INTERNATIONAL STANDARD

ISO/IEC 14443-2

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Identification cards — Contactless integrated circuit cards — Proximity cards —

Part 2: Radio frequency power and signal interface

Cartes d'identification — Cartes à circuit(s) intégré(s) sans contact — Cartes de proximité —

Partie 2: Interface radiofréquence et des signaux de communication

Reference number
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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.

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/IEC JTC 1, *Information technology*, Subcommittee SC 17, *Cards and personal identification*.

This third edition cancels and replaces the second edition (ISO/IEC 14443-2:2010), which has been technically revised.

It also incorporates the Amendments ISO/IEC 14443-2:2010/Amd 1:2011, ISO/IEC 14443-2:2010/Amd 2:2012 and ISO/IEC 14443-2:2010/Amd 3:2012.

ISO/IEC 14443 consists of the following parts, under the general title *Identification cards — Contactless integrated circuit cards — Proximity cards*:

— *Part 1: Physical characteristics*

— *Part 2: Radio frequency power and signal interface*

— *Part 3: Initialization and anticollision*

— *Part 4: Transmission protocol*

Introduction

ISO/IEC 14443 is one of a series of International Standards describing the parameters for identification cards as defined in ISO/IEC 7810 and the use of such cards for international interchange.

This part of ISO/IEC 14443 describes the electrical characteristics of two types of contactless interface between a proximity card and a proximity coupling device. The interface includes both power and bi-directional communication. It is intended to be used in conjunction with other parts of ISO/IEC 14443.

Contactless card standards cover a variety of types as embodied in ISO/IEC 10536 (close-coupled cards), ISO/IEC 14443 (proximity cards) and ISO/IEC 15693 (vicinity cards). These are intended for operation when very near, nearby and at a longer distance from associated coupling devices, respectively.

Identification cards — Contactless integrated circuit cards — Proximity cards —

Part 2:
Radio frequency power and signal interface

1 Scope

This part of ISO/IEC 14443 specifies the characteristics of the fields to be provided for power and bi-directional communication between proximity coupling devices (PCDs) and proximity cards or objects (PICCs).

This part of ISO/IEC 14443 does not specify the means of generating coupling fields, nor the means of compliance with electromagnetic radiation and human exposure regulations, which can vary according to country.

2 Normative references

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

ISO/IEC 10373-6, *Identification cards — Test methods — Part 6: Proximity cards*

ISO/IEC 14443-1:2016, *Identification cards — Contactless integrated circuit cards — Proximity cards — Part 1: Physical characteristics*

ISO/IEC 14443-3:2016, *Identification cards — Contactless integrated circuit cards — Proximity cards — Part 3: Initialization and anticollision*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
bit duration
time during which a logic level is defined, at the end of which a new bit starts

3.2
binary phase shift keying
phase shift keying where the phase shift is 180 degrees, resulting in two phase state possibilities

3.3
modified Miller
method of bit coding whereby a logic level during a bit duration is represented by the position of a pulse within the bit frame

3.4
modulation index
m
[1 − *b*] / [1 + *b*], where *b* is the ratio between the modulated amplitude and the initial signal amplitude

Note 1 to entry: The value of the index may be expressed as a percentage.

3.5
NRZ-L
method of bit coding whereby a logic level during a bit duration is represented by one of two defined physical states of a communication medium

3.6
operating volume
for each PICC class, the positions where the corresponding Reference PICC shows PCD compliance with all requirements of this part of ISO/IEC 14443 for this class

3.7
subcarrier
signal of frequency, *fs*, used to modulate a carrier of frequency, *fc*

3.8
Manchester
method of bit coding whereby a logic level during a bit duration is represented by a sequence of two defined physical states of a communication medium, the order of the physical states within the sequence defining the logical state

3.9
TR0
guard time between the end of a PCD transmission and the start of the PICC subcarrier generation

3.10
TR1
synchronization time between the start of the PICC subcarrier generation and the start of the PICC subcarrier modulation

4 Symbols and abbreviated terms

a	pulse shape factor, Type A
ACP	actual constellation point
AP	actual phase value
ASK	amplitude shift keying
b	ratio between the modulated and initial signal amplitude, Type B
BPSK	binary phase shift keying
EMD	electromagnetic disturbance, parasitically generated by the PICC
EPI	elementary phase interval
etu	elementary time unit
fc	frequency of operating field (carrier frequency)
fs	frequency of subcarrier
H	equivalent homogenous magnetic field strength
H_{INITIAL}	field strength of the unmodulated RF field
h_{ovs}	envelope overshoot for bit rates of $fc/64$, $fc/32$ and $fc/16$, Type A
h_{f}	envelope undershoot, Type B

h_r	envelope overshoot, Type B
ISI	inter symbol interference
ISI_d	inter symbol interference angle
ISI_m	inter symbol interference magnitude
NP	nominal phase value
NRZ-L	non-return to zero, (L for level)
OOK	on/off keying
PauseA	PCD modulation pulse, Type A
$\text{Ø}0$	initial phase of the subcarrier
P_H	complex constellation point of the maximum NP
P_L	complex constellation point of the minimum NP
PNP	previous nominal phase
PR	phase range
PSK	phase shift keying
PCD	proximity coupling device
PICC	proximity card or object
RF	radio frequency
t_1	PauseA length
t_2	PauseA “Low” time for a bit rate of $fc/128$
t_3	PauseA rise time for a bit rate of $fc/128$
t_4	PauseA rise time section for a bit rate of $fc/128$
t_5	PauseA “Low” time for bit rates of $fc/64$, $fc/32$ and $fc/16$
t_6	PauseA rise time for bit rates of $fc/64$, $fc/32$ and $fc/16$
$t_{6,\text{ max, PCD}}$	maximum value of t_6 for PCD transmission
$t_{6,\text{ max, PICC}}$	maximum value of t_6 for PICC reception
t_b	bit duration, Type A
t_f	envelope fall time, Type B
$t_{f,\text{ max, PCD}}$	maximum fall time for PCD transmission, Type B
$t_{f,\text{ max, PICC}}$	maximum fall time for PICC reception, Type B
t_r	envelope rise time, Type B
$t_{r,\text{ max, PCD}}$	maximum rise time for PCD transmission, Type B

$t_{r, max, PICC}$ maximum rise time for PICC reception, Type B

t_x pulse position, Type A

$V_{E, PCD}$ EMD limit, PCD

$V_{E, PICC}$ EMD limit, PICC

V_{LMA} load modulation amplitude

$V_{LMA, PCD}$ minimum load modulation amplitude for PCD reception

$V_{LMA, PICC}$ minimum load modulation amplitude for PICC transmission

\# number

5 General considerations

5.1 Initial dialogue

The initial dialogue between the PCD and the PICC shall be conducted through the following consecutive operations:

— activation of the PICC by the RF operating field of the PCD;

— the PICC shall wait silently for a command from the PCD;

— transmission of a command by the PCD;

— transmission of a response by the PICC.

These operations shall use the RF power and signal interface specified in the following clauses.

5.2 Compliance

5.2.1 PICC compliance

The PICC shall comply with all mandatory requirements of this part of ISO/IEC 14443 and may support optional requirements (bit rate, class, etc.). The PICC should fulfill all the requirements of one particular class in order to improve interoperability.

5.2.2 PCD compliance

The PCD shall comply with all mandatory requirements of this part of ISO/IEC 14443 and may support optional requirements (bit rate, support of PICCs of optional classes, etc.).

The PCD

— shall support PICCs of “Class 1”, “Class 2” and “Class 3”,

— may optionally support PICCs of “Class 4”,

— may optionally support PICCs of “Class 5” and

— may optionally support PICCs of “Class 6”.

PCD requirements measured with Reference PICCs 1, 2, and 3 are mandatory for all PCDs.

PCD requirements measured with Reference PICC 4 are only mandatory for PCDs supporting operation with “Class 4” PICCs.

PCD requirements measured with Reference PICC 5 are only mandatory for PCDs supporting operation with “Class 5” PICCs.

PCD requirements measured with Reference PICC 6 are only mandatory for PCDs supporting operation with “Class 6” PICCs.

For each supported PICC class, the PCD manufacturer shall indicate the operating volume within which the PCD fulfills all requirements of this part of ISO/IEC 14443.

NOTE As an indication of each operating volume, the manufacturer may give the operating range (e.g. 0 to X cm with PCD and PICC relative positions, e.g. PCD and PICC antennas parallel and concentric).

5.2.2.1 PCD supporting PICCs of particular class(es)

If a PCD is expected to operate with PICCs of only particular class(es), it is not mandatory for this PCD to support PICCs of other classes. This PCD shall comply with all other relevant clauses of this part of ISO/IEC 14443. The PCD manufacturer shall clearly state which class(es) are supported.

NOTE A PCD which does not support one of the mandatory classes 1, 2 and 3 is not fully compliant with this part of ISO/IEC 14443. It may be advertised as “supporting “Class X” PICCs only” or “compliant with Class(es) X requirements only”.

6 Power transfer

The PCD shall produce a high frequency alternating magnetic field. This field inductively couples to the PICC to transfer power and is modulated for communication.

6.1 Frequency

The frequency, *fc*, of the RF operating field shall be 13,56 MHz ± 7 kHz.

6.2 Operating field strength

Within the manufacturer specified operating volumes (see 3.6), the PCD shall generate a field strength of at least H_{min} and not exceeding H_{max} under unmodulated conditions, see Table 1.

The PCD

— shall support PICCs of “Class 1”, “Class 2” and “Class 3”,

— may optionally support PICCs of “Class 4”,

— may optionally support PICCs of “Class 5” and

— may optionally support PICCs of “Class 6”.

PCD requirements measured with Reference PICCs 1, 2, and 3 are mandatory for all PCDs.

PCD requirements measured with Reference PICC 4 are only mandatory for PCDs supporting operation with “Class 4” PICCs.

PCD requirements measured with Reference PICC 5 are only mandatory for PCDs supporting operation with “Class 5” PICCs.

PCD requirements measured with Reference PICC 6 are only mandatory for PCDs supporting operation with “Class 6” PICCs.

Table 1 — PCD field strength

	PCD	
	H_{min} A/m (rms)	H_{max} A/m (rms)
Measured with Reference PICC 1	1,5	7,5
Measured with Reference PICC 2	1,5	8,5
Measured with Reference PICC 3	1,5	8,5
Measured with Reference PICC 4 (optional)	2,0	12
Measured with Reference PICC 5 (optional)	2,5	14
Measured with Reference PICC 6 (optional)	4,5	18

The PCD shall not generate a field strength higher than the average and maximum levels specified for all mandatory and optional classes in ISO/IEC 14443-1:2016, 4.4 (alternating magnetic field) in any possible PICC position and orientation, measured with the associated Reference PICCs.

Test methods for the PCD operating field are defined in ISO/IEC 10373-6 and use a dedicated Reference PICC for each class.

NOTE 1 Although field measurements with some Reference PICCs may show values higher than 7,5 A/m (rms), the H_{max} limits specified in Table 1 do not allow PCDs to produce higher field strength than with first and second edition of ISO/IEC 14443-2. This is because PCD field distribution is usually not homogenous within the operating volumes and References PICCs have different measurement areas.

If the PICC meets the requirements of one particular class as specified in ISO/IEC 14443-1, then the PICC shall operate as intended continuously between H_{min} and H_{max} defined for its class, see Table 2; this includes all PICC requirements defined in this part of ISO/IEC 14443 and processing of the manufacturer specified set of commands.

