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

**Part 2:
Parameters for air interface
communications below 135 kHz**

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

*Partie 2: Paramètres de communications d'une interface d'air à moins
de 135 kHz*



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Foreword

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

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

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

ISO/IEC 18000-2 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 31, *Automatic identification and data capture techniques*.

This second edition cancels and replaces the first edition (ISO/IEC 18000-2:2004), which has been technically revised.

ISO/IEC 18000 consists of the following parts, under the general title *Information technology — Radio frequency identification for item management*:

- *Part 1: Reference architecture and definition of parameters to be standardized*
- *Part 2: Parameters for air interface communications below 135 kHz*
- *Part 3: Parameters for air interface communications at 13,56 MHz*
- *Part 4: Parameters for air interface communications at 2,45 GHz*
- *Part 6: Parameters for air interface communications at 860 MHz to 960 MHz*
- *Part 7: Parameters for active air interface communications at 433 MHz*

Introduction

The International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) draw attention to the fact that it is claimed that compliance with this document may involve the use of patents.

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The holders of these patent rights have assured ISO and IEC that they are willing to negotiate licences under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statements of the holders of these patent rights are registered with ISO and IEC. Information may be obtained from the following companies.

Patent number	Patent title	Patent holder	Contact	Affected sub clause
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US 6 177 858 Application 96 402556.3-Patent EP 0 777 194 CA 2 191 787 CA 2 191 788 US 5 923 251 Application 96 402554.8 Patent EP 0 777 192 US 5 808 550 Appication 96 402555.5- Patent EP 0 777 193		Winstead Assets Ltd	Craig Cook, director 12, rue des Petits Ruisseaux, 91370 Verrières le Buisson, France Phone +33(0) 169 752 170 Fax +33(0) 160 110 031 contact@spacecode-rfid.com	

CA 2 191 794 Application 90 909459.1-Patent EP 0 476 026 US 5426423 CA 2058 947				
EP 0640939,US 5430447,DE P69428309 EP831618, US5929801 (claims 1-15 and corresponding claims of other patents based on this patent) US 5793324 US 5053774 excluding claims 14-17 and 20 (and corresponding claims of other patents based on this patent)	Protection Against Manipulation of Batteryless Read/Write Transponders Method for Repeating Interrogations Until Failing to Receive Unintelligible Responses to Identify Plurality of Transponders by an Interrogator Transponder Signal Collision Avoidance System Transponder Arrangement	Texas Instruments Inc	Robby Holland Licensing Manager, Law Department P.o. Box 660199, MS 3999 Dallas, TX 75266-0199 Phone 1-972-917-4367 Fax 1-972-917-4418 Email r-holland3@ti.com	

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Information technology — Radio frequency identification for item management —

Part 2: Parameters for air interface communications below 135 kHz

1 Scope

This part of ISO/IEC 18000 defines the air interface for radio frequency identification (RFID) devices operating below 135 kHz. The purpose of this part of ISO/IEC 18000 is to provide a common technical specification for RFID devices that can be used by ISO committees developing RFID application standards. This part of ISO/IEC 18000 is intended to allow for compatibility and to encourage inter-operability of products in the international marketplace. This part of ISO/IEC 18000 defines the physical layer used for communication between the interrogator and the tag and further defines the communications protocol used in the air interface.

Two types of tag are defined by this part of ISO/IEC 18000: Type A and Type B, which differ only by their physical layer. Both support the same inventory (anti-collision) and protocol.

Type A tags are permanently powered by the interrogator, including during the tag-to-interrogator transmission, and operate at 125 kHz.

Type B tags are powered by the interrogator, except during the tag-to-interrogator transmission, and operate at 125 kHz or 134,2 kHz.

2 Conformance

In order to claim conformance, it is necessary to comply to all of the relevant clauses of this specification, except those marked 'optional'. It is also necessary to operate within the local national radio regulations (which may require further restrictions).

The rules for RFID device conformity evaluation are defined in ISO/IEC TR 18047-2.

The tag shall be of either Type A or B.

NOTE Nothing in this International Standard prevents a tag from being of both types, although for technical reasons, it is unlikely that such tags are ever marketed.

The interrogator shall support both Types A and B.

The interrogator may be configured as Type A only, Type B only or Types A and B.

When configured as Types A and B, and when in the Inventory phase, the interrogator shall alternate between Type A and Type B interrogation. See Annex B.

2.1 RF emissions general population

Device manufacturers claiming conformance to this part of ISO/IEC 18000 shall certify that RF emissions do not exceed the maximum permitted exposure limits recommended by either IEEE C95.1:2005 or ICNIRP according to IEC 62369-1. If a device manufacturer is unsure as to which recommendation is to be cited for compliance, the manufacturer shall certify to ICNIRP limits.

2.2 RF emissions and susceptibility health care setting

Device manufacturers claiming conformance to this part of ISO/IEC 18000 shall certify that RF emissions and susceptibility comply with IEC 60601-1-2.

3 Normative references

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

IEC 62369-1, *Evaluation of human exposure to electromagnetic fields from short range devices (SRDs) in various applications over the frequency range 0 GHz to 300 GHz — Part 1: Fields produced by devices used for electronic article surveillance, radio frequency identification and similar systems*

IEC 60601-1-2, *Medical electrical equipment — Part 1-2: General requirements for basic safety and essential performance — Collateral standard: Electromagnetic compatibility — Requirements and tests*

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

4 Terms and definitions

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

**4.1
anti-collision sequence**
algorithm used to prepare for and handle a dialogue between interrogator and one or more tags out of several in its energizing field

**4.2
bit rate**
number of bits transmitted per second

**4.3
byte**
8 bits of data designated b1 to b8, from the most significant bit (MSB, b8) to the least significant bit (LSB, b1)

**4.4
carrier off time**
time interval when the interrogation field is switched off

**4.5
charge up time**
time to charge the capacitor of the HDX tag

**4.6
commands**
interrogator to tag communication

4.7**differential bi-phase encoding**

method of encoding in which data bit 0 is represented by a mid-bit transition, data bit 1 is represented by no transition, and in which there is always a transition in between two bits

4.8**down-link**

communication process from the interrogator to the tag

4.9**encoding**

one-to-one relationship between basic information elements and modulation patterns

