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ISO/IEC JTC 1/SC 17/WG 8

Secretariat: DIN

Identification cards — Contactless integrated circuit cards - Proximity cards — Part 2: Radio frequency power and signal interface

AMENDMENT 1
Bits rates higher than *fc*/16 and up to *fc*

Cartes d'identification — Cartes à circuit intégré - Cartes de proximité — Partie 2: Interface radio fréquence

AMENDEMENT 1
Débits binaires supérieurs à fc/16 jusqu'à fc

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Foreword

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Amendment 1 to ISO/IEC 14443-2:2010 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 17, *Card and personal identification*.

Identification cards — Contactless integrated circuit cards - Proximity cards — Part 2: Radio frequency power and signal interface

Amendment 1: Bit rates higher than *fc*/16 up to *fc*

Page3, Clause 4

Add the following symbols:

CAL	Calibration Sequence
EOF	End of frame
etu	Elementary time unit
PSK	Phase shift keying
SOF	Start of frame
SYNC	Synchronization Sequence
TSC	Training Sequence
VHBR	Very High Bit rates

Page 6 , 8.1.1

Replace paragraph with:

"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 (~1,695 Mbit/s),
- *fc*/(16/3) (~2,542 Mbit/s),

- *fc*/4 (~3,39 Mbit/s),
- *fc*/(8/3) (~5,085 Mbit/s),
- *fc*/2 (~6,78 Mbit/s),
- *fc*/(4/3) (~10,17 Mbit/s),
- *fc*/2 (~13,56 Mbit/s)."

Page 14

Add new subclause

"8.1.2.3 Modulation for bit rates higher than fc/16

See 11.2"

Page 14, 8.1.3

Change title to "**Bit representation and coding for bit rates up to fc/16**"

Page 15

Add new subclause"

"8.1.4 Bit representation and coding for bit rates higher than fc/16

See 11.3"

Page 15, 8.2.1

Replace paragraph with:

"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 (~1,695 Mbit/s),
- *fc*/4 (~3,39 Mbit/s),
- *fc*/2 (~6,78 Mbit/s).

NOTE Higher bit rates may be added when defined."

Page 16, 8.2.3

Replace 8.2.3 with the following:

"8.2.3 Subcarrier

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

8.2.3.1 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 Bit rates of *fc*/8, *fc*/4 and *fc*/2

The frequency *fs* of the subcarrier shall be *fc*/8 (~1,695 MHz), *fc*/4 (~3,39 MHz) or *fc*/2 (~6,78 MHz) depending on the bit rate as specified in table 8.

Subcarrier frequency	Bit rate
fc/8	1,695 Mbit/s
fc/4	3,39 Mbit/s
fc/2	6,78 Mbit/s

Table 8 — Bit rates vs subcarrier frequency

"

Page 16, end of 8.2.4

Replace second paragraph with the following:

"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."

Page 17, 8.2.5.2

Change 8.2.5.2 headline text:

"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"

Page 18 , 9.1.1

Replace paragraph with:

"See 8.1.1"

Page 18, 9.1.2

Insert new subclause 9.1.2.1 with the following title and move all existing text of subclause 9.1.2 into this new subclause 9.1.2.1:

"**9.1.2.1: ASK Modulation**"

Page 18, 9.1.2

Replace paragraphs between Figure 12 and Figure 13 with:

"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,
  - 18 % 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 − *H*) % and 7 % for all supported bit rates,
- and less than
  - 15 % for bit rates of *fc*/128, *fc*/64, *fc*/32 and *fc*/16,
  - 18 % 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 *fc*/128, *fc*/64, *fc*/32 and *fc*/16 are illustrated in Figure 13."

Page 19, 9.1.2

Replace Table 9 caption text with:

"PCD transmission: Overshoot and undershoot for all supported bit rates"

Page 19, 9.1.2

Replace Table 10 caption text with:

"PICC reception: Overshoot and undershoot for all supported bit rates"

Page 23, 9.1.2

After Figure 17 add:

"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 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 and $t_{r,\ max,\ PICC}$ = 6/*fc*.