If the PICC does not claim to meet the requirements of one particular class as specified in ISO/IEC 14443-1, then:

— if the PICC antenna fits within the external rectangle defined in “Class 2” as specified in ISO/IEC 14443-1, then

  — the PICC shall operate as intended continuously between H_{min} and H_{max} defined for “Class 2”, see Table 2,

  — the PICC shall pass the loading effect test defined for “Class 2”;

— if the PICC antenna fits within the external rectangle or external circle defined in “Class 3” as specified in ISO/IEC 14443-1, then

  — the PICC shall operate as intended continuously between H_{min} and H_{max} defined for “Class 3”, see Table 2,

  — the PICC shall pass the loading effect test defined for “Class 3”;

— if the PICC antenna does not claim to fit within the external rectangle or external circle defined in “Class 2” or “Class 3” as specified in ISO/IEC 14443-1, then

  — the PICC shall operate as intended continuously between H_{min} and H_{max} defined for “Class 1”, see Table 2,

  — the PICC shall pass the loading effect test defined for “Class 1”.

NOTE 2 If the PICC does not claim to meet the requirements of one particular class, then the requirements defined above may not be sufficient to guarantee proper operation and interoperability with PCDs.

Table 2 — PICC operating field strength

	PICC	
	H_{min} A/m (rms)	H_{max} A/m (rms)
”Class 1” PICC	1,5	7,5
”Class 2” PICC	1,5	8,5
”Class 3” PICC	1,5	8,5
”Class 4” PICC	2,0	12
”Class 5” PICC	2,5	14
”Class 6” PICC	4,5	18

NOTE 3 Margins of field strength are effectively included by the test methods as specified in ISO/IEC 10373-6.

7 Signal interface

The PCD modulates the amplitude of the alternating magnetic field strength with modulation pulses in order to transmit data from the PCD to the PICC.

The PICC loads the alternating magnetic field with a modulated subcarrier signal (load modulation) in order to transmit data from the PICC to the PCD.

Within the manufacturer specified operating volumes (see 3.6), the PCD shall generate modulation pulses as described in the following clauses and shall be capable of receiving the minimum load modulation amplitude.

NOTE 1 As an indication of the operating volume, the manufacturer may give the operating range (e.g. 0 to X cm) within which all ISO/IEC 14443-2 requirements are fulfilled.

Test methods for the PCD communication signal interface are defined in ISO/IEC 10373-6.

Two communication signal interfaces, Type A and Type B, are described in the following clauses. The PCD shall alternate between modulation methods when idling before detecting the presence of a PICC of Type A or Type B.

Only one communication signal interface may be active during a communication session until deactivation by the PCD or removal of the PICC. Subsequent session(s) may then proceed with either modulation method.

Figure 1 and Figure 2 illustrate the concepts described in the following clauses.

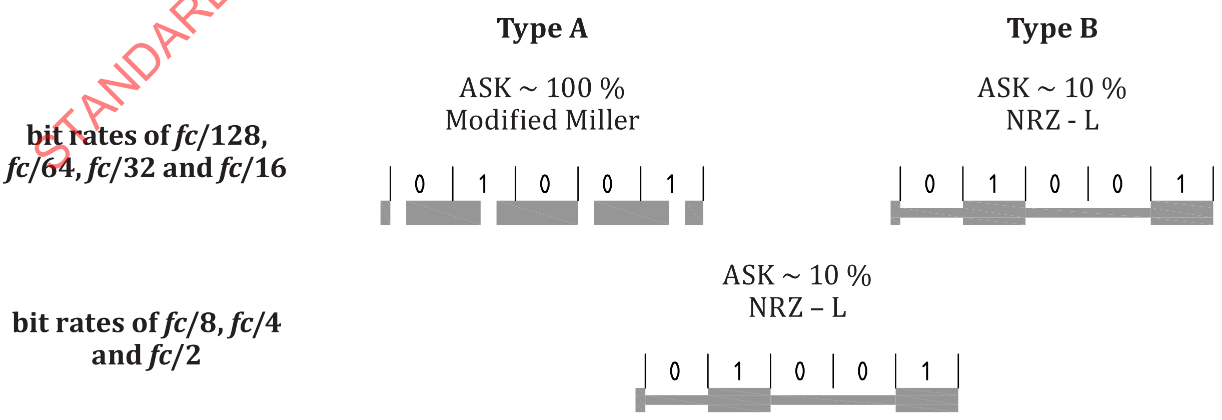


Figure 1 — Example PCD to PICC communication signals for Type A and Type B interfaces

NOTE 2 For the coding of modified Miller, see 8.1.3.1.

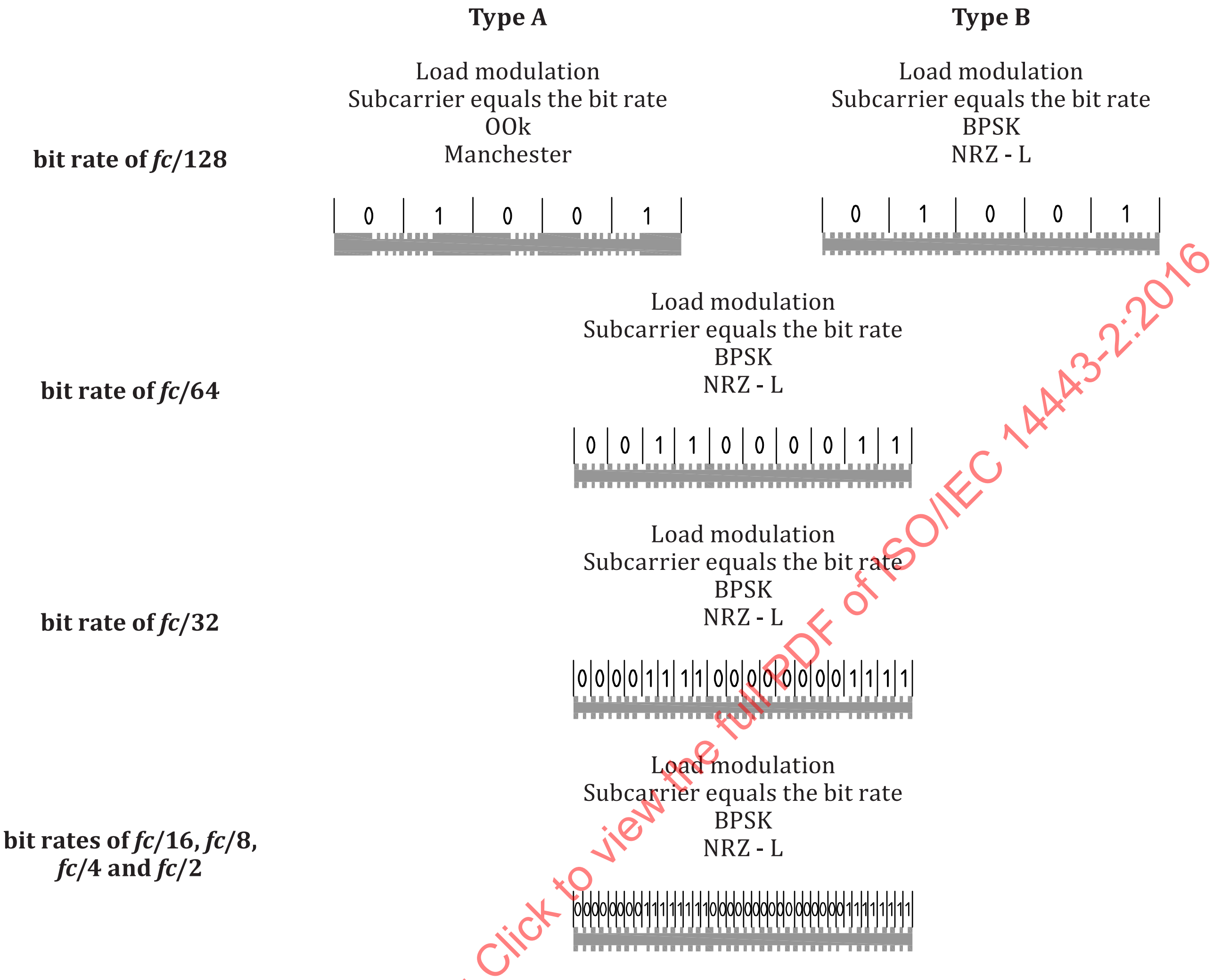


Figure 2 — Example PICC to PCD communication signals for Type A and Type B interfaces

8 Communication signal interface Type A

8.1 Communication PCD to PICC

8.1.1 Bit rate

The bit rate for the transmission during initialization and anticollision shall be *fc*/128 (~106 kbit/s).

The bit rate for the transmission after initialization and anticollision shall be one of the following:

— *fc*/128 (~106 kbit/s);

— *fc*/64 (~212 kbit/s);

— *fc*/32 (~424 kbit/s);

— *fc*/16 (~848 kbit/s);

— *fc*/8 (~1,70 Mbit/s);

— *fc*/4 (~3,39 Mbit/s);

— $fc/2$ (~6,78 Mbit/s);

— $3fc/4$ (~10,17 Mbit/s);

— fc (~13,56 Mbit/s);

— $3fc/2$ (~20,34 Mbit/s);

— $2fc$ (~27,12 Mbit/s).

8.1.2 Modulation

8.1.2.1 Modulation for a bit rate of *fc*/128

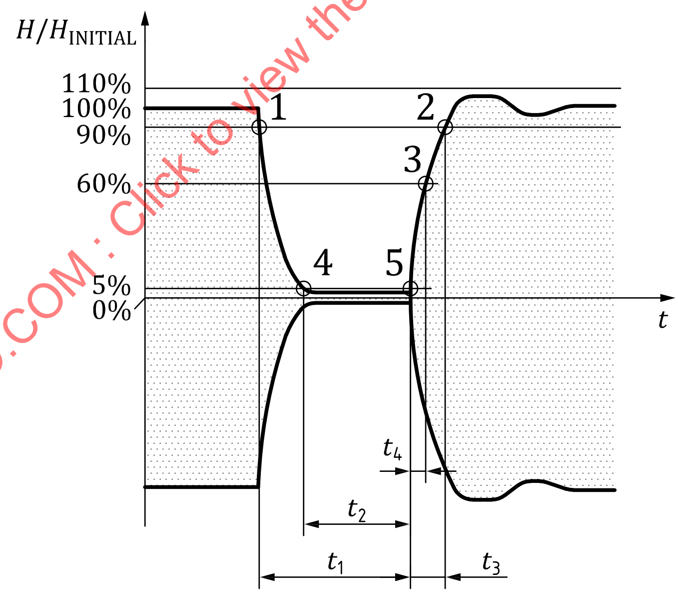
Communication from PCD to PICC for a bit rate of $fc/128$ shall use the modulation principle of ASK 100 % of the RF operating field to create a PauseA as shown in Figure 3.

The envelope of the PCD field shall decrease monotonically to less than 5 % of its initial value H_{INITIAL} and remain less than 5 % for more than t_2. This envelope shall comply with Figure 3.

If the envelope of the PCD field does not decrease monotonically, the time between a local maximum and the time of passing the same value before the local maximum shall not exceed 0,5 µs. This shall only apply if the local maximum is greater than 5 % of H_{INITIAL}.

The PauseA length t_1 is the time between 90 % of the falling edge and 5 % of the rising edge of the H-field signal envelope.