4.10**FDX**

communication protocol for Type A or FDX tags

4.11**frequency shift keying**

form of frequency modulation in which binary information is superimposed onto an electromagnetic field carrier by shifting between discrete frequencies of the field

4.12**full duplex**

communication protocol in which information is exchanged while the interrogator transmits the interrogation field

4.13**half duplex**

communication protocol in which information is exchanged after the interrogator has stopped transmitting the interrogation field (sequential method)

4.14**HDX**

communication protocol for Type B or HDX tags

4.15**interrogation field**

magnetic field generated by an interrogator to activate a tag and to transfer data to an advanced tag

4.16**interrogation frequency**

frequency of the magnetic field generated by the interrogator

4.17**interrogation period**

time duration the magnetic field is present

4.18**interrogator request**

bit pattern transmitted to the advanced tag to modify the tag status or to read and write information

4.19**manchester encoding**

method of encoding in which data bit 0 is represented by a positive mid-bit transition and data bit 1 is represented by a negative mid-bit transition

**4.20
modulation**

method of superimposing information onto an interrogation field by means of varying a specific parameter of the field

**4.21
non-return to zero encoding**

method of encoding in which data bit 1 is a high signal and data bit 0 is a low signal

**4.22
pulse interval encoding**

method of data encoding in which the transmitted information is represented by the time between the falling edges of fixed length pulses

NOTE The number of received carrier cycles defines data bit values or other code conditions.

**4.23
interrogator**

device used to communicate with a tag

**4.24
tag**

electronic device which is activated by the interrogator and communicates with it

**4.25
unique item identifier**

identification that uniquely identifies a specific entity during its life

5 Symbols and abbreviated terms

5.1 Symbols

NOTE All symbols are expressed with a letter, followed by an upper case letter (A or B or C when referring respectively to Type A or Type B or Annex C, p when referring to the protocol), followed by letters and/or numbers, as appropriate. The main symbols are listed below, where X represents A or B or C. Timings are expressed with an upper case T and according to the above rule. Other symbols specific to A, B or C are specified in the relevant clauses.

f_{Xc} Carrier frequency of the operating field

T_{Xd0} Period of Data Symbol "0"

T_{Xd1} Period of Data Symbol "1"

T_{Xc} Period of carrier frequency ($T_{Xc} = 1/f_{Xc}$)

T_{Xcv} Code Violation Duration

T_{Apx} Tag wait time before transmitting response after end of frame

T_{Ad} Modulation Coding Time where $T_{Ad} = 32 / f_{Ac}$

etu elementary time unit (1 etu = 16/62,5 kHz)

5.2 Abbreviated terms

AFI	application family identifier
ASK	amplitude shift keying
BSS	block security status
BWP	block write protection
CRC	cyclic redundancy check
CRCT	response cyclic redundancy check flag
DSFID	data storage format identifier
EOF	end of frame (pattern)
FDX	full duplex – Type A tag
HDX	half duplex – Type B tag
ICR	IC reference number
kbps	unit for transmission speed: 1000 bit/s or 1000 Baud
LSB	least significant bit
MFC	manufacturer code
MSB	most significant bit
MSN	manufacturer serial number
NOB	number of blocks-1
NOS	number of slots (in the anti-collision mode)
NRZ	non return to zero
RF	radio frequency
RFID	radio frequency identification
RFU	reserved for future use
SOF	start of frame (pattern)
UII	unique item identifier (includes ICR, MFC and MSN)
UMS	user data memory structure

6 Physical layer

6.1 Type A (FDX)

6.1.1 Power transfer

Power transfer to the tag is accomplished by radio frequency via coupling antennas in the tag and in the interrogator. The RF operating field supplies permanently power from the interrogator to the FDX tag. For communication between interrogator and tag, the field is modulated.

6.1.2 Frequency

The carrier frequency of the RF operating field is $f_{Ac} = 125 \pm 0,1$ kHz.

6.1.3 Communication signal interface interrogator to tag

6.1.3.1 Modulation

Communications between interrogator and tag takes place using ASK modulation with a modulation index of 100%.

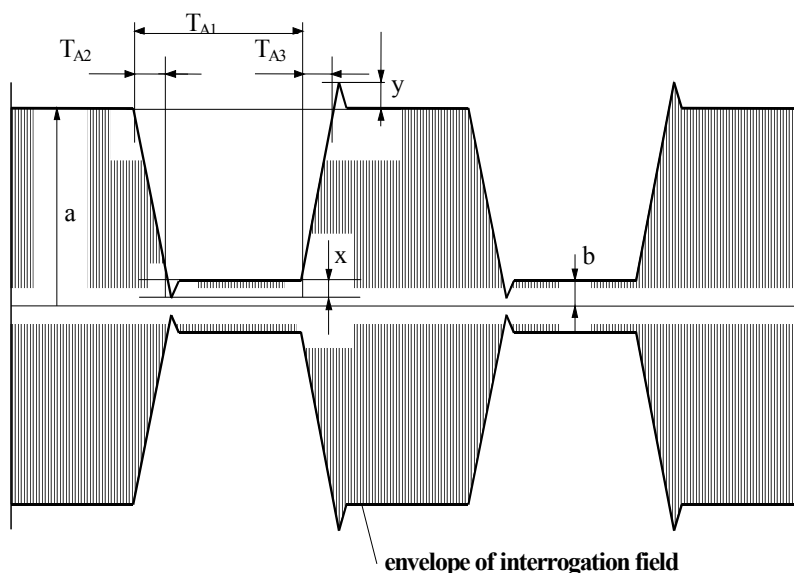


Figure 1 — Modulation details of data transmission from interrogator to tag

Table 1 — Modulation coding times

	Min	Max
$m = (a-b)/(a+b)$	90 %	100 %
T_{A1}	$4 * T_{Ac}$	$10 * T_{Ac}$
T_{A2}	0	$0,5 * T_{A1}$
T_{A3}	0	$0,5 * T_{Ad0}$
x	0	$0,05 * a$
y	0	$0,05 * a$

Notes:

$$T_{A1} + T_{A3} + 3 * T_c < T_{Ad0}$$

$$T_{Ac} = 1/f_{Ac} = 8 \mu s$$

6.1.3.2 Data rate and data coding

The interrogator-to-tag communication uses Pulse Interval Encoding (Figure 2). The interrogator creates pulses by switching the carrier as described in Figure 1. The time between the falling edges of the pulses determines either the value of the data bit "0" and "1", a Code violation or a Stop condition. (note: with equal distributed data bits "0" and "1", the data rate is in the range of 5,1 kbps). Data coding Times are shown in Table 2.

