-5, first preload the entire CRC register (Q[4:0]) with the value 01001₂, then clock the received data and CRC-5 {data, CRC-5} bits into the input labeled DATA, MSB first. The CRC-5 check passes if the value in Q[4:0] = 00000₂.

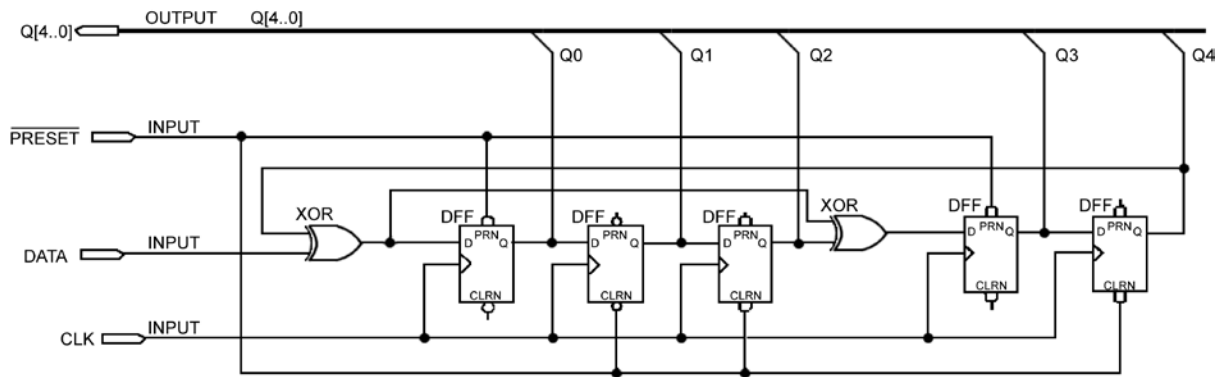


Figure F.1: Example CRC-5 circuit

Table F.1: CRC-5 register preload values

Register	Preload value
Q0	1
Q1	0
Q2	0
Q3	1
Q4	0

F.2 Example CRC-16 encoder/decoder

An exemplary schematic diagram for a CRC-16 encoder/decoder is shown in Figure F.2, using the polynomial and preset defined in Table 6.11 (the polynomial used to calculate the CRC-16, $x^{16} + x^{12} + x^5 + 1$, is the CRC-CCITT International Standard, ITU Recommendation X.25).

To calculate a CRC-16, first preload the entire CRC register (i.e. Q[15:0], Q15 being the MSB and Q0 the LSB) with the value FFFF_h. Second, clock the data bits to be encoded into the input labeled DATA, MSB first. After clocking in all the data bits, Q[15:0] holds the ones-complement of the CRC-16. Third, invert all the bits of Q[15:0] to produce the CRC-16.

There are two methods to check a CRC-16:

Method 1: First preload the entire CRC register (Q[15:0]) with the value FFFF_h, then clock the received data and CRC-16 {data, CRC-16} bits into the input labeled DATA, MSB first. The CRC-16 check passes if the value in Q[15:0]=1D0F_h.

Method 2: First preload the entire CRC register (Q[15:0]) with the value FFFF_h. Second, clock the received data bits into the input labeled DATA, MSB first. Third, invert all bits of the received CRC-16, and clock the inverted CRC-16 bits into the input labeled DATA, MSB first. The CRC-16 check passes if the value in Q[15:0]=0000_h.

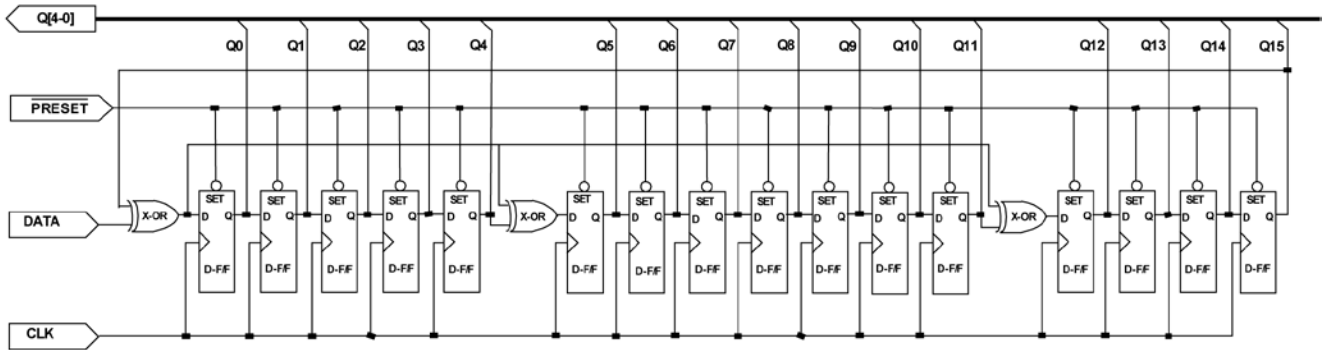


Figure F.2: Example CRC-16 circuit

F.3 Example CRC-16 calculations

This example shows the StoredCRC (a CRC-16) that a Tag may calculate at power-up.

As shown in Figure 6.19, EPC memory contains a StoredCRC starting at address 00_h, a StoredPC starting at address 10_h, zero or more EPC words starting at address 20_h, an optional XPC_W1 starting at address 210_h, and an optional XPC_W2 starting at address 220_h. As described in 6.3.2.1.2.1, a Tag calculates its StoredCRC over its StoredPC and EPC. Table F.2 shows the StoredCRC that a Tag may calculate and logically map into EPC memory at power-up, for the indicated example StoredPC and EPC word values. In each successive column, one more word of EPC memory is written, with the entire EPC memory written in the rightmost column. The indicated StoredPC values correspond to the number of EPC words written, with StoredPC bits 15_h–1F_h set to zero. Entries marked N/A mean that that word of EPC memory is not included as part of the CRC calculation.