In case of an overshoot, the field shall remain within 90 % of H_{INITIAL} and 110 % of H_{INITIAL}.



Key

1 start of t_1

2 end of t_3

3 end of t_4

4 start of t_2

5 end of t_1 and t_2, start of t_3 and t_4

Figure 3 — PauseA for a bit rate of *fc*/128

The PCD shall generate a PauseA with timing parameters defined in Table 3.

Table 3 — PCD transmission: PauseA timing parameters for a bit rate of *fc*/128

Parameter	Condition	Min	Max
t_1		$28/fc$	$40{,}5/fc$
t_2	$t_1 > 34/fc$	$7/fc$	t_1
	$t_1 \leq 34/fc$	$10/fc$	
t_3		$1{,}5 \times t_4$	$16/fc$
t_4		0	$6/fc$

NOTE 1 PCD implementations may be restricted to generate a PauseA with values of $t_1 = n/fc$ (n = integer). Therefore, measurement of t_1 should be rounded to the closest n in the unit $1/fc$.

NOTE 2 The maximum value of t_2 is a function of the measured value of t_1.

NOTE 3 The minimum value of t_3 is a function of the measured value of t_4.

The PICC shall be able to receive a PauseA with timing parameters defined in Table 4.

Table 4 — PICC reception: PauseA timing parameters for a bit rate of *fc*/128

Parameter	Condition	Min	Max
t_1		$27{,}5/fc$	$41/fc$
t_2	$t_1 > 34/fc$	$6/fc$	t_1
	$t_1 \leq 34/fc$	$9/fc$	
t_3		$1{,}5 \times t_4$	$17/fc$
t_4		0	$7/fc$

NOTE 4 The maximum value of t_2 is a function of the set value of t_1.

NOTE 5 The minimum value of t_3 is a function of the set value of t_4.

For a bit rate of $fc/128$, the PCD shall generate a PauseA with a rise time t_3

— greater than both $0/fc$ and $(t_1 - t_2) - 24{,}5/fc$, and

— less than both $(t_1 - t_2) + 7/fc$ and $16/fc$.

For a bit rate of $fc/128$, the PICC shall be able to receive a PauseA with a rise time t_3

— greater than both $0/fc$ and $(t_1 - t_2) - 26/fc$, and

— less than both $(t_1 - t_2) + 8/fc$ and $17/fc$.

NOTE 6 Minimum and maximum values of $(t_1 - t_2)$ are derived from minimum and maximum values of t_1 and t_2 defined in Table 3 and Table 4.

The timing parameters for PCD and PICC are illustrated in Figure 4.

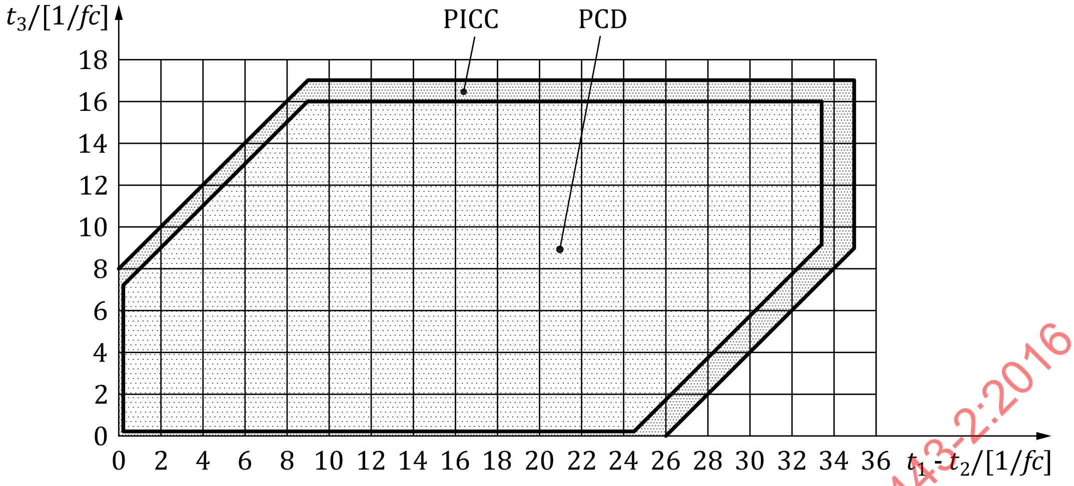


Figure 4 — PauseA timing parameters for a bit rate of *fc*/128

The PICC shall detect the end of PauseA after the field exceeds 5 % of H_{INITIAL} and before it exceeds 60 % of H_{INITIAL}. Figure 5 shows the definition of the end of PauseA. This definition applies to all modulation envelope timings.

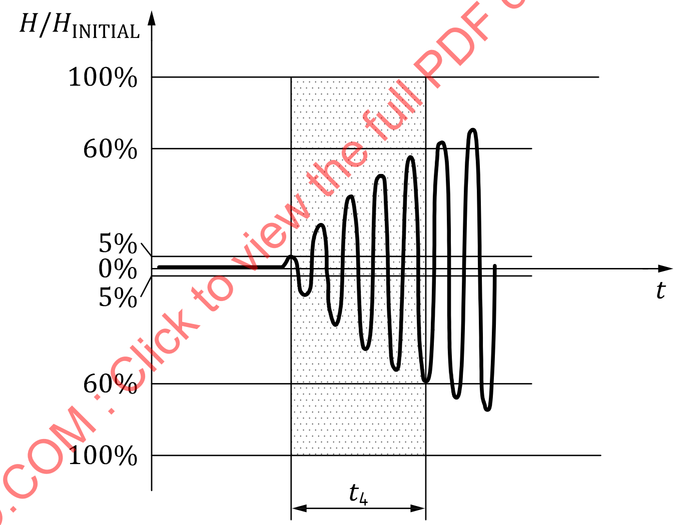


Figure 5 — End of PauseA for a bit rate of *fc*/128

8.1.2.2 Modulation for bit rates of *fc*/64, *fc*/32 and *fc*/16

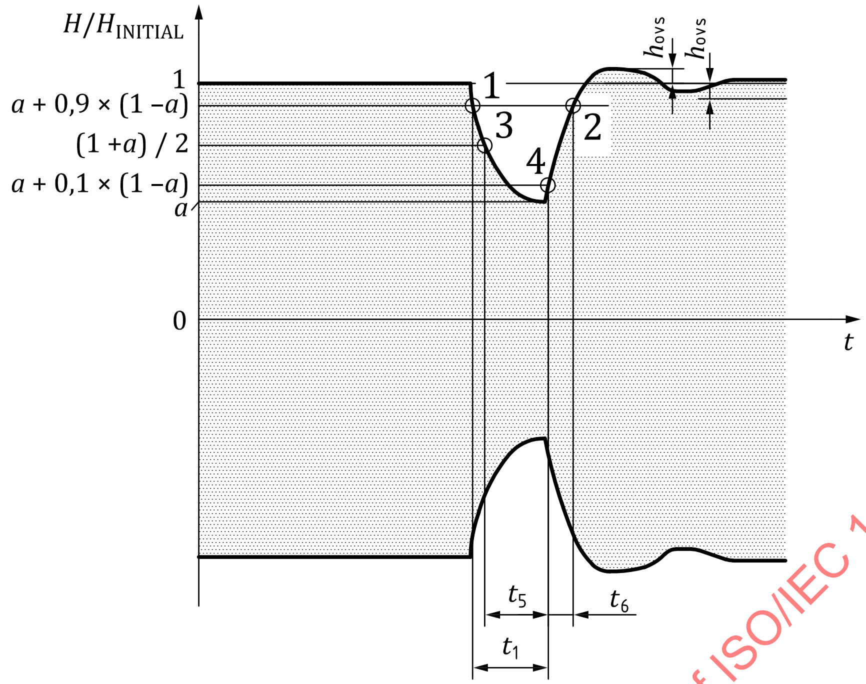
Communication from PCD to PICC for bit rates of *fc*/64 (~212 kbit/s), *fc*/32 (~424 kbit/s) and *fc*/16 (~848 kbit/s) shall use the modulation principle of ASK (with different values for "*a*") of the operating field strength to create a PauseA as shown in Figure 6.

The envelope of the PCD field shall decrease monotonically to the maximum value of parameter "*a*" as defined in Table 5. Then, if the envelope evolution becomes non-monotonic, the difference between any local maximum and the lowest previous minimum (within the same PauseA) shall not exceed 0,09 times the difference between the initial amplitude and the previous lowest minimum.

The parameter "*a*" is the lowest minimum within PauseA.

Figure 6 is an illustration of PauseA for bit rates of *fc*/64, *fc*/32 and *fc*/16.

In case of an overshoot, the field shall remain within $H_{\mathrm{INITIAL}} \times (1 - h_{\mathrm{ovs}})$ and $H_{\mathrm{INITIAL}} \times (1 + h_{\mathrm{ovs}})$.



Key

1 start if t_1

2 end of t_6

3 start of t_5

4 end of t_1 and t_5, start of t_6

Figure 6 — PauseA for bit rates of *fc*/64, *fc*/32 and *fc*/16

The PCD shall generate a PauseA with timing and amplitude parameters defined in Table 5.

Table 5 — PCD transmission: PauseA parameters for bit rates of *fc*/64, *fc*/32 and *fc*/16

Parameter	Bit rate	Min	Max
a	$fc/64$	0	0,18
	$fc/32$	0	0,38
	$fc/16$	0,22	0,58
t_1	$fc/64$	$16{,}5/fc$	$20/fc$
	$fc/32$	$8{,}0/fc$	$10/fc$
	$fc/16$	$4{,}0/fc$	$5/fc$
t_5	$fc/64$	$t_1/2 + 4/fc$	t_1
	$fc/32$	$t_1/2 + 1/fc$	t_1
	$fc/16$	$t_1/2$	t_1
t_6	$fc/64$	see requirements above Figure 7	
	$fc/32$	see requirements above Figure 8	
	$fc/16$	see requirements above Figure 9	
h_{ovs}	fc/64, fc/32 and fc/16	0	$[1 - t_6 / (2 \times t_{6,\,\max,\,\mathrm{PCD}})] \times 0{,}10 \times (1 - a)$

NOTE 1 The minimum and maximum values of t_5 are functions of the measured value of t_1.

NOTE 2 The maximum value of h_{OVS} for PCD transmission is a function of the measured value of t_6 and of $t_{6,\,\max,\,\mathrm{PCD}}$ (see requirements above Figure 7, Figure 8, or Figure 9).

NOTE 3 PCD implementations may be restricted to generate a PauseA with values of t_1 = n/*fc* (n = integer). Therefore, measurement of t_1 should be rounded to the closest n in the unit 1/*fc*.

The PICC shall be able to receive a PauseA with timing and amplitude parameters defined in Table 6.

Table 6 — PICC reception: PauseA parameters for bit rates of *fc*/64, *fc*/32 and *fc*/16

Parameter	Bit rate	Min	Max
a	*fc*/64	0	0,2
	fc/32	0	0,4
	fc/16	0,2	0,6
t_1	*fc*/64	16/*fc*	20/*fc*
	fc/32	8/*fc*	10/*fc*
	fc/16	4/*fc*	5/*fc*
t_5	*fc*/64	$t_1/2 + 3/fc$	t_1
	fc/32	$t_1/2 + 1/fc$	t_1
	fc/16	$t_1/2$	t_1
t_6	*fc*/64	see requirements above Figure 7	
	fc/32	see requirements above Figure 8	
	fc/16	see requirements above Figure 9	
h_{ovs}	*fc*/64, *fc*/32 and *fc*/16	0	$[1 - t_6 / (2 \times t_{6,\,\mathrm{max,\,PICC}})] \times 0{,}11 \times (1 - a)$

NOTE 4 The minimum and maximum values of t_5 are functions of the set value of t_1.