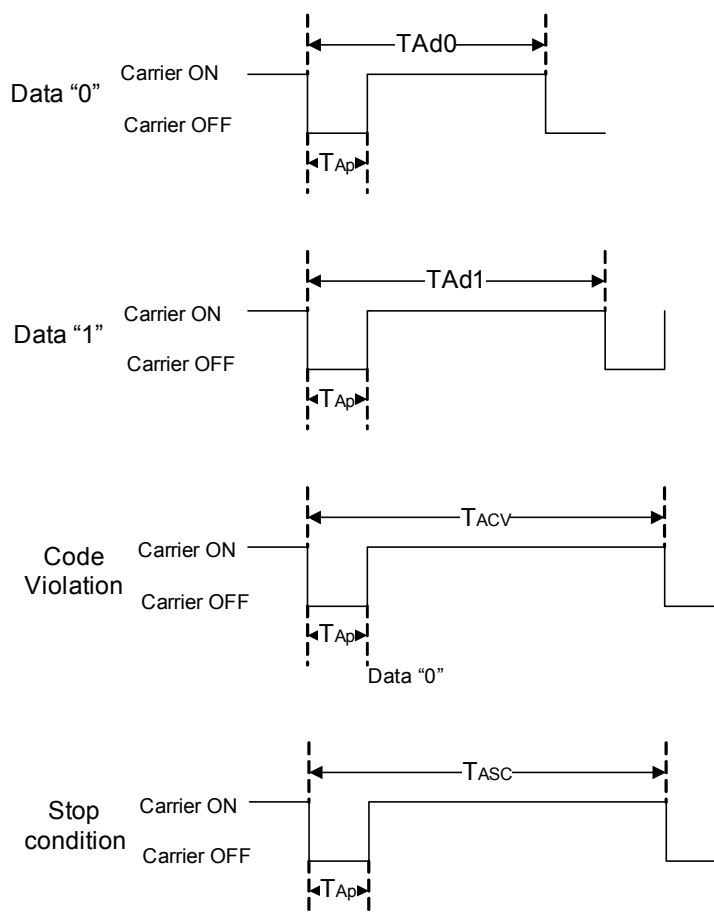


Figure 2 — Interrogator to tag: Pulse interval encoding

Table 2 — Data coding Times

Meaning	Symbol	min	max
"Carrier off" time	T_{Ap}	$4 * T_{Ac}$	$10 * T_{Ac}$
Data "0" time	T_{Ad0}	$18 * T_{Ac}$	$22 * T_{Ac}$
Data "1" time	T_{Ad1}	$26 * T_{Ac}$	$30 * T_{Ac}$
"Code violation" time	T_{Acv}	$34 * T_{Ac}$	$38 * T_{Ac}$
"Stop condition" time	T_{Asc}	$\geq 42 * T_{Ac}$	n/a

NOTE $T_{Ac} = 1/f_{Ac} = 8 \mu s$.

6.1.3.3 Start of frame pattern

The interrogator request starts always with a Start of frame pattern (SOF) for ease of synchronization. The SOF pattern consists of a data bit "0" pattern and a "Code violation" pattern.

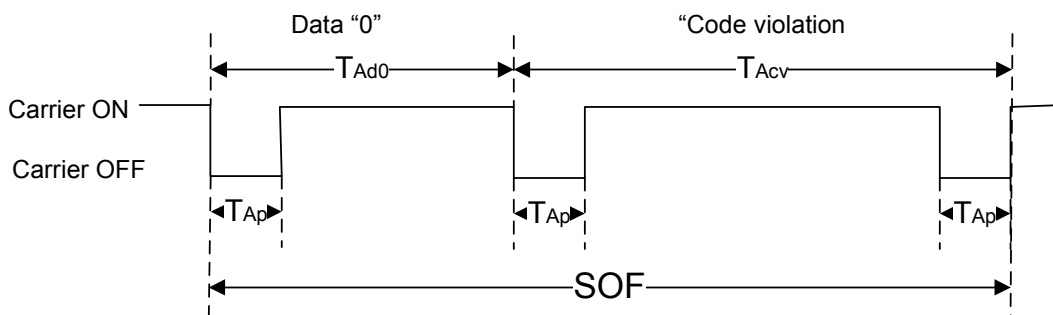


Figure 3 — Start of frame pattern

The tag shall be ready to receive a SOF from the interrogator within 1,2 ms after having sent a response to the interrogator.

The tag shall be ready to receive a SOF from the interrogator within 2,5 ms after the interrogator has established the powering field.

6.1.3.4 End of frame pattern

For slot switching during a multi-slot anti-collision sequence, the interrogator request is an EOF pattern. The EOF pattern is represented by a "Stop condition".

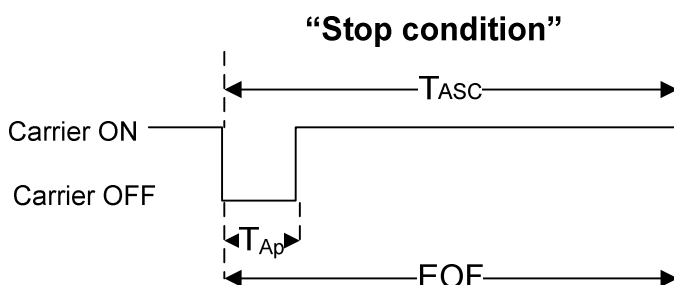


Figure 4 — End of frame pattern

6.1.4 Communication signal interface tag to interrogator

6.1.4.1 Data rate and data coding

The tag shall communicate with the interrogator via an inductive coupling, where the interrogator carrier is load modulated as follows:

- $1/T_{Ad}$ Manchester coded data signal of the tag response
- $1/(2 \cdot T_{Ad})$ dual pattern data coding when responding within the INVENTORY process

Where $T_{Ad} = 32 / f_{Ac}$ and f_{Ac} is the carrier frequency of the operating field

NOTE: The slower data rate used during the inventory process allows for improving the collision detection when several tags are present in the interrogator field, especially if some tags are in the near field and others in the far field.