Table F.2: EPC memory contents for an example Tag

EPC word starting address	EPC word contents	EPC word values						
00 _h	StoredCRC	E2F0 _h	CCAE _h	968F _h	78F6 _h	C241 _h	2A91 _h	1835 _h
10 _h	StoredPC	0000 _h	0800 _h	1000 _h	1800 _h	2000 _h	2800 _h	3000 _h
20 _h	EPC word 1	N/A	1111 _h	1111	1111 _h	1111 _h	1111 _h	1111 _h
30 _h	EPC word 2	N/A	N/A	2222 _h	2222 _h	2222 _h	2222 _h	2222 _h
20 _h	EPC word 3	N/A	N/A	N/A	3333 _h	3333 _h	3333 _h	3333 _h
40 _h	EPC word 4	N/A	N/A	N/A	N/A	4444 _h	4444 _h	4444 _h
50 _h	EPC word 5	N/A	N/A	N/A	N/A	N/A	5555 _h	5555 _h
60 _h	EPC word 6	N/A	N/A	N/A	N/A	N/A	N/A	6666 _h

Annex G

(Normative)

Multiple- and dense-Interrogator channelized signaling

This Annex describes channelized signaling in the optional multiple- and dense-Interrogator operating modes. It provides methods that Interrogators may use, as permitted by local authorities, to maximize the spectral efficiency and performance of RFID systems while minimizing the interference to non-RFID systems.

Because regulatory requirements vary worldwide, and even within a given regulatory region are prone to ongoing reinterpretation and revision, this Annex does not specify multiple- or dense-Interrogator operating requirements for any given regulatory region. Instead, this Annex merely outlines the goals of channelized signaling, and defers specification of the Interrogator operating requirements for each individual regulatory region to the channel plans located at <http://www.gs1.org/epcglobal/implementation>.

When an Interrogator in a multiple- or dense-Interrogator environment instructs Tags to use subcarrier backscatter, the Interrogator shall adopt the channel plan found at the above-referenced link for the regulatory region in which it is operating. When an Interrogator in a multiple- and dense-Interrogator environment instructs Tags to use FM0 backscatter, the Interrogator shall adopt a channel plan in accordance with local regulations.

Regardless of the regulatory region and the choice of Tag backscatter data encoding,

- Interrogator signaling (both modulated and CW) shall be centered in a channel with the frequency accuracy specified in 6.3.1.2.1, unless local regulations specify tighter frequency accuracy, in which case the Interrogator shall meet the local regulations, and
- Interrogator transmissions shall satisfy the multiple- or dense-Interrogator transmit mask in 6.3.1.2.11 (as appropriate), unless local regulations specify a tighter mask, in which case the Interrogator shall meet the local regulations.

If an Interrogator uses SSB-ASK modulation, the transmit spectrum shall be centered in the channel during R=>T signaling, and the CW shall be centered in the channel during Tag backscatter.

G.1 Overview of dense-Interrogator channelized signaling (informative)

In environments containing two or more Interrogators, the range and rate at which Interrogators singulate Tags can be improved by preventing Interrogator transmissions from colliding spectrally with Tag responses. This section describes three frequency-division multiplexing (FDM) methods that minimize such Interrogator-on-Tag collisions. In each of these methods, Interrogator transmissions and Tag responses are separated spectrally.

1. *Channel-boundary backscatter*: Interrogator transmissions are constrained to occupy only a small portion of the center of each channel, and Tag backscatter is situated at the channel boundaries.
2. *Alternative-channel backscatter*: Interrogator transmissions are located in a subset of the channels, and Tag backscatter is located in a different subset of the channels.
3. *In-channel backscatter*: Interrogator transmissions are constrained to occupy only a small portion of the center of each channel, and Tag backscatter is situated near but within the channel boundaries.

Figure G.1, shows examples of these FDM dense-Interrogator methods. For optimum performance, the operating requirements located at <http://www.gs1.org/epcglobal/implementation> suggest (but do not require) choosing values for BLF and M that allow a guardband between Interrogator signaling and Tag responses.

Example 1: Channel-boundary backscatter

At the time of this protocol FCC 15.247 authorizes frequency-hopping operation in the ISM band from 902–928 MHz with 500 kHz maximum channel width, and does not prohibit channel-boundary backscatter. In such an environment Interrogators will use 500 kHz channels with channel-boundary backscatter. Example 1 of Figure G.1 shows Interrogator transmissions using PR-ASK modulation with $T_{\text{ari}} = 25 \mu\text{s}$, and 62.5 kbps Tag data backscatter on a 250 kHz subcarrier ($\text{BLF} = 250 \text{ kHz}$; $M = 4$). Interrogators center their R=>T signaling in the channels, with transmissions unsynchronized in time, hopping among channels.

Example 2: Alternative-channel backscatter

At the time of this protocol ETSI EN 302 208 allows four high-power 200 kHz channels, each spaced 600 kHz apart, in the 865–868 MHz frequency range, with adjacent-channel Tag backscatter. In such an environment Interrogators will use alternative-channel backscatter. Example 2 of Figure G.1 shows Interrogator transmis-

sions using SSB-ASK modulation with $T_{\text{ari}} = 25 \mu\text{s}$, and 75 kbps Tag data backscatter on a 300 kHz subcarrier (BLF = 300 kHz, $M = 4$).

Example 3: FDM in-channel backscatter

A hypothetical regulatory region allocates four 500 kHz channels and disallows adjacent-channel and channel-boundary backscatter. In such an environment Interrogators will use in-channel backscatter. Example 3 of Figure G.1 shows Interrogator transmissions using PR-ASK modulation with $T_{\text{ari}} = 25 \mu\text{s}$, and 25 kbps Tag data backscatter on a 200 kHz subcarrier (BLF = 200 kHz, $M = 8$).