NOTE 5 The maximum value of h_{OVS} for PICC reception is a function of the set value of t_6 and of t_{6}, max, PICC (see requirements above Figure 7, Figure 8, or Figure 9).

NOTE 6 The PauseA length t_1 is the time between an envelope amplitude of $[a + 0{,}9 \times (1 - a)]$ on the falling edge and $[a + 0{,}1 \times (1 - a)]$ on the rising edge.

For a bit rate of *fc*/64, the PCD shall generate a PauseA with a rise time t_6

— greater than both 0/*fc* and $(t_1 - t_5) - 3/fc$, and

— less than both $(t_1 - t_5) + 8/fc$ and $t_{6,\,\mathrm{max,\,PCD}} = 11/fc$.

For a bit rate of *fc*/64, the PICC shall be able to receive a PauseA with a rise time t_6

— greater than both 0/*fc* and $(t_1 - t_5) - 4/fc$, and

— less than both $(t_1 - t_5) + 9/fc$ and $t_{6,\,\mathrm{max,\,PICC}} = 12/fc$.

NOTE 7 Minimum and maximum values of $(t_1 - t_5)$ are derived from minimum and maximum values of t_1 and t_5 defined in Table 5 and Table 6.

The timing parameters for PCD and PICC are illustrated in Figure 7.

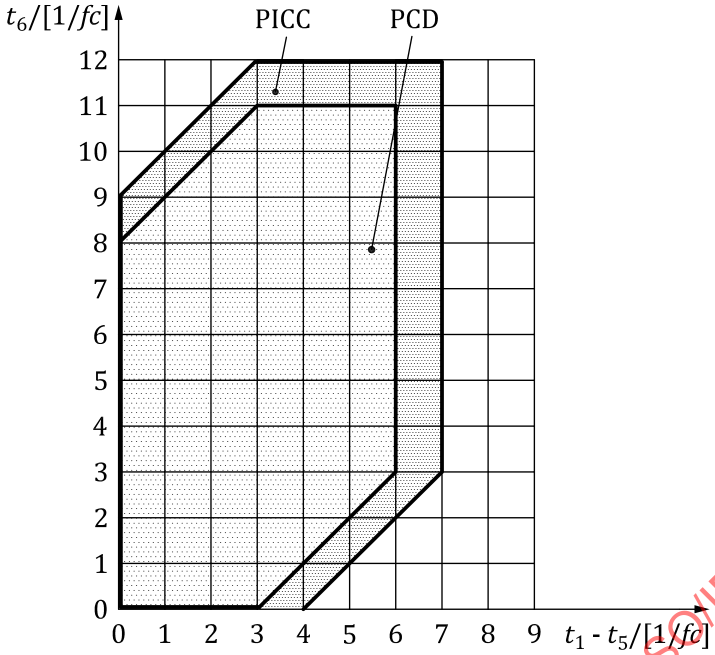


Figure 7 — PauseA timing parameters for a bit rate of *fc*/64

For a bit rate of $fc/32$, the PCD shall generate a PauseA with a rise time t_6

— greater than $0/fc$, and

— less than both $(t_1 - t_5) + 8/fc$ and $t_{6,\,\mathrm{max,\,PCD}} = 9/fc$.

For a bit rate of $fc/32$, the PICC shall be able to receive a PauseA with a rise time t_6

— greater than $0/fc$, and

— less than both $(t_1 - t_5) + 8/fc$ and $t_{6,\,\mathrm{max,\,PICC}} = 10/fc$.

The timing parameters for PCD and PICC are illustrated in Figure 8.

NOTE 8 Minimum and maximum values of $(t_1 - t_5)$ are derived from minimum and maximum values of t_1 and t_5 defined in Table 5 and Table 6.

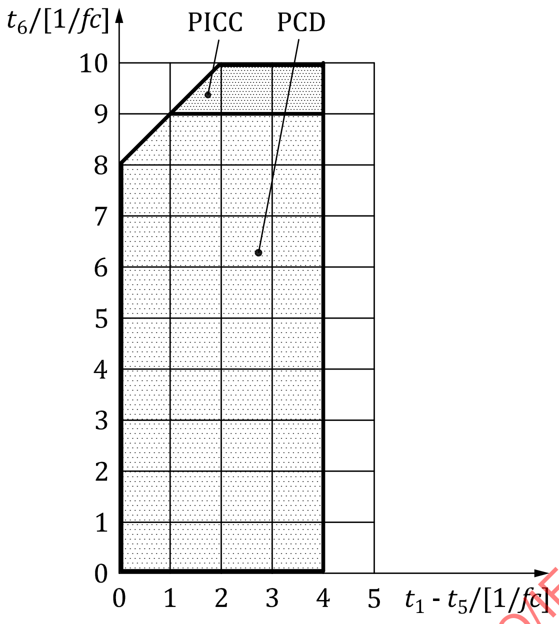


Figure 8 — PauseA timing parameters for a bit rate of *fc*/32

For a bit rate of $fc/16$, the PCD shall generate a PauseA with a rise time t_6

— greater than $0/fc$, and

— less than both $(t_1 - t_5) + 4/fc$ and $t_{6,\ \mathrm{max,\ PCD}} = 5{,}5/fc$.

For a bit rate of $fc/16$ the PICC shall be able to receive a PauseA with a rise time t_6

— greater than $0/fc$, and

— less than both $(t_1 - t_5) + 4{,}5/fc$ and $t_{6,\ \mathrm{max,\ PICC}} = 6/fc$.

NOTE 9 Minimum and maximum values of $(t_1 - t_5)$ are derived from minimum and maximum values of t_1 and t_5 defined in Table 5 and Table 6.

The timing parameters for PCD and PICC are illustrated in Figure 9.

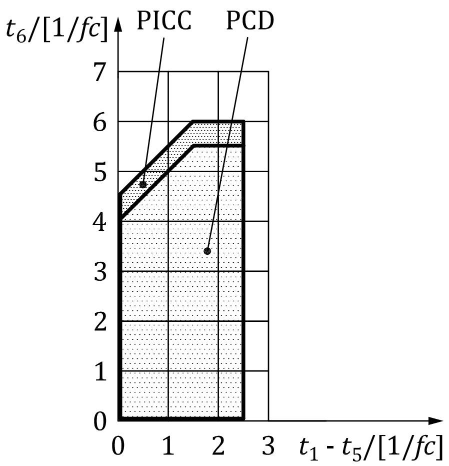


Figure 9 — PauseA timing parameters for a bit rate of *fc*/16

8.1.2.3 Modulation for bit rates of *fc*/8, *fc*/4 and *fc*/2

See 9.1.2.1.

8.1.2.4 Modulation for bit rates of 3*fc*/4, *fc*, 3*fc*/2 and 2*fc*

See A.1.

8.1.3 Bit representation and coding

8.1.3.1 Bit representation and coding for bit rates of *fc*/128, *fc*/64, *fc*/32 and *fc*/16

The following sequences are defined:

— sequence X: after a time of half the bit duration (t_x), a PauseA shall occur;

— sequence Y: for the full bit duration (t_b), no modulation shall occur;

— sequence Z: at the beginning of the bit duration (t_b), a PauseA shall occur.

Figure 10, together with the timing parameters in Table 7, illustrates sequences X, Y and Z.

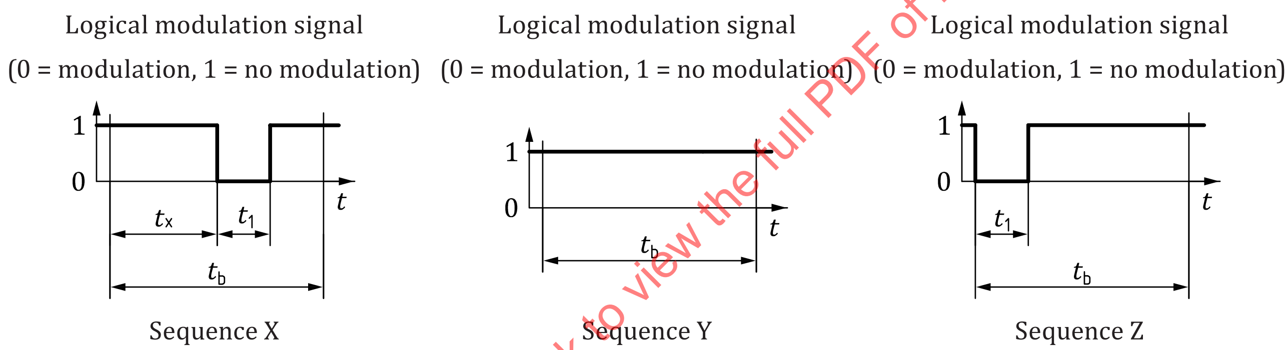


Figure 10 — Sequences for Type A communication PCD to PICC

Table 7 — Parameters for sequences

Parameter	Bit rate			
	fc/128	*fc*/64	*fc*/32	*fc*/16
t_b	128/*fc*	64/*fc*	32/*fc*	16/*fc*
t_x	64/*fc*	32/*fc*	16/*fc*	8/*fc*
t_1	see t_1 of Table 3	see t_1 of Table 5		

The above sequences shall be used to code the following information:

— logic “1”: sequence X;

— logic “0”: sequence Y with the following two exceptions:

i) if there are two or more contiguous “0”s, sequence Z shall be used from the second “0” on;

ii) if the first bit after a “start of communication” is “0”, sequence Z shall be used to represent this and any “0”s which follow directly thereafter.

— start of communication: sequence Z;

— end of communication: logic “0” followed by sequence Y;

— no information: at least two sequences Y.

8.1.3.2 Bit representation and coding for bit rates of *fc*/8, *fc*/4 and *fc*/2

Bit representation and coding is defined in 9.1.3.1.

Start of communication is defined in ISO/IEC 14443-3:2016, 7.1.4.

End of communication is defined in ISO/IEC 14443-3:2016, 7.1.5.

8.1.3.3 Bit representation and coding for bit rates of 3*fc*/4, *fc*, 3*fc*/2 and 2*fc*

See A.2.

8.2 Communication PICC to PCD

8.2.1 Bit rate

The bit rate for the transmission during initialization and anticollision shall be *fc*/128 (~106 kbit/s).

The bit rate for the transmission after initialization and anticollision shall be one of the following:

— *fc*/128 (~106 kbit/s);

— *fc*/64 (~212 kbit/s);

— *fc*/32 (~424 kbit/s);

— *fc*/16 (~848 kbit/s);

— *fc*/8 (~1,70 Mbit/s);

— *fc*/4 (~3,39 Mbit/s);

— *fc*/2 (~6,78 Mbit/s).

8.2.2 Load modulation

The PICC shall be capable of communication to the PCD via an inductive coupling area where the carrier frequency is loaded to generate a subcarrier with frequency, *fs*. The subcarrier shall be generated by switching a load in the PICC.

If the PICC meets the requirements of one particular class as specified in ISO/IEC 14443-1, then the load modulation amplitude V_{LMA} of the PICC shall be at least $V_{\mathrm{LMA,\,PICC}}$ specified for its class when measured as described in ISO/IEC 10373-6, using the test PCD assembly defined for its class, where H is the value of magnetic field strength in A/m (rms).