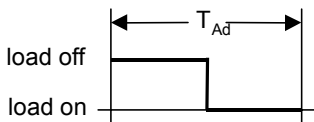
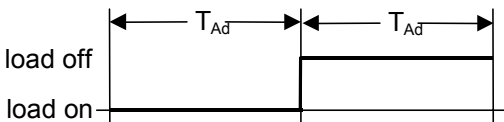
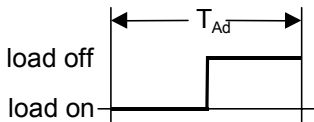
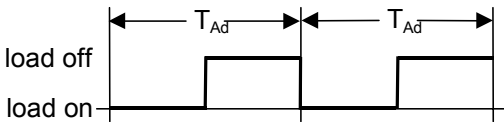
Data Element	International Standard command	Inventory command
Data "0"		
Data "1"		

Figure 5 — Tag to interrogator: load modulation coding

6.1.4.2 Start of frame pattern

The tag response starts always with a Start of frame (SOF) pattern. The SOF pattern is a Manchester coded bit sequence of "110".

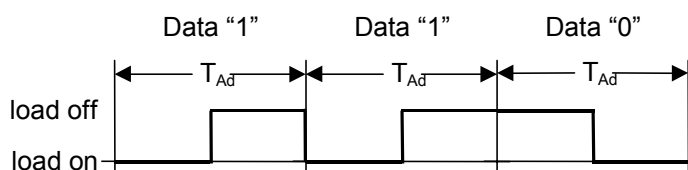


Figure 6 — Start of frame pattern

6.1.4.3 End of frame pattern

A specific EOF pattern is neither used nor specified for the FDX tag response. An EOF is detected by the interrogator if there is no load modulation for more than two data bit periods (T_{Ad}).

6.1.5 General Protocol Timing Specifications

For write like requests where an erase and or programming operation is required, the tag shall return its response when it has completed the write/lock operation and latest either after 20 ms upon detection of the last falling edge of the interrogator request.

T_{Ap1} is not applicable for write like requests.

6.1.5.1 Waiting Time before Transmitting its Response after an EOF from the Interrogator

When the FDX tag has detected an EOF of a valid interrogator request or when this EOF is in the normal sequence of a valid interrogator request, it shall wait for a time T_{Ap1} before starting to transmit its response to an interrogator request or when switching to the next slot in an inventory process.

T_{Ap1} starts from the detection of the falling edge of the EOF received from the interrogator.

NOTE The synchronisation on the falling edge of the interrogator to tag EOF is needed to ensure the required synchronisation of the tag responses.

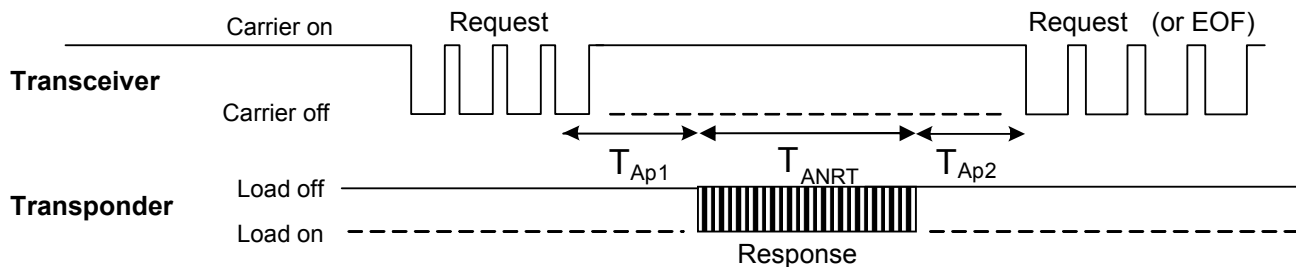


Figure 7 — FDX - General Protocol Timing Diagram

The minimum value of T_{Ap1} is $T_{Ap1min} = 204 T_{Ac}$

The typical value of T_{Ap1} is $T_{Ap1typ} = 209 T_{Ac}$

The maximum value of T_{Ap1} is $T_{Ap1max} = 213 T_{Ac}$

If the FDX tag detects a carrier modulation during this time T_{Ap1} , it shall reset its T_{Ap1} timer and wait for a further time T_{Ap1} before starting to transmit its response to an interrogator request or to switch to the next slot when in an inventory process.

6.1.5.2 Interrogator Waiting Time before Sending a Subsequent Request

- When the interrogator has received a tag response to a previous request other than INVENTORY and QUIET, it shall wait a time T_{Ap2} before sending a subsequent request. T_{Ap2} starts from the time the last bit has been received from the tag.
- When the interrogator has sent a QUIET request (which causes no tag response), it shall wait a time T_{Ap2} before sending a subsequent request. T_{Ap2} starts from the end of the QUIET request's EOF (falling edge of EOF pulse + $42 T_{Ac}$).

The minimum value of T_{Ap2} is $T_{Ap2min} = 150 T_{Ac}$. It ensures that the tags are ready to receive a subsequent request.

NOTE The interrogator should wait at least 2.5 ms after it has activated the electromagnetic field before sending the first request, to ensure that the tag(s) are ready to receive a request.

- When the interrogator has sent an inventory request, it is in an inventory process. See the subsequent clause 6.1.5.3.

6.1.5.3 Interrogator Waiting Time Before Switching to Next Inventory Slot

An inventory process is started when the interrogator sends an inventory request.

To switch to the next slot, the interrogator sends an EOF after waiting a time specified in the following sub-clauses.

6.1.5.4 Interrogator Started to Receive One or More FDX Tag Responses

During an inventory process, when the interrogator has started to receive one or more tag responses (i.e. it has detected a tag SOF and/or a collision), it shall

- wait for the complete reception of the tag responses (i.e. when a tag's last bit has been received or when the tag nominal response time T_{ANRT} has elapsed),
- wait an additional time T_{Ap2} and then send an EOF to switch to the next slot, if a 16 slot anti-collision request is processed, or send a subsequent request (which could be again an inventory request).

T_{Ap2} starts from the time the last bit has been received from the tag.

The minimum value of T_{Ap2} is $T_{Ap2min} = 150 T_{Ac}$.

T_{ANRT} is dependant on the anti-collisions current mask value and on the setting of the CRCT flag.