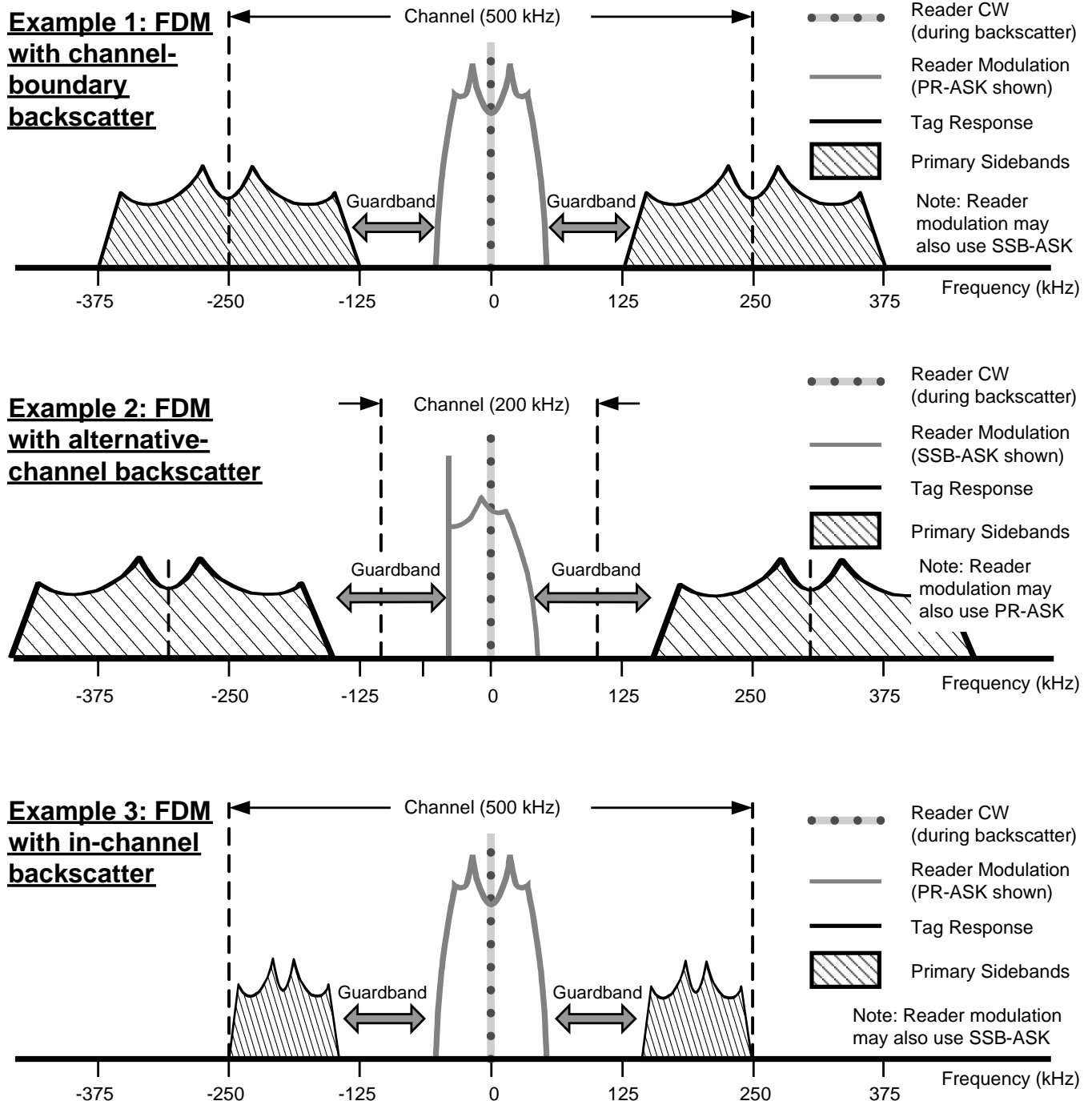


Figure G.1: Examples of dense-Interrogator-mode operation

Annex H

(informative)

Interrogator-to-Tag link modulation

H.1 Baseband waveforms, modulated RF, and detected waveforms

Figure H.1 shows R=>T baseband and modulated waveforms as generated by an Interrogator, and the corresponding waveforms envelope-detected by a Tag, for DSB- or SSB-ASK modulation, and for PR-ASK modulation.