If the PICC does not claim to meet the requirements of one particular class as specified in ISO/IEC 14443-1, then the load modulation amplitude V_{LMA} of the PICC shall be at least $V_{\mathrm{LMA,\,PICC}}$ specified for “Class 1” when measured as described in ISO/IEC 10373-6, using the test PCD assembly defined for “Class 1”, where H is the value of magnetic field strength in A/m (rms).

Table 8 specifies for each PICC class both the load modulation amplitude limit $V_{\mathrm{LMA,\,PICC}}$ and the relevant test PCD assembly to measure the PICC load modulation amplitude V_{LMA}.

Table 8 — PICC load modulation amplitude limit

	PICC	
	$V_{\text{LMA, PICC}}$ [mV (peak)]	**Test PCD assembly**
”Class 1” PICC	$22/H^{0,5}$	Test PCD assembly 1
”Class 2” PICC	Min(14 ; $22/H^{0,5}$)	Test PCD assembly 1
”Class 3” PICC	Min(14 ; $22/H^{0,5}$)	Test PCD assembly 1
”Class 4” PICC	Min(18 ; $40/H^{0,5}$)	Test PCD assembly 2
”Class 5” PICC	Min(14 ; $34/H^{0,5}$)	Test PCD assembly 2
”Class 6” PICC	Min(7 ; $26/H^{0,5}$)	Test PCD assembly 2

The PCD shall be able to receive a V_{LMA} of at least $V_{\text{LMA, PCD}}$ when measured as described in ISO/IEC 10373-6, using test PCD assembly 1, with Reference PICCs 1, 2 and 3, where H is the value of magnetic field strength in A/m (rms).

If the PCD supports operation with “Class 4” PICCs, it shall be able to receive a V_{LMA} of at least $V_{\text{LMA, PCD}}$ when measured as described in ISO/IEC 10373-6, using test PCD assembly 2, with Reference PICC 4, where H is the value of magnetic field strength in A/m (rms).

If the PCD supports operation with “Class 5” PICCs, it shall be able to receive a V_{LMA} of at least $V_{\text{LMA, PCD}}$ when measured as described in ISO/IEC 10373-6, using test PCD assembly 2, with Reference PICC 5, where H is the value of magnetic field strength in A/m (rms).

If the PCD supports operation with “Class 6” PICCs, it shall be able to receive a V_{LMA} of at least $V_{\text{LMA, PCD}}$ when measured as described in ISO/IEC 10373-6, using test PCD assembly 2, with Reference PICC 6, where H is the value of magnetic field strength in A/m (rms).

Table 9 specifies for each Reference PICC both the load modulation reception limit $V_{\text{LMA, PCD}}$ and the test PCD assembly to use to measure the PCD sensitivity.

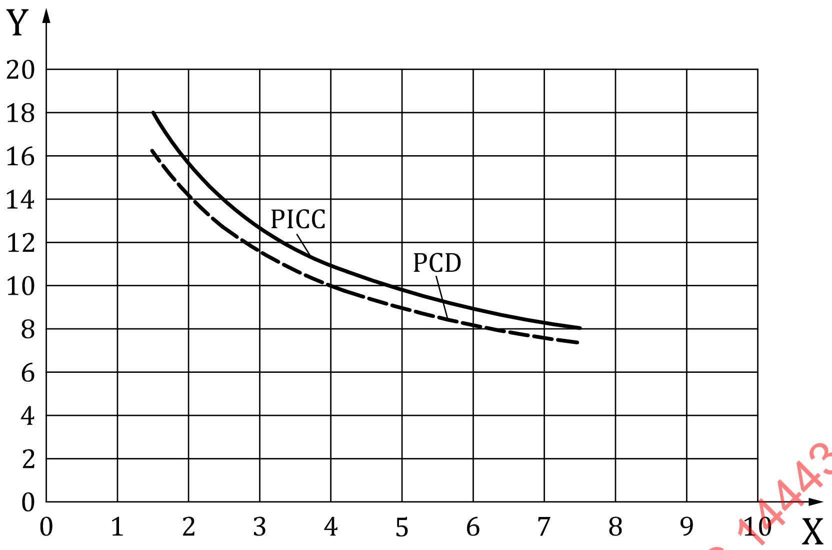
Table 9 — PCD load modulation reception limit

	PCD	
	$V_{\text{LMA, PCD}}$ [mV (peak)]	**Test PCD assembly**
Measured with Reference PICC 1	$20/H^{0,5}$	Test PCD assembly 1
Measured with Reference PICC 2	Min(12,5 ; $20/H^{0,5}$)	Test PCD assembly 1
Measured with Reference PICC 3	Min(12,5 ; $20/H^{0,5}$)	Test PCD assembly 1
Measured with Reference PICC 4 (optional)	Min(16 ; $36/H^{0,5}$)	Test PCD assembly 2
Measured with Reference PICC 5 (optional)	Min(13 ; $31/H^{0,5}$)	Test PCD assembly 2
Measured with Reference PICC 6 (optional)	Min(6 ; $23/H^{0,5}$)	Test PCD assembly 2

NOTE 1 The PICC load modulation amplitude limits of classes 2 to 6 are less strict than the previous PICC limit in the second edition of ISO/IEC 14443-2.

NOTE 2 For “Class 4”, “Class 5” and “Class 6” PICCs, the use of test PCD assembly 2 increases the measured values of load modulation by a factor of approximately 2 compared with test PCD assembly 1.

Figure 11, Figure 12, Figure 13, Figure 14 and Figure 15 are illustrations of the PCD and PICC load modulation amplitude limits for each class.

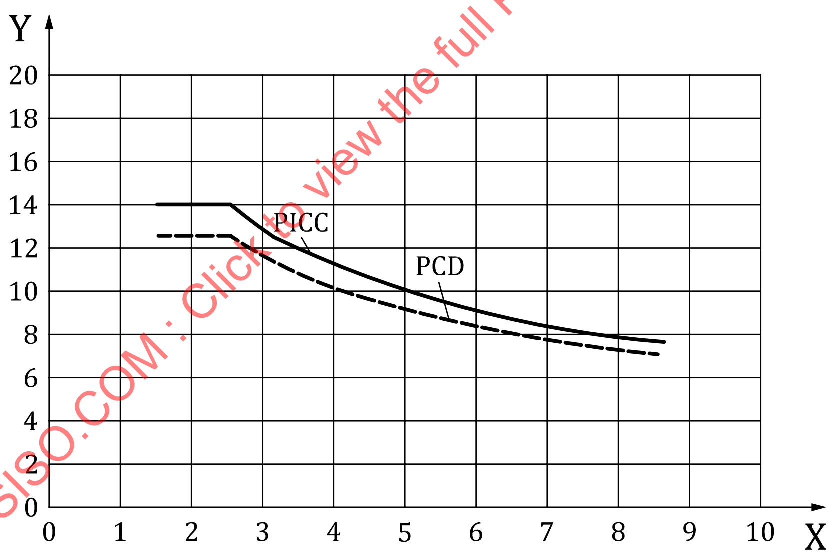


Key

X field strength [A/m (rms)]

Y load modulation amplitude [mV (peak)]

Figure 11 — Load modulation amplitude limits for "Class 1"

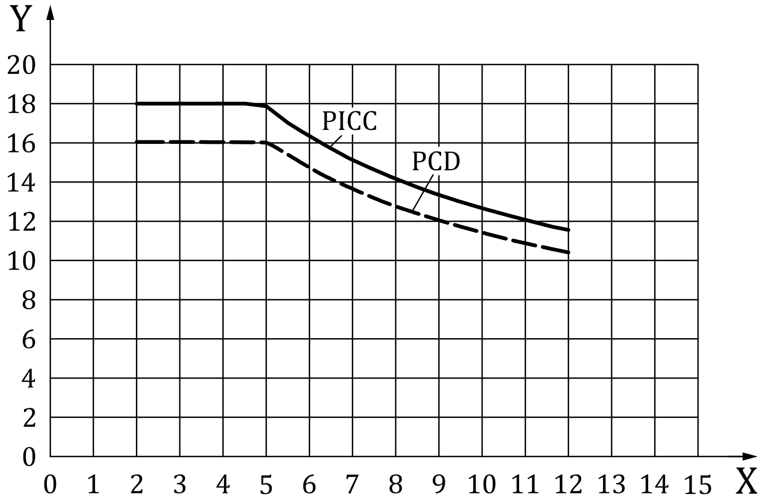


Key

X field strength [A/m (rms)]

Y load modulation amplitude [mV (peak)]

Figure 12 — Load modulation amplitude limits for "Class 2" and "Class 3"

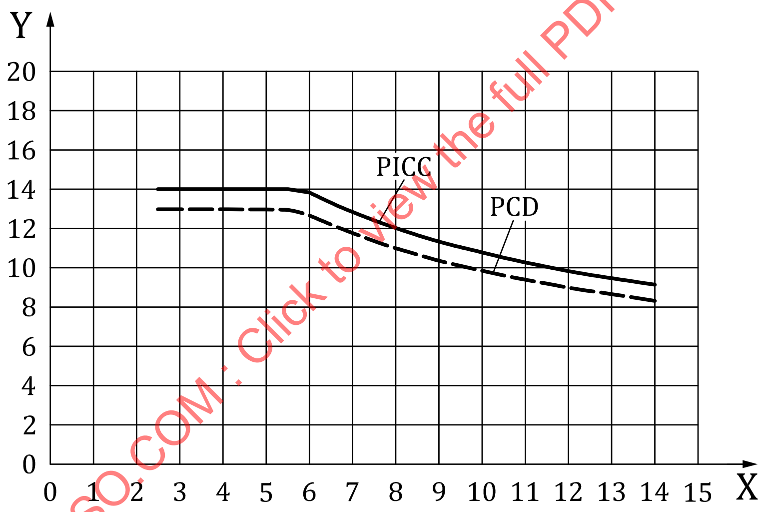


Key

X field strength [A/m (rms)]

Y load modulation amplitude [mV (peak)]

Figure 13 — Load modulation amplitude limits for “Class 4”

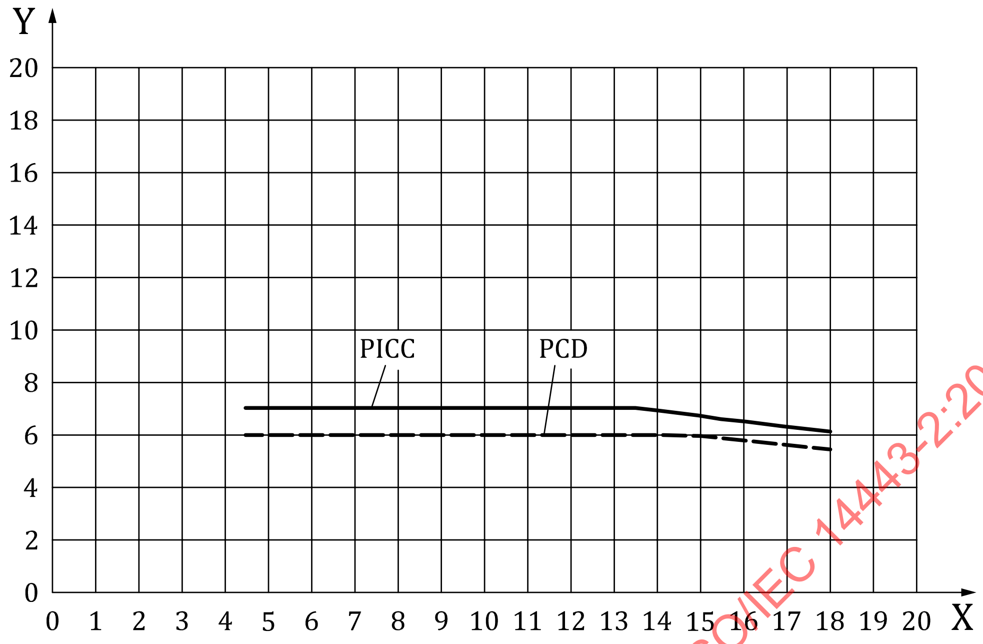


Key

X field strength [A/m (rms)]

Y load modulation amplitude [mV (peak)]

Figure 14 — Load modulation amplitude limits for “Class 5”



Key

X field strength [A/m (rms)]

Y load modulation amplitude [mV (peak)]

Figure 15 — Load modulation amplitude limits for "Class 6"

8.2.3 Subcarrier

The PICC shall generate a subcarrier only when data is to be transmitted.