6.1.5.5 Interrogator Receives no FDX Tag Response

During an inventory process, when the interrogator has received no tag response, it shall wait a time T_{Ap3} before sending a subsequent EOF to switch to the next slot, if a 16 slot anti-collision request is processed, or sending a subsequent request (which could be again an inventory request).

T_{Ap3} starts from the time the interrogator has generated the falling edge of the last sent EOF.

The minimum value of T_{Ap3} is $T_{Ap3min} = T_{Ap1max} + T_{ApSOF}$

T_{ApSOF} is the time duration for a tag to transmit an SOF to the interrogator.

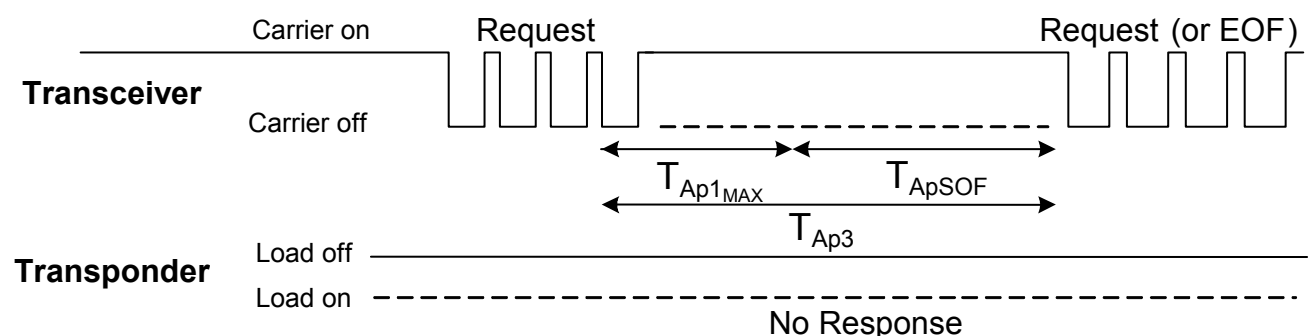


Figure 8 — FDX - Protocol Timing Diagram without Tag Response

Table 3 — Overview timing parameters FDX

Symbol	Minimum	Maximum
T_{ApSOF}	$3 * T_{Ad}$	$3 * T_{Ad}$
T_{Ap1}	$204 T_{Ac}$	$213 T_{Ac}$
T_{Ap2}	$150 T_{Ac}$	
T_{Ap3}	$T_{Ap1max} + T_{ApSOF}$	

6.2 Type B (HDX)

6.2.1 Power transfer

HDX tags have to be charged before operation which is done by switching on the interrogator's field for a defined time (Charge time). This charge phase is executed at the beginning of every request and the duration of the Charge time depends on the system parameters and distance to the interrogator.

During the execution of the INVENTORY request, the tags shall be charged at the beginning as already defined above. Between the inventory slots the tags shall be re-charged. This re-charge time is depending on the amount of additional data requested in an inventory request and the physical parameters.

Table 4 — HDX, Charge and Re-charge Times

Meaning	Symbol	min	max
Charge time	T_{CH} [ms]	20	
Re-charge time	T_{RCH} [ms]	5	

6.2.1.1 Frequency

The carrier frequency of the RF operating field is $f_{Bc} = 125 \text{ kHz} \pm 0,1 \text{ kHz}$ or $134,2 \pm 0,1 \text{ kHz}$.

6.2.2 Communication signal interface interrogator to tag

6.2.2.1 Modulation

Communication between interrogator and tag takes place using ASK modulation with a modulation index of 100%.