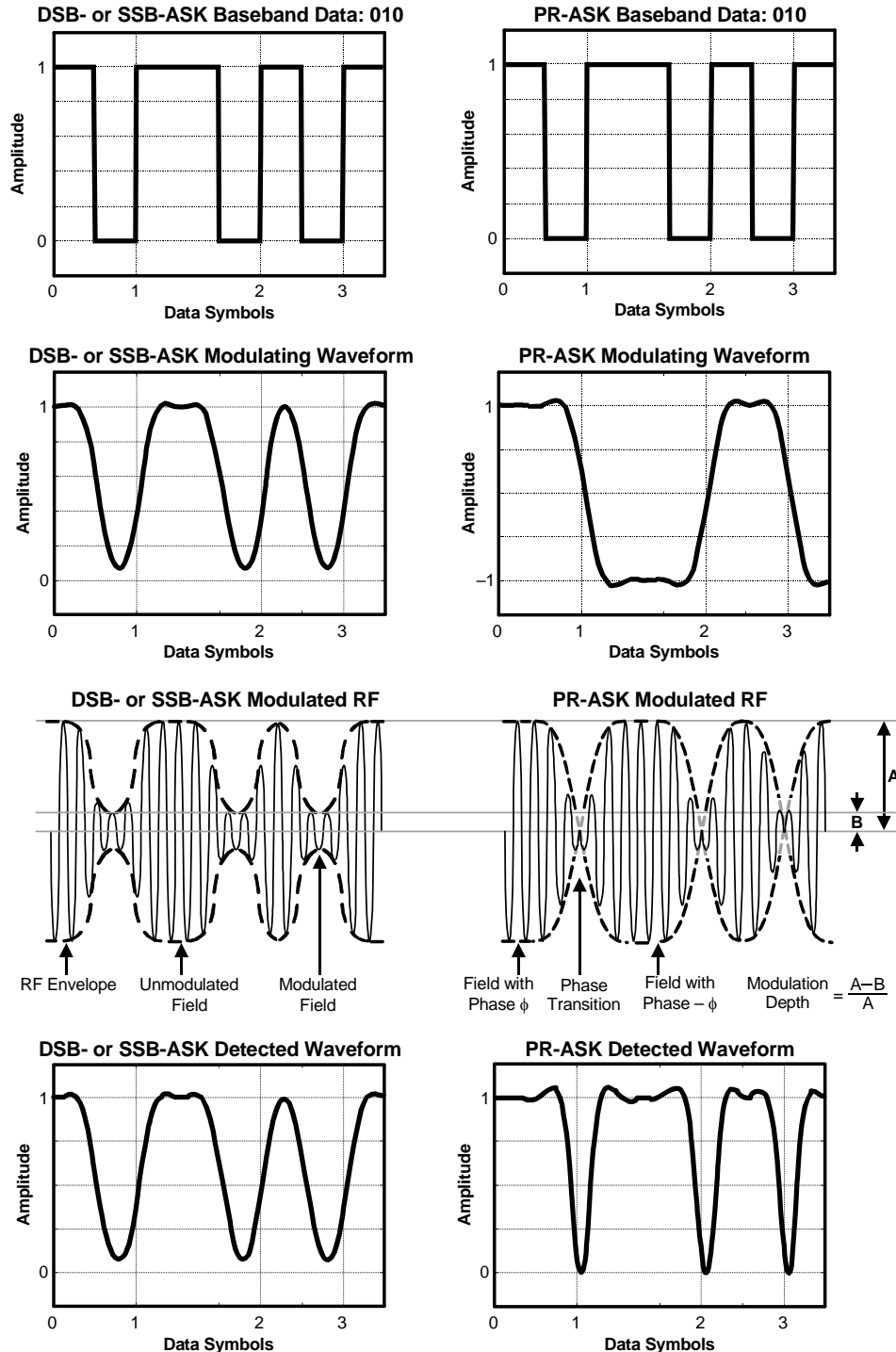


Figure H.1: Interrogator-to-Tag modulation

Annex I

(Normative)

Error codes

I.1 Tag error codes and their usage

If a Tag is required to backscatter an error code then the Tag shall use one of the error codes shown in Table I.2. See [Annex C](#) for the conditions in which a Tag is required to backscatter an error code.

- If a Tag supports error-specific codes then it shall use the error-specific codes shown in Table I.2.
- If a Tag does not support error-specific codes then it shall backscatter error code 00001111₂ (indicating a non-specific error) as shown in Table I.2.
- A Tag shall backscatter error codes only from the **open** or **secured** states.
- A Tag shall not backscatter an error code if it receives an invalid or improper access command, or an access command with an incorrect handle.
- If an error is described by more than one error code then the more specific error code shall take precedence and shall be the code that the Tag backscatters.
- The header for an error code is a 1-bit, unlike the header for a success response which is a 0-bit.

Table I.1: Tag error-reply format

	Header	Error Code	RN	CRC
# of bits	1	8	16	16
description	1	Error code	<u>handle</u>	CRC-16

Table I.2: Tag error codes

Error-Code Support	Error Code	Error-Code Name	Error Description
Error-specific	00000000 ₂	Other error	Catch-all for errors not covered by other codes
	00000001 ₂	Not supported	The Tag does not support the specified parameters or feature
	00000010 ₂	Insufficient privileges	The Interrogator did not authenticate itself with sufficient privileges for the Tag to perform the operation
	00000011 ₂	Memory overrun	The Tag memory location does not exist, is too small, or the Tag does not support the specified EPC length
	00000100 ₂	Memory locked	The Tag memory location is locked or permalocked and is either not writeable or not readable.
	00000101 ₂	Crypto suite error	Catch-all for errors specified by the cryptographic suite
	00000110 ₂	Command not encapsulated	The Interrogator did not encapsulate the command in an <i>AuthComm</i> or <i>SecureComm</i> as required
	00000111 ₂	ResponseBuffer overflow	The operation failed because the ResponseBuffer overflowed
	00001000 ₂	Security timeout	The command failed because the Tag is in a security timeout
	00001011 ₂	Insufficient power	The Tag has insufficient power to perform the operation
Non-specific	00001111 ₂	Non-specific error	The Tag does not support error-specific codes

Annex J

(normative)

Slot counter

J.1 Slot-counter operation

As described in 6.3.2.6.8, Tags implement a 15-bit slot counter. As described in 6.3.2.10, Interrogators use the slot counter to regulate the probability of a Tag responding to a *Query*, *QueryAdjust*, or *QueryRep* command. Upon receiving a *Query* or *QueryAdjust* a Tag preloads a Q-bit value, drawn from the Tag's RNG (see 6.3.2.7), into its slot counter. Q is an integer in the range (0, 15). A *Query* specifies Q; a *QueryAdjust* may modify Q from the prior *Query*.

A Tag in the **arbitrate** state shall decrement its slot counter every time it receives a *QueryRep* command, transitioning to the **reply** state and backscattering an RN16 when its slot-counter value reaches 0000_h. A Tag whose slot-counter value reached 0000_h, who replied, and who was not acknowledged (including a Tag that responded to the original *Query* and was not acknowledged) returns to **arbitrate** with a slot-counter value of 0000_h.