8.2.3.1 Subcarrier for bit rates of *fc*/128, *fc*/64, *fc*/32 and *fc*/16

The frequency, *fs*, of the subcarrier shall be *fc*/16 (~848 kHz). Consequently, during initialization and anticollision, one bit duration is equivalent to 8 periods of the subcarrier. After initialization and anticollision, the number of subcarrier periods is determined by the bit rate.

8.2.3.2 Subcarrier for bit rates of *fc*/8, *fc*/4 and *fc*/2

The frequency, *fs*, of the subcarrier shall be *fc*/8 (~1,70 MHz), *fc*/4 (~3,39 MHz) or *fc*/2 (~6,78 MHz) depending on the bit rate as specified in Table 10.

Table 10 — Subcarrier frequency vs bit rate

Bit rate	Subcarrier frequency
fc/8 (~1,70 Mbit/s)	*fc*/8
fc/4 (~3,39 Mbit/s)	*fc*/4
fc/2 (~6,78 Mbit/s)	*fc*/2

8.2.4 Subcarrier modulation

Every bit period shall start with a defined phase relation to the subcarrier. The bit period shall start with the loaded state of the subcarrier (the unloaded state of the subcarrier is the stable state when the PICC is not sending bits).

At the bit rate of *fc*/128, the subcarrier is modulated using OOK with the sequences defined in 8.2.5.1. At bit rates of *fc*/64, *fc*/32, *fc*/16, *fc*/8, *fc*/4 and *fc*/2, the subcarrier is modulated using BPSK with the sequences defined in 8.2.5.2.

8.2.5 Bit representation and coding

8.2.5.1 Bit representation and coding for a bit rate of *fc*/128

The following sequences are defined:

— sequence D: the carrier shall be modulated with the subcarrier for the first half (50 %) of the bit duration;

— sequence E: the carrier shall be modulated with the subcarrier for the second half (50 %) of the bit duration;

— sequence F: the carrier is not modulated with the subcarrier for one bit duration.

Bit coding shall be Manchester with the following definitions:

— logic “1”: sequence D;

— logic “0”: sequence E;

— start of communication: sequence D;

— end of communication: sequence F;

— no information: no subcarrier.

8.2.5.2 Bit representation and coding for bit rates of *fc*/64, *fc*/32, *fc*/16, *fc*/8, *fc*/4 and *fc*/2

Bit coding shall be NRZ-L with the following definitions:

— logic “1”: the carrier shall be modulated with the subcarrier for one bit duration;

— logic “0”: the carrier shall be modulated with the inverted subcarrier for one bit duration;

— start of communication: burst of 32 subcarrier cycles (phase as logic “1”) followed by inverted subcarrier for one bit duration (phase as logic “0”);

— end of communication: the carrier is not modulated with the subcarrier for one bit duration;

— no information: the carrier is not modulated with the subcarrier.

9 Communication signal interface Type B

9.1 Communication PCD to PICC

9.1.1 Bit rate

The bit rate for the transmission during initialization and anticollision shall be nominally *fc*/128 (~106 kbit/s).

The bit rate for the transmission after initialization and anticollision shall be one of the following:

— *fc*/128 (~106 kbit/s);

— *fc*/64 (~212 kbit/s);

— *fc*/32 (~424 kbit/s);

— *fc*/16 (~848 kbit/s);

— *fc*/8 (~1,70 Mbit/s);

— *fc*/4 (~3,39 Mbit/s);

— *fc*/2 (~6,78 Mbit/s);

— 3*fc*/4 (~10,17 Mbit/s);

— *fc* (~13,56 Mbit/s);

— 3*fc*/2 (~20,34 Mbit/s);

— 2*fc* (~27,12 Mbit/s).

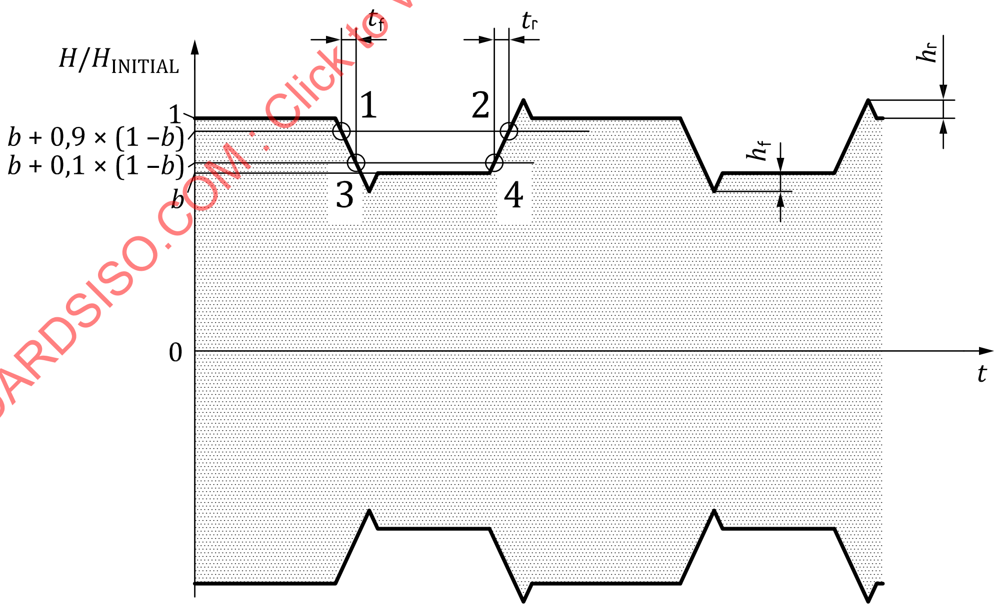
Bit boundary tolerances and character separation are defined in ISO/IEC 14443-3:2016, 7.1.1 and 7.1.2, respectively.

9.1.2 Modulation

9.1.2.1 Modulation for bit rates of *fc*/128, *fc*/64, *fc*/32, *fc*/16, *fc*/8, *fc*/4 and *fc*/2

Communication from PCD to PICC shall use the modulation principle of ASK 10 % of the RF operating field.

The modulation waveform shall comply with Figure 16. The rising and falling edges of the modulation shall be monotonic. The rise and fall times (t_r, t_f) shall be measured between 10 % and 90 % of the actual modulation step.



Key

1 start of t_f

2 end of t_r

3 end of t_f

4 start of t_r

Figure 16 — Type B modulation waveform

The PCD shall generate for any bit combination a modulation waveform with a modulation index, *m*

— greater than 8 % for all supported bit rates, and

— less than

  — 14 % for bit rates of *fc*/128, *fc*/64, *fc*/32 and *fc*/16,

  — 20 % for bit rates of *fc*/8, *fc*/4 and *fc*/2.

The PICC shall be able to receive for any bit combination a modulation waveform with a modulation index, *m*

— greater than

  — both (9,5 – 1,5H/H_{min}) % and 7 % for bit rates of *fc*/128, *fc*/64, *fc*/32 and *fc*/16,

  — 8 % for bit rates of *fc*/8, *fc*/4 and *fc*/2;

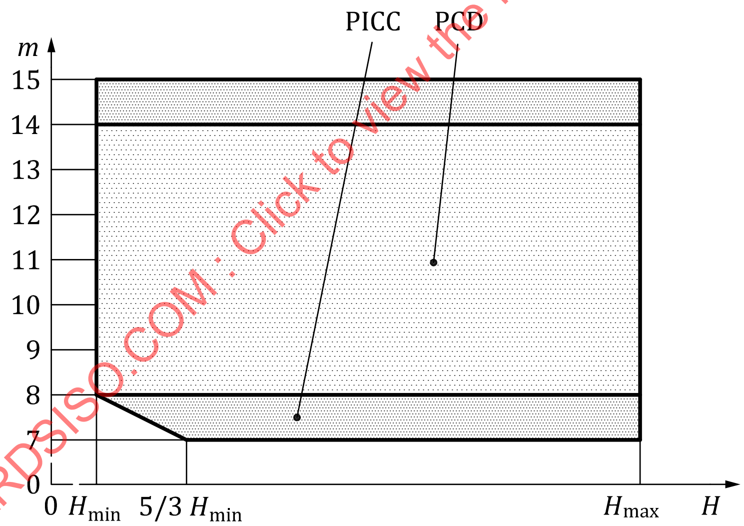
— and less than

  — 15 % for bit rates of *fc*/128, *fc*/64, *fc*/32 and *fc*/16,

  — 21 % for bit rates of *fc*/8, *fc*/4, and *fc*/2.

NOTE 1 Minimum and maximum values of *H* are defined in Table 1 and Table 2.

The limits for the modulation index, *m*, for bit rates of *fc*/128, *fc*/64, *fc*/32 and *fc*/16 are illustrated in Figure 17.



Key

m [%]

H [A/m (rms)]

Figure 17 — Type B modulation index *m* for bit rates of *fc*/128, *fc*/64, *fc*/32 and *fc*/16

The overshoot and undershoot of the PCD modulation waveform shall remain within limits specified in Table 11.

Table 11 — PCD transmission: Overshoot and undershoot for all supported bit rates

Parameter	Min	Max
h_f	0	$[1 - t_f / (2 \times t_{f,\,max,\,PCD})] \times 0{,}10 \times (1 - b)$
h_r	0	$[1 - t_r / (2 \times t_{r,\,max,\,PCD})] \times 0{,}10 \times (1 - b)$

NOTE 2 The maximum value of h_f / h_r is a function of the measured value of t_f / t_r. and of $t_{f,\,max,\,PCD}$ / $t_{r,\,max,\,PCD}$ (see requirements above Figure 18, Figure 19, Figure 20, or Figure 21).

The PICC shall be able to receive a modulation waveform with overshoot and undershoot defined in Table 12.

Table 12 — PICC reception: Overshoot and undershoot for all supported bit rates

Parameter	Min	Max
h_f	0	$[1 - t_f / (2 \times t_{f,\,max,\,PICC})] \times 0{,}11 \times (1 - b)$
h_r	0	$[1 - t_r / (2 \times t_{r,\,max,\,PICC})] \times 0{,}11 \times (1 - b)$

NOTE 3 The maximum value of h_f / h_r is a function of the set value of t_f / t_r and of $t_{f,\,max,\,PICC}$ / $t_{r,\,max,\,PICC}$ (see requirements above Figure 18, Figure 19, Figure 20, or Figure 21).