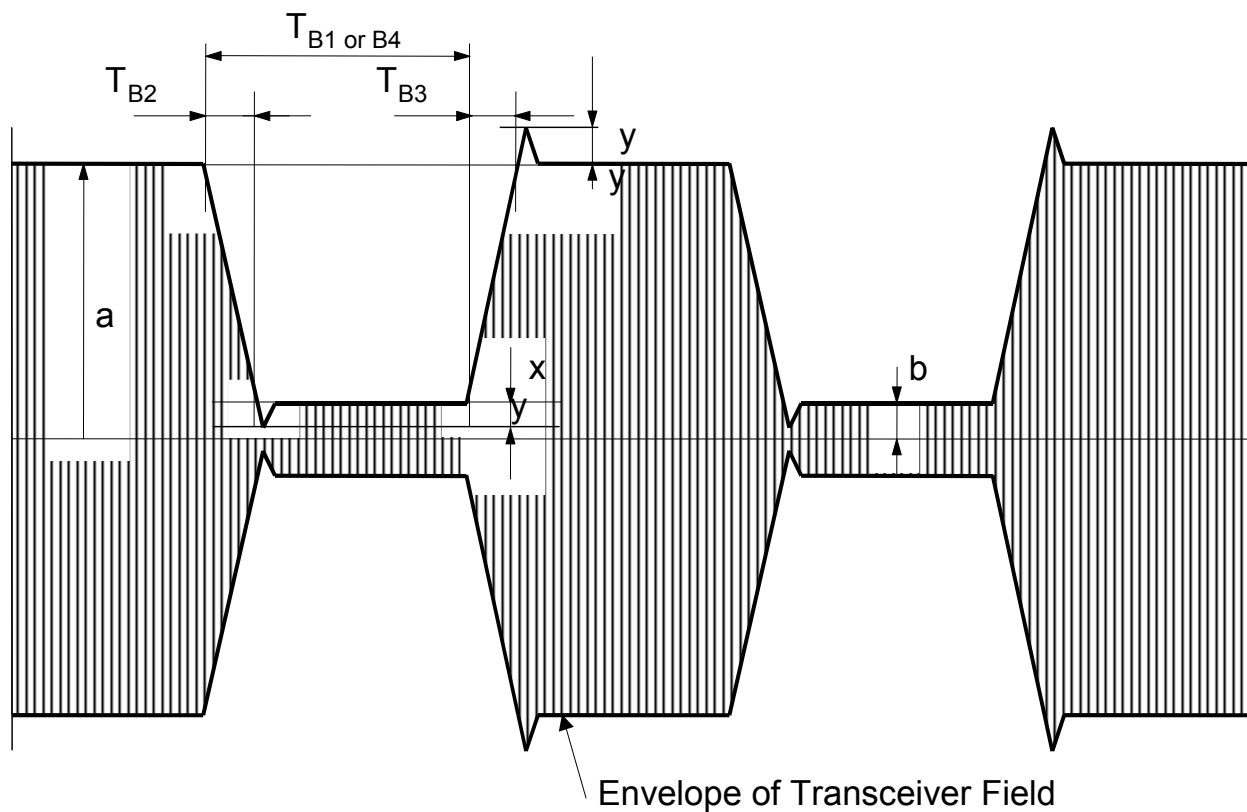


Figure 9 — Modulation details of data transmission from interrogator to tag

Table 5 — Modulation coding times

	Min	nom	max
T_{B1}	$14 * T_{Bc}$	$20 * T_{Bc}$	$26 * T_{Bc}$
T_{B2}	$2 * T_{Bc}$	$7 * T_{Bc}$	$10 * T_{Bc}$
T_{B3}	$5 * T_{Bc}$	$13 * T_{Bc}$	$20 * T_{Bc}$
T_{B4}	$34 * T_{Bc}$	$40 * T_{Bc}$	$46 * T_{Bc}$
X	0	n/a	$0,05 * a$
Y	0	n/a	$0,05 * a$

6.2.2.2 Data rate and data coding

The interrogator-to-tag communication uses Pulse interval encoding. The interrogator creates pulses by switching the carrier as described in Figure 9. The time between the falling edges of the pulses determines either the value of the data bit "0" and "1", a Code violation or a Stop condition.

Assuming equal distribution of data bits "0" and "1", the data rates are:

- Data rate: 2,83 kbps (nominal)

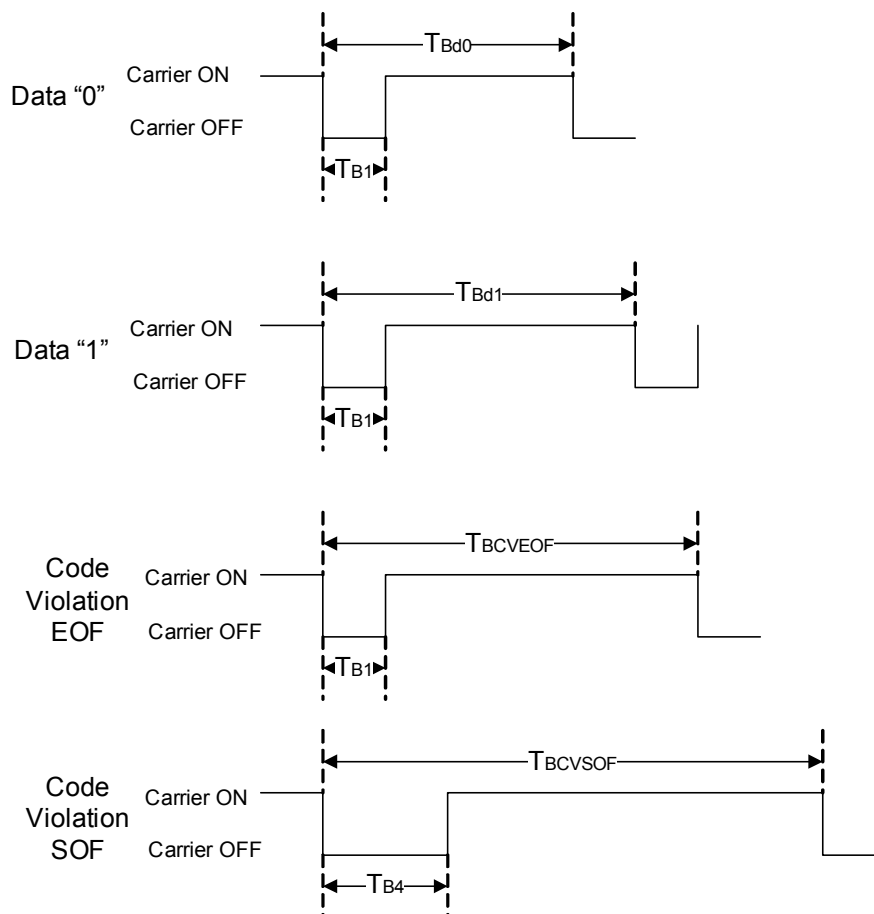


Figure 10 — Interrogator to tag: modulation and coding

Table 6 — Data coding times

Symbol	min	Nom	Max
T_{Bd0}	$40 * T_C$	$43 * T_C$	$46 * T_C$
T_{Bd1}	$50 * T_C$	$52 * T_C$	$54 * T_C$
T_{BCVEOF}	$70 * T_C$		
T_{BCVSOF}	$100 * T_C$	$107 * T_C$	$114 * T_C$

NOTE $T_{Bc} = 1/f_{Bc} \approx 7,452 \mu s$

6.2.2.3 Start of frame pattern

The interrogator request starts always with a Start of frame (SOF) pattern (Figure 9). The SOF consists of a "Code violation a Data "1" and a Data "0" pattern that defines a clear start of frame.

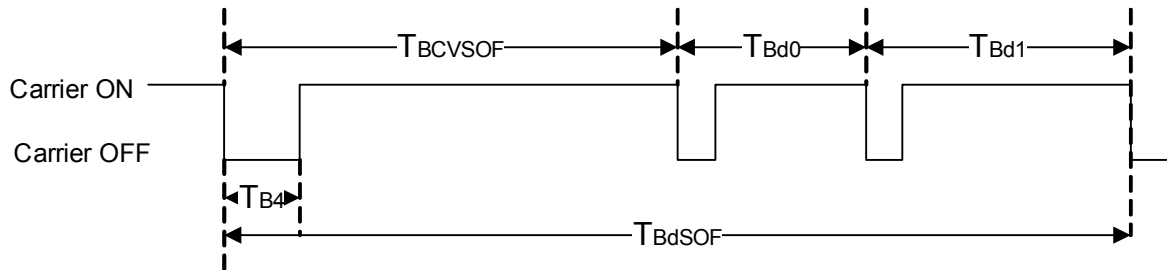


Figure 11 — HDX - Start of frame pattern (SOF) Pattern

6.2.2.4 End of frame

For EOF of the HDX-ADV interrogator request the code violation pattern T_{BcvEOF} is used (Figure 10).