A Tag that returns to **arbitrate** with a slot-counter value of 0000_h shall decrement its slot-counter from 0000_h to 7FFF_h (i.e. the slot counter rolls over) at the next *QueryRep* with matching session. Because the slot-counter value is now nonzero, the Tag remains in **arbitrate**. Slot counters implements continuous counting, meaning that, after a slot counter rolls over it begins counting down again from 7FFF_h, effectively preventing subsequent Tag replies until the Tag receives either a *Query* or a *QueryAdjust* and loads a new random value into its slot counter.

[Annex B](#) and [Annex C](#) contain tables describing a Tag's response to Interrogator commands; "slot" is a parameter in these tables.

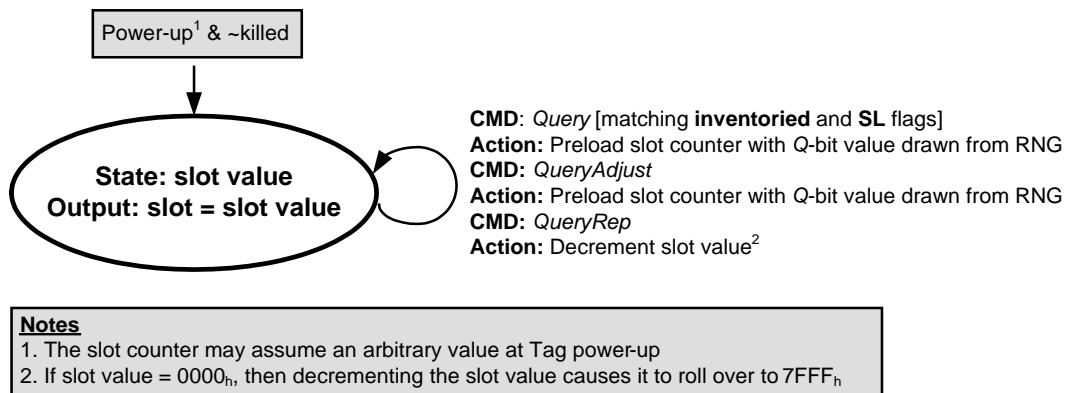


Figure J.1: Slot-counter state diagram

Annex K

(informative)

Example data-flow exchange

K.1 Overview of the data-flow exchange

The following example describes a data exchange, between an Interrogator and a single Tag, during which the Interrogator reads the kill password stored in the Tag's Reserved memory. This example assumes that:

- The Tag has been singulated and is in the **acknowledged** state.
- The Tag's Reserved memory is locked (but not permalocked), so the Interrogator issues the access password and transitions the Tag to the **secured** state before performing the read operation.
- The random numbers the Tag generates (listed in sequence, and not random for reasons of clarity) are:
 - RN16_0 1600_h (the RN16 the Tag backscattered prior to entering **acknowledged**)
 - RN16_1 1601_h (will become the handle for the entire access sequence)
 - RN16_2 1602_h
 - RN16_3 1603_h
- The Tag's EPC is 64 bits in length.
- The Tag's access password is ACCEC0DE_h.
- The Tag's kill password is DEADC0DE_h.
- The 1st half of the access password EXORed with RN16_2 = ACCE_h ⊗ 1602_h = BACC_h.
- The 2nd half of the access password EXORed with RN16_3 = C0DE_h ⊗ 1603_h = D6DD_h.

K.2 Tag memory contents and lock-field values

Table K.1 and Table K.2 show the example Tag memory contents and lock-field values, respectively.

Table K.1: Tag memory contents

Memory Bank	Memory Contents	Memory Addresses	Memory Values
TID	TID[15:0]	10 _h –1F _h	54E2 _h
	TID[31:16]	00 _h –0F _h	A986 _h
EPC	EPC[15:0]	50 _h –5F _h	3210 _h
	EPC[31:16]	40 _h –4F _h	7654 _h
	EPC[47:32]	30 _h –3F _h	BA98 _h
	EPC[63:48]	20 _h –2F _h	FEDC _h
	StoredPC[15:0]	10 _h –1F _h	2000 _h
	StoredCRC[15:0]	00 _h –0F _h	as calculated (see Annex F)
Reserved	access password[15:0]	30 _h –3F _h	C0DE _h
	access password[31:16]	20 _h –2F _h	ACCE _h
	kill password[15:0]	10 _h –1F _h	C0DE _h
	kill password[31:16]	00 _h –0F _h	DEAD _h

Table K.2: Lock-field values

Kill Password		Access Password		EPC Memory		TID Memory		User Memory	
1	0	1	0	0	0	0	0	N/A	N/A

K.3 Data-flow exchange and command sequence

The data-flow exchange follows the *Access* procedure outlined in Figure 6.26 with a *Read* command added at the end. The sequence of Interrogator commands and Tag replies is:

- Step 1: *Req_RN*[RN16_0, CRC-16]
Tag backscatters RN16_1, which becomes the handle for the entire access sequence
- Step 2: *Req_RN*[handle, CRC-16]
Tag backscatters RN16_2
- Step 3: *Access*[access password[31:16] EXORed with RN16_2, handle, CRC-16]
Tag backscatters handle
- Step 4: *Req_RN*[handle, CRC-16]
Tag backscatters RN16_3
- Step 5: *Access*[access password[15:0] EXORed with RN16_3, handle, CRC-16]
Tag backscatters handle
- Step 6: *Read*[MemBank=Reserved, WordPtr=00h, WordCount=2, handle, CRC-16]
Tag backscatters kill password

Table K.3 shows the detailed Interrogator commands and Tag replies. For reasons of clarity, the CRC-16 has been omitted from all commands and replies.