For a bit rate of fc/128, the PCD shall generate a modulation waveform with

— a fall time, t_f, between 0/fc and t_f, max, PCD = 16/fc, and

— a rise time, t_r

  — greater than both 0/fc and t_f – 8/fc, and

  — less than both t_f + 8/fc and t_r, max, PCD = 16/fc.

For a bit rate of fc/128, the PICC shall be able to receive a modulation waveform with

— a fall time, t_f, between 0/fc and $t_{f,\,max,\,PICC}$ = 17/fc, and

— a rise time, t_r

  — greater than both 0/fc and t_f – 9/fc, and

  — less than both t_f + 9/fc and $t_{r,\,max,\,PICC}$ = 17/fc.

The timing parameters for PCD and PICC are illustrated in Figure 18.

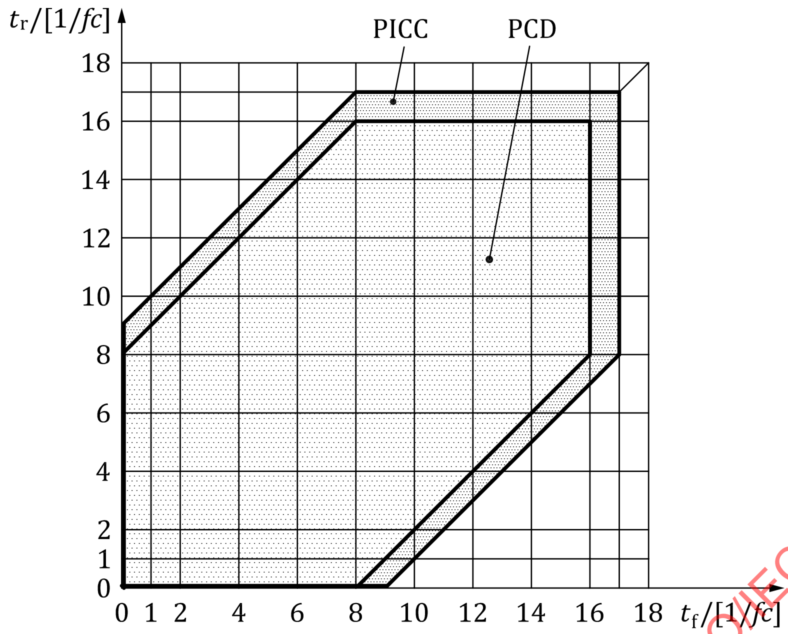


Figure 18 — Type B modulation waveform timing parameters for a bit rate of *fc*/128

For a bit rate of $fc/64$, the PCD shall generate a modulation waveform with

— a fall time, t_f, between $0/fc$ and $t_{f,\ max,\ PCD} = 14/fc$, and

— a rise time, t_r

  — greater than both $0/fc$ and $t_f - 6/fc$, and

  — less than both $t_f + 6/fc$ and $t_{r,\ max,\ PCD} = 14/fc$.

For a bit rate of $fc/64$, the PICC shall be able to receive a modulation waveform with

— a fall time, t_f, between $0/fc$ and $t_{f,\ max,\ PICC} = 14/fc$, and

— a rise time, t_r

  — greater than both $0/fc$ and $t_f - 7/fc$, and

  — less than both $t_f + 7/fc$ and $t_{r,\ max,\ PICC} = 14/fc$.

The timing parameters for PCD and PICC are illustrated in Figure 19.

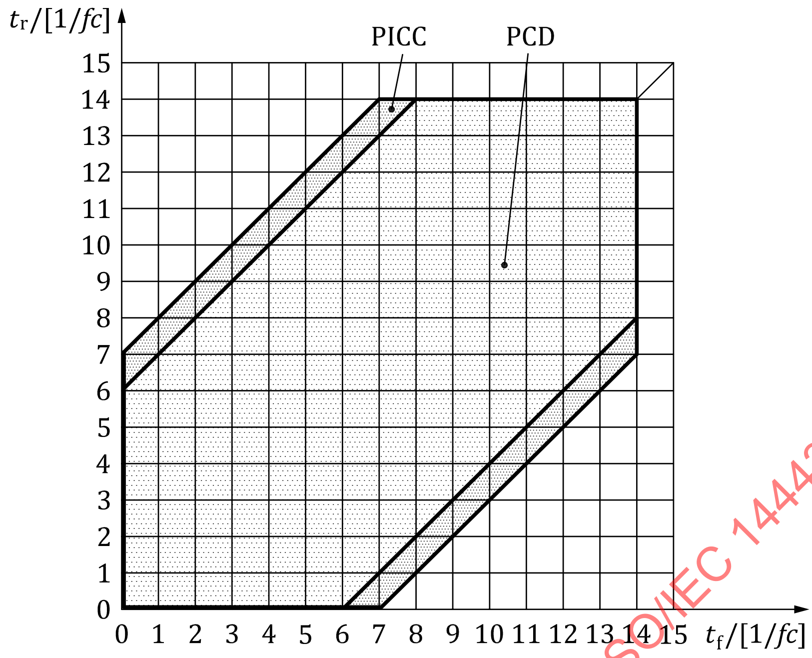


Figure 19 — Type B modulation waveform timing parameters for a bit rate of *fc*/64

For a bit rate of *fc*/32, the PCD shall generate a modulation waveform with

— a fall time, t_f, between 0/*fc* and $t_{f,\ max,\ PCD}$ = 11/*fc*, and

— a rise time, t_r

  — greater than both 0/*fc* and t_f − 4,5/*fc*, and

  — less than both t_f + 4,5/*fc* and $t_{r,\ max,\ PCD}$ = 11/*fc*.

For a bit rate of *fc*/32. the PICC shall be able to receive a modulation waveform with

— a fall time, t_f, between 0/*fc* and $t_{f,\ max,\ PICC}$ = 11/*fc*, and

— a rise time, t_r

  — greater than both 0/*fc* and t_f − 5,5/*fc*, and

  — less than both t_f + 5,5/*fc* and $t_{r,\ max,\ PICC}$ = 11/*fc*.

The timing parameters for PCD and PICC are illustrated in Figure 20.

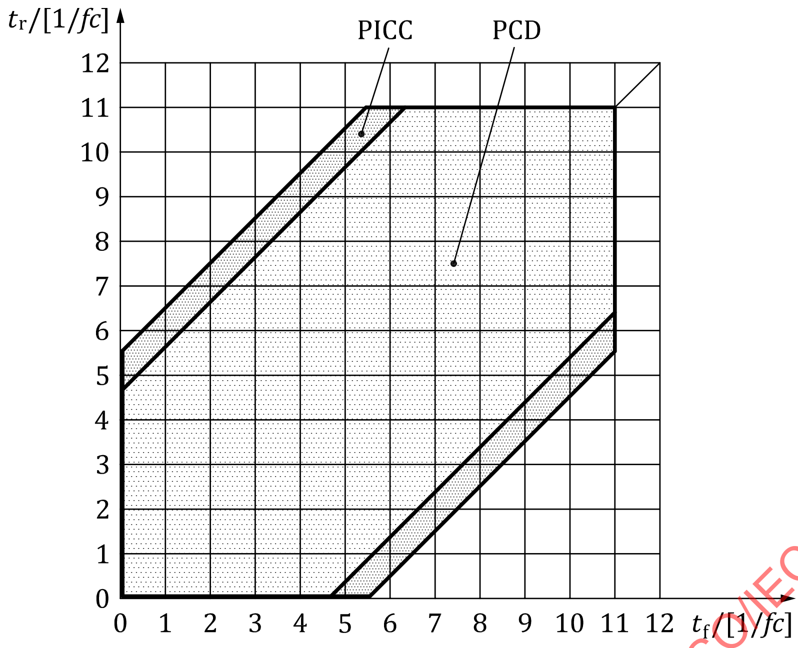


Figure 20 — Type B modulation waveform timing parameters for a bit rate of *fc*/32

For a bit rate of *fc*/16, the PCD shall generate a modulation waveform with

— a fall time, t_f, between 0/*fc* and $t_{f,\ max,\ PCD}$ = 8/*fc*, and

— a rise time, t_r

— greater than both 0/*fc* and t_f – 4/*fc*, and

— less than both t_f + 4/*fc* and $t_{r,\ max,\ PCD}$ = 8/*fc*.

For a bit rate of *fc*/16, the PICC shall be able to receive a modulation waveform with

— a fall time, t_f, between 0/*fc* and $t_{f,\ max,\ PICC}$ = 8/*fc*, and

— a rise time, t_r

— greater than both 0/*fc* and t_f – 4/*fc*, and

— less than both t_f + 4/*fc* and $t_{r,\ max,\ PICC}$ = 8/*fc*.

The timing parameters for PCD and PICC are illustrated in Figure 21.

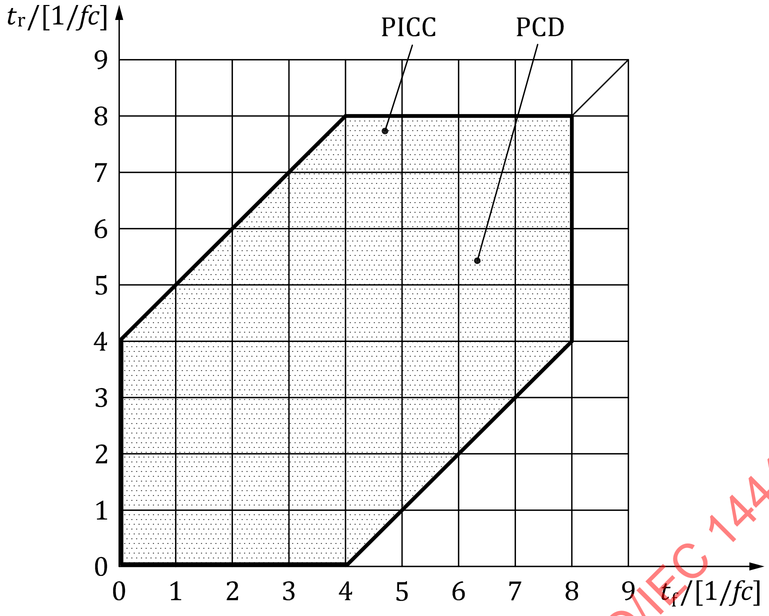


Figure 21 — Type B modulation waveform timing parameters for a bit rate of *fc*/16

For a bit rate of $fc/8$, the PCD shall generate for any bit combination a modulation waveform with

— a fall time, t_f, between $0/fc$ and $t_{f,\ max,\ PCD} = 6/fc$, and

— a rise time, t_r

— greater than both $0/fc$ and $t_f - 3/fc$, and

— less than both $t_f + 3/fc$ and $t_{r,\ max,\ PCD} = 6/fc$.

For a bit rate of $fc/8$, the PICC shall be able to receive for any bit combination a modulation waveform with

— a fall time, t_f, between $0/fc$ and $t_{f,\ max,\ PICC} = 6/fc$, and

— a rise time, t_r

— greater than both $0/fc$ and $t_f - 3/fc$, and

— less than both $t_f + 3/fc$ and $t_{r,\ max,\ PICC} = 6/fc$.

The timing parameters for PCD and PICC are illustrated in Figure 22.