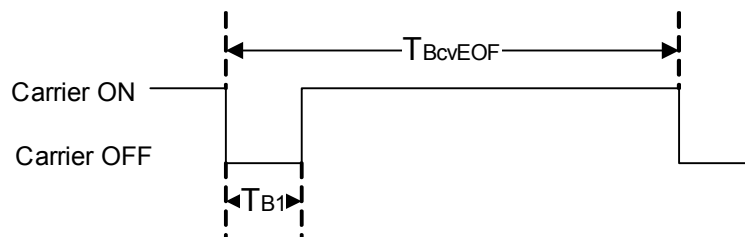


Figure 12 — HDX - End of Frame (EOF) Pattern

For the 16 slots inventory sequence, the EOF that instructs the tags to switch to the next slot is defined as the rising edge of the interrogator field followed by a time t_{RCH} .

In both cases, the tag shall receive this sequence before transmitting its response SOF.

6.2.3 Communication Signal Interface tag to interrogator

6.2.3.1 Data rate and data coding

The tag shall be capable to communicate with the interrogator via an inductive coupling, whereby the power is switched off and the data are FSK modulated using the frequencies:

- $f_{B0} = 134,2 \pm 3 \text{ kHz}$ for the data bit "0" encoding
- $f_{B1} = 123,7 \pm 3 \text{ kHz}$ for the data bit "1" encoding

The data coding is based on the NRZ method.

The average data rate is 8 kbit/s.

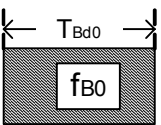
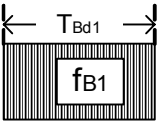
Data Element	International Standard command	Comment
Data bit "0"		$T_{Bd0} = 16/f_{B0}$
Data bit "1"		$T_{Bd1} = 16/f_{B1}$

Figure 13 — Tag to interrogator: modulation and coding

6.2.3.2 Start of frame pattern

The tag response starts always with a Start of frame (SOF) pattern. The SOF pattern is coded with a bit pattern of "011101".

f_{B1} represents the frequency for data bit "1" (T_{Bd1}) and f_{B0} for data bit "0" (T_{Bd0}).

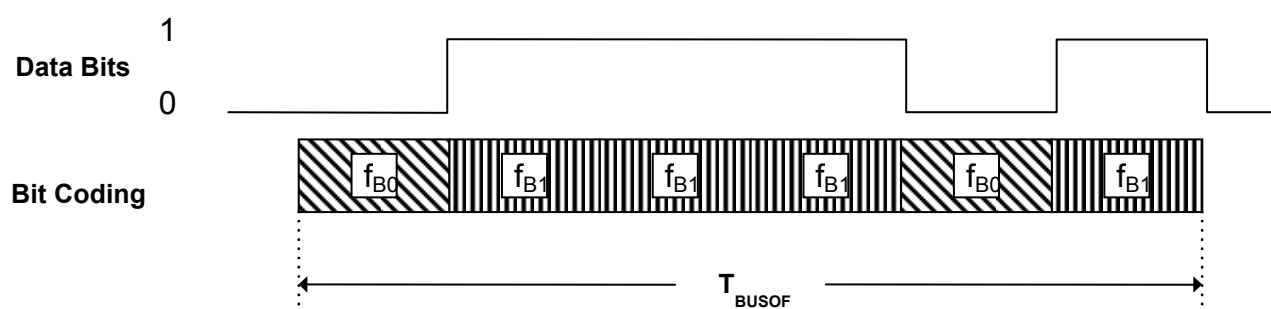


Figure 14 — HDX - Start of frame pattern

6.2.3.3 End of frame pattern

The tag response ends always with an End of frame (EOF) pattern. The EOF pattern is coded with a bit pattern of "101110".

f_{B1} represents the frequency for data bit "1" (T_{Bd1}) and f_{B0} for data bit "0" (T_{Bd0}).

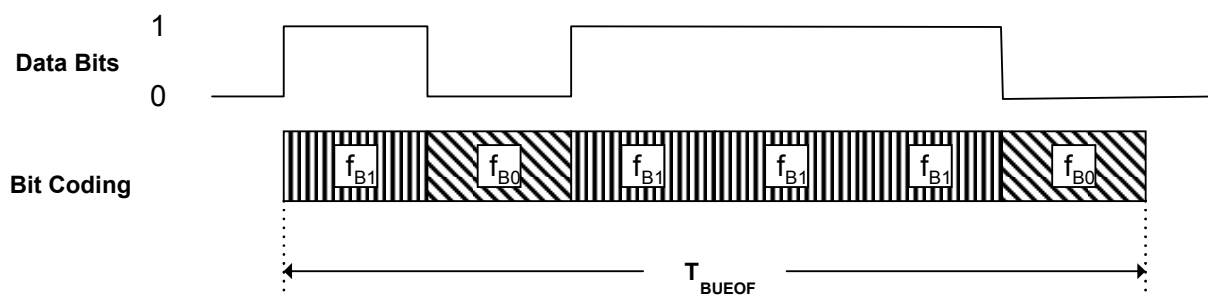


Figure 15 — HDX - End of frame pattern

6.2.4 General protocol Timing Specification

For write like requests where an erase and or programming operation is required a programming time of < 20ms shall be used. The tag shall return its response after switching off the transmitter field.

6.2.4.1 Waiting Time Before Transmitting its Response After Receipt of an EOF from the Interrogator

After the transmission of the request frame the interrogator switches off the field. When the tag has detected the falling edge of the field after a valid interrogator request, it shall wait for a time T_{Bp1} before transmitting its response to an interrogator request.

T_{Bp1} starts from the detection of the falling edge of the field by the tag.

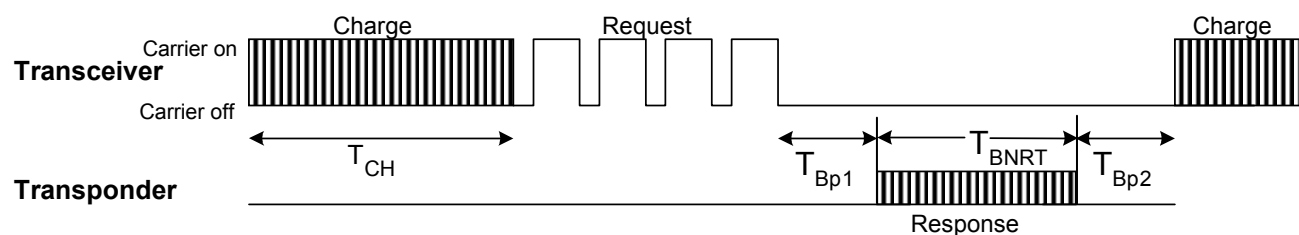


Figure 16 — Protocol Timing Diagram Including Charge-Up Phase

The minimum and maximum values of T_{Bp1} are given in Table 7.