Table K.3: Interrogator commands and Tag replies

Step	Data Flow	Command	Parameter and/or Data	Tag State
1a: <i>Req_RN</i> command	R => T	11000001	0001 0110 0000 0000 (RN16_0=1600h)	acknowledged → open
1b: Tag response	T => R		0001 0110 0000 0001 (<u>handle</u> =1601h)	
2a: <i>Req_RN</i> command	R => T	11000001	0001 0110 0000 0001 (<u>handle</u> =1601h)	open → open
2b: Tag response	T => R		0001 0110 0000 0010 (RN16_2=1602h)	
3a: <i>Access</i> command	R => T	11000110	1011 1010 1100 1100 (BACC _h) 0001 0110 0000 0001 (<u>handle</u> =1601h)	open → open
3b: Tag response	T => R		0001 0110 0000 0001 (<u>handle</u> =1601h)	
4a: <i>Req_RN</i> command	R => T	11000001	0001 0110 0000 0001 (<u>handle</u> =1601h)	open → open
4b: Tag response	T => R		0001 0110 0000 0011 (RN16_2=1603h)	
5a: <i>Access</i> command	R => T	11000110	1101 0110 1101 1101 (D6DD _h) 0001 0110 0000 0001 (<u>handle</u> =1601h)	open → secured
5b: Tag response	T => R		0001 0110 0000 0001 (<u>handle</u> =1601h)	
6a: <i>Read</i> command	R => T	11000010	00 (MemBank=Reserved) 00000000 (WordPtr=kill password) 00000010 (WordCount=2) 0001 0110 0000 0001 (<u>handle</u> =1601h)	secured → secured
6b: Tag response	T => R		0 (header) 1101 1110 1010 1101 (DEAD _h) 1100 0000 1101 1110 (CODE _h)	

Annex L

(informative)

Optional Tag Features

The following options are available to Tags certified to this protocol.

L.1 Optional Tag memory banks, memory-bank sizes, and files

Reserved memory: Reserved memory is optional. If a Tag does not implement kill and access passwords then the Tag need not physically implement Reserved memory. Because a Tag with non-implemented passwords operates as if it has zero-valued password(s) that are permanently read/write locked, these passwords must still be logically addressable in Reserved memory at the memory locations specified in 6.3.2.1.1.1 and 6.3.2.1.1.2.

EPC memory: EPC memory is required, but its size is Tag-manufacturer defined. The minimum size is 32 bits, to contain a 16-bit StoredCRC and a 16-bit StoredPC. EPC memory may be larger than 32 bits, to contain an EPC whose length may be 16 to 496 bits (if a Tag does not support XPC functionality) or to 464 bits (if a Tag supports XPC functionality), as well as an optional XPC word or words. See 6.3.2.1.2.

TID memory: TID memory is required, but its size is Tag-manufacturer defined. The minimum-size TID memory contains an 8-bit ISO/IEC 15963 allocation class identifier (either E0_h or E2_h) in memory locations 00_h to 07_h, as well as sufficient identifying information for an Interrogator to uniquely identify the custom commands and/or optional features that a Tag supports. TID memory may optionally contain other data. See 6.3.2.1.3.

User memory: User memory is optional. A Tag may partition User memory into one or more files whose memory allocation may be *static* or *dynamic*. The Tag manufacturer chooses where a Tag stores its FileType and FileNum data. The Tag manufacturer also chooses the file-allocation block size (from one to 1024 words). User memory and the files in it may be encoded according to the GS1 EPC Tag Data Standard or to ISO/IEC 15961/15962. See 6.3.2.1.4, 6.3.2.1.4.1, 6.3.2.1.4.2, and 6.3.2.11.3.

L.2 Optional Tag commands

Proprietary: A Tag may support proprietary commands. See 2.3.3.

Custom: A Tag may support custom commands. See 2.3.4.

Challenge: A Tag may support the *Challenge* command. See 6.3.2.12.1.2.

Access: A Tag may support the *Access* command. See 6.3.2.12.3.6.

BlockWrite: A Tag may support the *BlockWrite* command. See 6.3.2.12.3.7.

BlockErase: A Tag may support the *BlockErase* command. See 6.3.2.12.3.8.

BlockPermalock: A Tag may support the *BlockPermalock* command. See 6.3.2.12.3.9.

Authenticate: A Tag may support the *Authenticate* command. See 6.3.2.12.3.10.

AuthComm: A Tag may support the *AuthComm* command. 6.3.2.12.3.11.

SecureComm: A Tag may support the *SecureComm* command. See 6.3.2.12.3.12.

KeyUpdate: A Tag may support the *KeyUpdate* command. See 6.3.2.12.3.13.

TagPrivilege: A Tag may support the *TagPrivilege* command. See 6.3.2.12.3.14.

ReadBuffer: A Tag may support the *ReadBuffer* command. See 6.3.2.12.3.15.

Untraceable: A Tag may support the *Untraceable* command. See 6.3.2.12.3.16.

FileOpen: A Tag may support the *FileOpen* command. See 6.3.2.12.3.17.

FileList: A Tag may support the *FileList* command. See 6.3.2.12.3.18.

FilePrivilege: A Tag may support the *FilePrivilege* command. See 6.3.2.12.3.19.

FileSetup: A Tag may support the *FileSetup* command. See 6.3.2.12.3.20.

L.3 Optional Tag passwords, security, and keys

Kill password: A Tag may implement a kill password. A Tag that does not implement a kill password operates as if it has a zero-valued kill password that is permanently read/write locked. See 6.3.2.1.1.1.

Access password: A Tag may implement an access password. A Tag that does not implement an access password operates as if it has a zero-valued access password that is permanently read/write locked. See 6.3.2.1.1.2.

Security timeout: A Tag may implement a security timeout. See 6.3.2.5.

Cryptographic security and keys: A Tag may support one or more cryptographic suites, each of which may implement Tag, Interrogator, and/or mutual authentication. A Tag may support up to 256 keys. A key may have a CryptoSuperuser, AuthKill, Untraceable, or a DecFilePriv privilege. A key may also have a property defined by the cryptographic suite and/or a custom property. See 6.3.2.11.2.