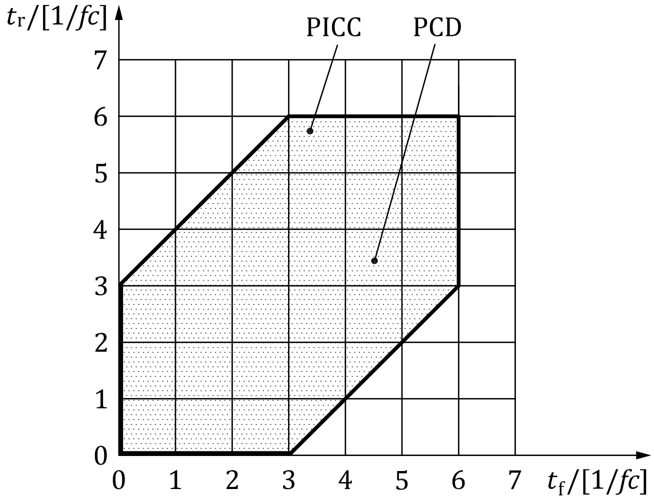


Figure 22 — Modulation waveform timing parameters for a bit rate of *fc*/8

For a bit rate of *fc*/4, the PCD shall generate for any bit combination a modulation waveform with

— a fall time, t_f, between 0/*fc* and $t_{f,\, max,\, PCD}$ = 4/*fc*, and

— a rise time, t_r

  — greater than both 0/*fc* and t_f − 2/*fc*, and

  — less than both t_f + 2/*fc* and $t_{r,\, max,\, PCD}$ = 4/*fc*.

For a bit rate of *fc*/4, the PICC shall be able to receive for any bit combination a modulation waveform with

— a fall time, t_f, between 0/*fc* and $t_{f,\, max,\, PICC}$ = 4/*fc*, and

— a rise time, t_r

  — greater than both 0/*fc* and t_f − 2/*fc*, and

  — less than both t_f + 2/*fc* and $t_{r,\, max,\, PICC}$ = 4/*fc*.

The timing parameters for PCD and PICC are illustrated in Figure 23.

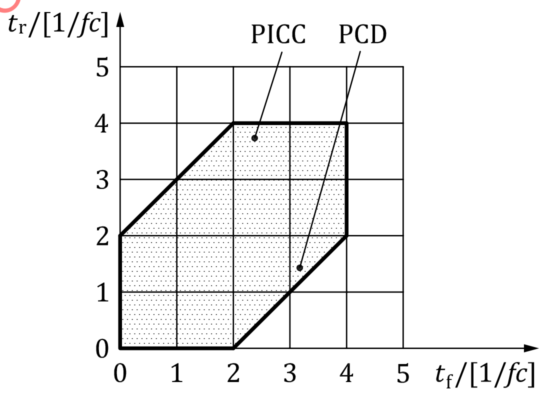


Figure 23 — Modulation waveform timing parameters for a bit rate of *fc*/4

For a bit rate of *fc*/2, the PCD shall generate for any bit combination a modulation waveform with

— a fall time, t_f, less than $t_{f,\, max,\, PCD}$ = 3/*fc*, and

— a rise time, t_r less than $t_{r,\,max,\,PCD} = 3/fc$.

For a bit rate of $fc/2$, the PICC shall be able to receive for any bit combination a modulation waveform with

— a fall time, t_f, less than $t_{f,\,max,\,PICC} = 3/fc$, and

— a rise time, t_r, less than $t_{r,\,max,\,PICC} = 3/fc$.

9.1.2.2 Modulation for bit rates of 3*fc*/4, *fc*, 3*fc*/2 and 2*fc*

See A.1.

9.1.3 Bit representation and coding

9.1.3.1 Bit representation and coding for bit rates of *fc*/128, *fc*/64, *fc*/32, *fc*/16, *fc*/8, *fc*/4 and *fc*/2

Bit coding format shall be NRZ-L with logic levels defined as follows:

logic “1”: carrier high field amplitude (no modulation applied);

logic “0”: carrier low field amplitude.

9.1.3.2 Bit representation and coding for bit rates of 3*fc*/4, *fc*, 3*fc*/2 and 2*fc*

See A.2.

9.2 Communication PICC to PCD

9.2.1 Bit rate

See 8.2.1.

9.2.2 Load modulation

See 8.2.2.

9.2.3 Subcarrier

See 8.2.3.

9.2.4 Subcarrier modulation

The subcarrier shall be BPSK modulated. Phase shifts shall only occur at nominal positions of rising or falling edges of the subcarrier.

9.2.5 Bit representation and coding

Bit coding shall be NRZ-L where a change of logic level shall be denoted by a phase shift (180 degrees) of the subcarrier.

The initial logic level for NRZ-L at the start of a PICC frame shall be established by the following sequence.

— After any command from the PCD, a guard time TR0 shall apply in which the PICC shall not generate a subcarrier. TR0 shall be greater than $1024/fc$ (~75,5 µs).

— The PICC shall then generate a subcarrier with no phase transition for a synchronization time TR1. This establishes an initial subcarrier phase reference *Ø0*. TR1 shall be greater than $80/fs$.

— This initial phase state *Ø0* of the subcarrier shall be defined as logic “1” so that the first phase transition represents a change from logic “1” to logic “0”.

— Subsequently, the logic level is defined according to the initial phase of the subcarrier.

Ø0: represents logic “1”

Ø0 + 180°: represents logic “0”

10 Electromagnetic disturbance levels

10.1 PCD limits

The PCD shall not detect any load modulation amplitude below $V_{E,\ PCD}$ at a field strength H [A/m (rms)], when measured as specified in ISO/IEC 10373-6.

$V_{E,\ PCD}$ is as follows:

— $2/3 + 3/H^2$ [mV (peak)] for $H_{min} \leq H \leq 4{,}5$ A/m (rms);

— 0,81 mV (peak) for 4,5 A/m (rms) $< H \leq H_{max}$.

WARNING — This limit is referenced to “Class 1” only and may be detrimental to communication with PICCs of the other classes. Values for other classes will be specified in the future.

10.2 PICC limits

This EMD requirement is applicable for “Class 1” PICC only.

WARNING — Requirements for the classes other than “Class 1” will be specified in the future. However, the PICC limit for “Class 1” may ultimately be applied to “Class 2” and “Class 3” PICCs.

The EMD level before PICC data transmission shall be below $V_{E,\ PICC}$ at a field strength H [A/m (rms)], for at least the duration of the low EMD time $t_{E,\ PICC}$, when measured as specified in ISO/IEC 10373-6.

$V_{E,\ PICC}$ for “Class 1” PICC is as follows:

— $2/3 + 3/H^2$ [mV (peak)] for $H_{min} \leq H \leq 4{,}5$ A/m (rms);

— 0,81 mV (peak) for 4,5 A/m (rms) $< H \leq H_{max}$

During this low EMD time, the EMD level may exceed $V_{E,\ PICC}$ for no more than two short periods of $16/fc$ if

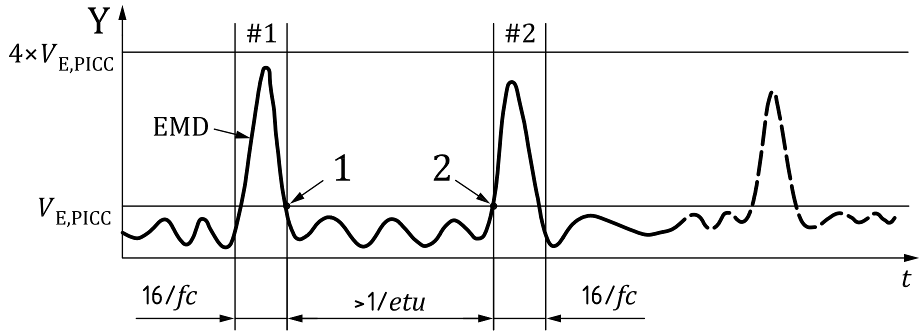
— it never exceeds $4 \times V_{E,\ PICC}$, and

— in case of two periods, the time between the two periods is greater than 1 etu.

Figure 24 shows an illustration of such allowed EMD spikes.

NOTE The low EMD time $t_{E,\ PICC}$ is defined in ISO/IEC 14443-3.

WARNING — This limit is referenced to “Class 1” only and values for the other classes may be specified in the future.



Key

1 end of spike period #1

2 start of spike period #2

Y amplitude [mV]

t time

Figure 24 — Illustration of allowed EMD spikes

Annex A
(normative)

Bit rates of 3*fc*/4, *fc*, 3*fc*/2 and 2*fc* from PCD to PICC

A.1 Modulation for bit rates of 3*fc*/4, *fc*, 3*fc*/2 and 2*fc*

For communication from PCD to PICC using bit rates of 3*fc*/4, fc, 3*fc*/2 and 2*fc*, information is encoded by PSK modulation of RF carrier of the operating field.

For bit rates of 3*fc*/4, *fc*, 3*fc*/2 and 2*fc*, information is encoded by PSK modulation of the RF carrier. The RF carrier is phase modulated with an NP at each etu. For each bit rate, the length of an etu and the number of NPs are specified in Table A.1.

Table A.1 — etu and number of NPs

Bit rate	etu	number of NPs
3*fc*/4 (~10,17 Mbit/s)	4/*fc*	8
fc (~13,56 Mbit/s)	4/*fc*	16
3*fc*/2 (~20,34 Mbit/s)	2/*fc*	8
2*fc* (~27,12 Mbit/s)	2/*fc*	16

The difference between 2 consecutive NPs is defined as EPI, specified in Table A.2 and illustrated in Figure A.1.

Table A.2 — EPI

Bit rate	EPI
3*fc*/4 (~10,17 Mbit/s)	8°
fc (~13,56 Mbit/s)	4°
3*fc*/2 (~20,34 Mbit/s)	8°
2*fc* (~27,12 Mbit/s)	4°

The difference between the angle of P_H and the angle of P_L defines the phase range PR as illustrated in Figure A.1.

The PCD and PICC shall respect the PR limits as specified in Table A.3 and Table A.4.

Table A.3 — PR for PCD transmission

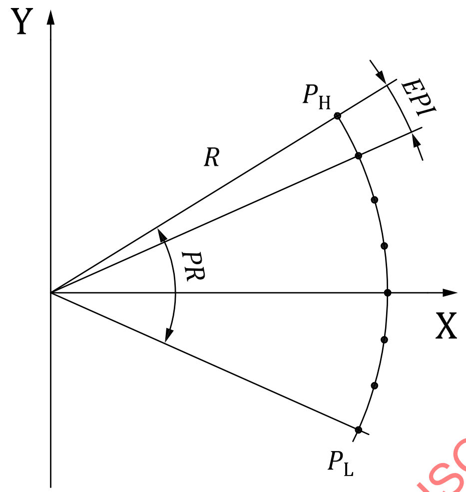
Bit rate	Minimum PR	Maximum PR
3*fc*/4, 3*fc*/2	54°	58°
fc, 2*fc*	58°	62°

Table A.4 — PR for PICC reception

Bit rate	Minimum PR	Maximum PR
3*fc*/4, 3*fc*/2	52°	60°
fc, 2*fc*	56°	64°

A.1.1 NP Tolerances

Due to the limited bandwidth channel, the intended NP phase modulation is affected by inter symbol interference (ISI) resulting in an ACP at the end of each etu. The angle of the ACP is defined as AP. This is described in a constellation diagram with ISI_m and ISI_d as specified below and illustrated in Figure A.2.



Key

X real

Y imaginary

Figure A.1 — Nominal constellation points