If the HDX-ADV tag detects a carrier modulation during this time T_{Hp1} , it shall reset its T_{Hp1} timer and wait for a further time T_{Hp1} before starting to transmit its response to an interrogator request or to switch to the next slot when in an inventory process.

6.2.4.2 Interrogator Waiting Time Before Sending a Subsequent Request

When the interrogator has received the last bit of a tag response to a previous request, the interrogator can switch on the carrier signal to re-charge the tag, timing according to Table 7.

6.2.4.3 Interrogator Waiting Time Before Switching to Next Inventory Slot

An inventory process is started when the interrogator sends an inventory request.

To switch to the next slot, the interrogator switches on the field to re-charge the tags in the field. The rising edge of the field followed by the time T_{RCH} triggers the tag to switch to the next slot.

6.2.4.4 Interrogator Started to Receive One or More Tag Responses

During an inventory process, when the interrogator has started to receive one or more tag responses (i.e. it has detected a tag SOF and/or a collision), it may:

- wait for the complete reception of the tag responses (i.e. when a tag last bit has been received or when the tag nominal response time T_{BNRT} has elapsed), or
- switch on the field to re-charge the tags and switch to the next slot (choice selection if NOS flag was set to 0), or
- send a subsequent request.

T_{BNRT} depends on the current mask value and of the CRCT flag setting.

6.2.4.5 Interrogator Received no Tag Response

During an inventory process, when the interrogator has received no tag response (empty slot), it shall wait at least a time of T_{Bp3} before starting to recharge the tag and switch to the next slot (during a 16 slot anti-collision request) or sending a subsequent request (which could be again an inventory request).

T_{Bp3} starts from the time the interrogator has switched off the field and has generated the falling edge of the last sent EOF. See Figure 17 and Table 7 for an overview.

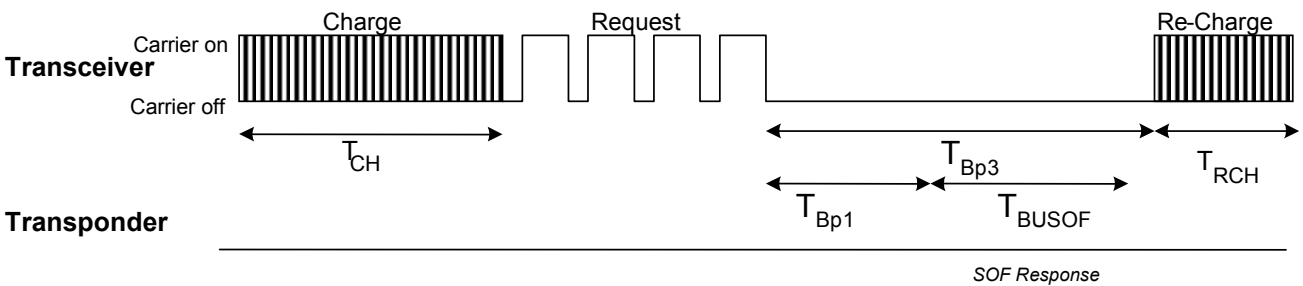


Figure 17 — Protocol Timing Diagram Including Charge and Re-Charge Time Period

The minimum value of T_{Bp3} is $T_{Bp3min} = T_{Bp1max} + T_{BUSOF}$

T_{BUSOF} is the time duration for a HDX tag to transmit a SOF to the interrogator (see clause 6.2.2.3).

Table 7 — Overview timing parameters HDX

Symbol	Minimum	Nominal	Maximum
T_{BUSOF}		0.75 ms	
T_{Bp1}	1,9 ms		3 ms
T_{Bp2}	2,2 ms		
T_{Bp3}	$T_{Bp1max} + T_{BUSOF}$		
T_{BNRT}	Depends on the requested data and options. Must be calculated in the interrogator for every request and flag setting combination.		

6.3 Physical and Media Access Control (MAC) Parameters

6.3.1 Interrogator to tag link

Table 8 — Interrogator to tag link

Ref.	Parameter	Description Type A	Description Type B	Options/Comments
M1-INT: 1	Operating Frequency Range	One interrogator to tag link channel at 125 kHz	One interrogator to tag link channel at 134,2 kHz	
M1-INT: 1a	Default Operating Frequency	125 kHz	134,2 kHz	
M1-INT: 1b	Operating Channels (for Spread Spectrum systems)	Not appropriate for this MODE		
M1-INT: 1c	Operating Frequency Accuracy	Within $\pm 0,1$ kHz		
M1-INT: 1d	Frequency Hop Rate (for Frequency Hopping [FHSS] systems)	Not appropriate for this MODE		
M1-INT: 1e	Frequency Hop Sequence (for Frequency Hopping [FHSS] systems)	Not appropriate for this MODE		
M1-INT: 2	Occupied Channel Bandwidth	± 8 kHz	± 4 kHz	3 dB Bandwidth
M1-INT: 2a	Minimum Receiver Bandwidth	± 10 kHz		3 dB Bandwidth
M1-INT: 3	Interrogator Transmit Maximum EIRP Power Limits within Communication Zone	65,5 dB μ A/m		at d = 10m see ITUR 012E-WB9
M1-INT: 3a	Interrogator Transmit Spurious Emissions	27 dB μ A/m		at 9 kHz descending 3dB/octave, until 10 MHz
M1-INT: 4a	Interrogator Transmit Spurious Emissions, In-Band (for Spread Spectrum systems)	Not appropriate for this MODE		
M1-INT: 4b	Interrogator Transmit Spurious Emissions, Out-of-Band	See M1-INT-3		
M1-INT: 5	Interrogator Transmitter Spectrum Mask	Emissions below 135 kHz 65,5 dB μ A/m @ f<135kHz	65.5 dB μ A/m @ f<135kHz 50 dB μ A/m @ f<135-140kHz 30 dB μ A/m @ f<140-148,5kHz	