Random-number generator: A cryptographic suite may specify different RNG requirements for cryptographic operations than for other Tag operations. See 6.3.2.7.

L.4 Optional Tag replies

A Tag may implement an *in-process* reply and a ResponseBuffer. See 6.3.1.6.3 and 6.3.1.6.4.

L.5 Optional Tag PC and XPC bit designations and values

PC: The **UMI** bit may be fixed by the Tag manufacturer or computed by the Tag. A Tag may be used in a GS1 EPCglobal™ or a non-GS1 EPCglobal™ Application (**T**=0 or **T**=1 respectively). If **T**=0 then the **XI** bit may be either (i) the logical OR of bits 210_h–217_h of XPC_W1 or (ii) the logical OR of bits 210_h–218_h of XPC_W1; the Tag manufacturer shall choose whether the Tag implements (i) or (ii). If **T**=1 then **XI** is the logical OR of the entirety of XPC_W1 (210_h–21F_h). Bits 18_h – 1F_h of the StoredPC may be RFU or an AFI. When forming a PacketPC, a Tag may substitute bits 218_h–21F_h of its XPC_W1 for bits 18_h–1F_h of its StoredPC. See 6.3.2.1.2.2.

XPC: A Tag may implement an XPC_W1. If the Tag implements an XPC_W1 then it may implement an XPC_W2. A Tag's XPC_W1 may support the **XEB**, **B**, **C**, **SLI**, **TN**, **U**, **K**, **NR**, and **H** flags, corresponding to whether the Tag has a nonzero XPC_W2, a battery, a computed response, an asserted **SL** flag, a Tag notification, an untraceability indicator, is killable, is not removable, or is attached to hazardous material. These XPC_W1 bits may be fixed, written, computed, or set based on the application. Bits 211_h–217_h of XPC_W1 may be zero or as defined in ISO/IEC 18000-63. All bits of XPC_W2 may be zero or as defined in ISO/IEC 18000-63. See 6.3.2.1.2.5.

L.6 Optional Tag error-code reporting format

A Tag may support error-specific or non-error-specific error-code reporting. See [Annex I](#).

L.7 Optional Tag backscatter modulation format

A Tag may support ASK and/or PSK backscatter modulation. See 6.3.1.3.1.

L.8 Optional Tag functionality

A Tag may use one of the methods described in [Annex F](#) to verify a CRC-5 or a CRC-16. See 6.3.1.5.

A Tag may compute its CRC-16 using one of two methods. A Tag may store the CRC-16 in volatile or nonvolatile memory. See 6.3.2.1.2.1.

A Tag may limit access to the **secured** state via one or more physical mechanisms. See 6.3.2.11.

A Tag may support authenticated kill. See 6.3.2.12.3.4.

A Tag may store its lock bits in a readable or an unreadable memory location. See 6.3.2.12.3.5.

Annex M

(informative)

Cryptographic-Suite Checklist

A cryptographic suite typically includes at a minimum the parameters, functionality, procedures, behavior, and error conditions shown in the checklist of Table M.1.

Table M.1: Required elements of a cryptographic suite

Required Element of a Cryptographic Suite	Included?
A <u>CSI</u>	
Message fields for commands supported by the cryptographic suite from the set <i>Challenge</i> , <i>Authenticate</i> , <i>AuthComm</i> , <i>SecureComm</i> , and <i>KeyUpdate</i> .	
Functional descriptions of and bit fields for all parameters, formatting, encoding, decoding, and integrity protection used in or by all <u>messages</u> and <u>responses</u> for the supported cryptographic commands.	
Conditions in which one or more security commands (see 6.3.2.11.2) cause a Tag to enforce a security timeout	
Conditions under which the Tag resets its cryptographic engine and the parameters of such a reset	
Randomness requirements including RN length, uniqueness, predictability, generation rate, nonce, etc.	
How an Interrogator specifies a <u>KeyID</u> in a <u>message</u> field.	
Whether <u>messages</u> and/or <u>responses</u> include an explicit step count.	
Whether the cryptographic suite requires a <i>KeyUpdate</i> to be encapsulated in a <i>SecureComm</i> or an <i>AuthComm</i> .	
The formatting of every <u>message</u> and every <u>response</u> for every cryptographic command	
Whether and when an Interrogator and/or a Tag use authenticated or secure communications	
Flow diagrams showing sequencing, timing, state transitions, and error conditions for every step in every operation supported by the cryptographic suite, including but not limited to:	
<ul style="list-style-type: none"> Whether the Tag or Interrogator require one or more wait states in the generation, execution, or receipt of any cryptographic commands or responses. 	
<ul style="list-style-type: none"> Mechanism(s) for a multipass authentication (if any) 	
<ul style="list-style-type: none"> How Tag and Interrogator derive session keys (if any) 	
<ul style="list-style-type: none"> The beginning and ending Tag state for every step in a cryptographic authentication 	
<ul style="list-style-type: none"> Definitions for and locations in the flow diagrams for when (1) a Tag considers an Interrogator to be authenticated, and (2) an Interrogator considers a Tag to be authenticated 	
<ul style="list-style-type: none"> An enumeration of every potential cryptographic error that an Interrogator or a Tag may encounter and the Interrogator and Tag behavior for each. A few representative examples of such errors include (1) one entity replies incorrectly or fails to reply part way thru a cryptographic operation, (2) one entity cannot complete a cryptographic computation, (3) one entity replies with an incorrect step count, and (4) many others. 	

Annex N

(normative)

Application Conformance

To be certified as alteration-EAS, Tag-alteration, and/or consumer-electronics conformant, Tags and Interrogators shall support the optional clauses or portions of optional clauses cited in the corresponding sections of Table N.1, respectively, as mandatory. To be clear, those features in the cited optional clause or portion of optional clause specified with a “may” shall become a “shall”; those specified with a “shall” shall remain a “shall”.

Table N.1: Required clauses for certification, by type

Alteration EAS	Tag Alteration (Core)	Consumer Electronics
6.3.2.1.3 <ul style="list-style-type: none"> an E_{2h} class identifier and an XTID (see 4.1) are mandatory a nonzero XTID serialization field is mandatory 	6.3.2.1.3 <ul style="list-style-type: none"> an E_{2h} class identifier and an XTID (see 4.1) are mandatory a nonzero XTID serialization field is mandatory 	6.3.2.1.3 <ul style="list-style-type: none"> an E_{2h} class identifier and an XTID (see 4.1) are mandatory a nonzero XTID serialization field is mandatory
6.3.2.1.2.5 <ul style="list-style-type: none"> SLI and K bits in XPC_W1 are mandatory 	6.3.2.1.2.5 <ul style="list-style-type: none"> SLI, K, and NR bits in XPC_W1 are mandatory 	6.3.2.1.2.5 <ul style="list-style-type: none"> SLI, K, NR, and H bits in XPC_W1 are mandatory
6.3.2.11 <ul style="list-style-type: none"> a Tag shall implement the mechanisms in this protocol that prevent it from transitioning directly from the acknowledged to the secured state 	6.3.2.11 <ul style="list-style-type: none"> a Tag shall implement the mechanisms in this protocol that prevent it from transitioning directly from the acknowledged to the secured state 	6.3.2.11 <ul style="list-style-type: none"> a Tag shall implement the mechanisms in this protocol that prevent it from transitioning directly from the acknowledged to the secured state
6.3.2.12.3.16 <ul style="list-style-type: none"> <i>Untraceable</i> command¹. A Tag may, but is not required to, support range reduction or the U bit. 	6.3.2.12.3.16 <ul style="list-style-type: none"> <i>Untraceable</i> command¹. A Tag may, but is not required to, support range reduction or the U bit. 	6.3.2.12.3.9 <ul style="list-style-type: none"> <i>BlockPermalock</i> command¹
6.3.2.5 <ul style="list-style-type: none"> Security timeout for the <i>Access</i> command with a timeout range as specified in Table 6.20 is mandatory 	6.3.2.5 <ul style="list-style-type: none"> Security timeout for the <i>Access</i> command with a timeout range as specified in Table 6.20 is mandatory 	6.3.2.5 <ul style="list-style-type: none"> Security timeout for the <i>Access</i> command with a timeout range as specified in Table 6.20 is mandatory
6.3.2.1.4.1 <ul style="list-style-type: none"> ≥32 bits User memory is mandatory 	Intentionally left blank	6.3.2.12.3.17 <ul style="list-style-type: none"> <i>FileOpen</i> command¹
Intentionally left blank	Intentionally left blank	6.3.2.11.3 <ul style="list-style-type: none"> At least 2 files are mandatory
Tag Alteration (Challenge)	Tag Alteration (Authenticate)	Tag Alteration (Full)
All requirements of Tag Alteration (Core)	All requirements of Tag Alteration (Core)	All requirements of Tag Alteration (Core)
6.3.2.12.1.2 <ul style="list-style-type: none"> <i>Challenge</i> command¹ 	6.3.2.12.3.10 <ul style="list-style-type: none"> <i>Authenticate</i> command¹ 	6.3.2.12.1.2 <ul style="list-style-type: none"> <i>Challenge</i> command¹
Intentionally left blank	Intentionally left blank	6.3.2.12.3.7 <ul style="list-style-type: none"> <i>Blockwrite</i> command¹
Intentionally left blank	Intentionally left blank	6.3.2.12.3.10 <ul style="list-style-type: none"> <i>Authenticate</i> command¹
Intentionally left blank	Intentionally left blank	6.3.2.12.3.12 <ul style="list-style-type: none"> <i>SecureComm</i> command¹
Intentionally left blank	Intentionally left blank	6.3.2.12.3.13 <ul style="list-style-type: none"> <i>KeyUpdate</i> command¹

1: The command in its entirety is mandatory

Annex O

(informative)

Revision History

Table O.1: Revision history

Date & Version Number	Section(s)	Change
Sept 8, 2004 Version 1.0.4	All	Modified Chicago protocol V1.0.3 as per August 17, 2004 "combo" CRC change template.
Sept 14, 2004 Version 1.0.5	All	Modified Gen2 protocol V1.0.4 as per September 10, 2004 CRC review.
Sept 17, 2004 Version 1.0.6	All	Modified Gen2 protocol V1.0.5 as per September 17, 2004 HAG review.
Sept 24, 2004 Version 1.0.7	All	Modified Gen2 protocol V1.0.6 as per September 21, 2004 CRC review to fix errata. Changed OID to EPC.
Dec 11, 2004 Version 1.0.8	Multiple	Modified Gen2 protocol V1.0.7 as per the V1.0.7 errata.
Jan 26, 2005 Version 1.0.9	Multiple	Modified Gen2 protocol V1.0.8 as per the V1.0.8 errata and AFI enhancement requests.
Dec 1, 2005 Version 1.1.0	Multiple	Harmonized Gen2 protocol V1.0.9 with the ISO 18000-6 Type C amendment.
May 11, 2008 Version 1.2.0	Multiple	Modified Gen2 protocol V1.1.0 to satisfy the ILT JRG requirements V1.2.3.
Oct 22, 2013 Version 2.0.0	Multiple	Modified Gen2 protocol V1.2.0 to satisfy EAS JRG requirements V0.8, TA JRG requirements V0.7, and CE JRG requirements V1.5.4.
April 23, 2015 Version 2.0.1	Multiple	Modified Gen2 protocol V2.0.0 to fix errata