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

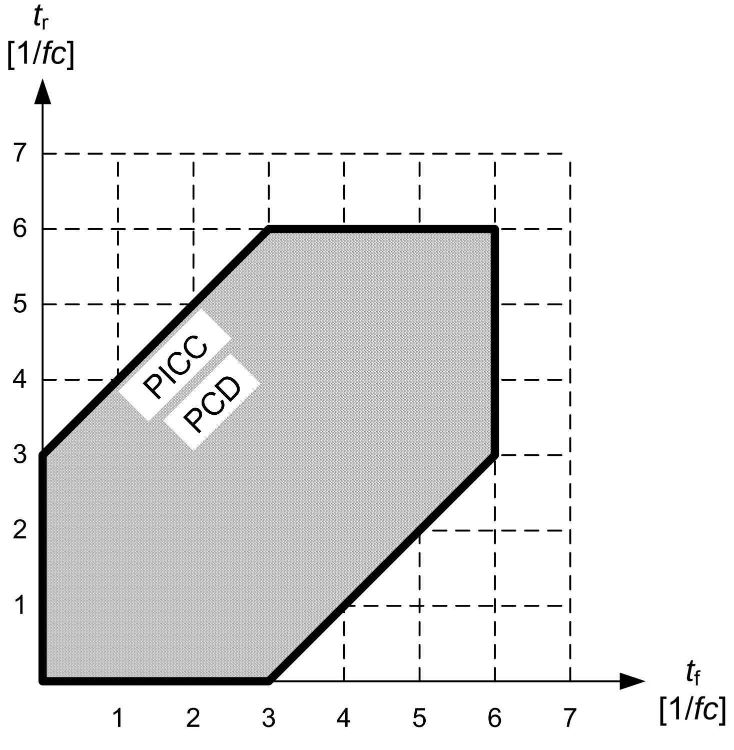


Figure 18 — Type B modulation waveform timing parameters for a bit rate of *fc*/8

For bit rates of *fc*/4 and *fc*/2 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 and $t_{r,\ max,\ PCD}$ = 4/*fc*.

For bit rates of $fc/4$ and $fc/2$ 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 and $t_{r,\ max,\ PICC} = 4/fc$.

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

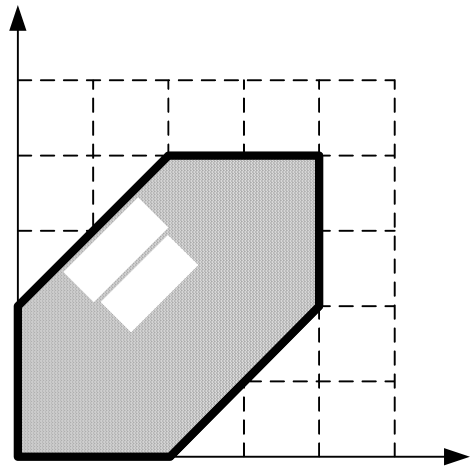


Figure 19 — Type B modulation waveform timing parameters for bit rates of *fc*/4 and *fc*/2

"

Page 23, 9.1.2

Insert new subclause 9.1.2.2 with the following title and content:

"9.1.2.2: PSK Modulation

See 11.2."

Page 24, 9.1.3

Change title to "Bit representation and coding for ASK modulation"

Page 24, 9.1.3

Add a new subclause with the following title and content

"9.1.4 : Bit representing and coding for PSK modulation

See 11.3."

Page 24, 9.2.1

Replace paragraph with the following:

"See 8.2.1."

Page 24, 9.2.5

Replace 1st bullet of 2nd paragraph with the following:

— "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)."

Page 24, end of the document

Create a new clause 11 as follows:

11 PSK modulation from PCD to PICC

11.1 Bit rate

The bit rate for the transmission after the very high bit rate selection shall be one of the following

Type of modulation Phase N Unitary Φ_{Seg}	2PSK $2 = 2^1$ $\Phi_{Seg} = 60°$	4PSK $4 = 2^2$ $\Phi_{Seg} = 60°$	8PSK $8 = 2^3$ $\Phi_{Seg} = 56°$	16PSK $16 = 2^4$ $\Phi_{Seg} = 60°$
1 etu ≅ 16/*fc* (~1180 ns)		*4PSK16:* *fc*/8 (~1,695 Mbit/s)	*8PSK16:* *fc*/(16/3) (~2,54 Mbit/s)	*16PSK16:* *fc*/4 (~3,39 Mbit/s)
1 etu ≅ 8/*fc* (~590 ns)	*2PSK8:* *fc*/8 (~1,695 Mbit/s)	*4PSK8:* *fc*/4 (~3,39 Mbit/s)	*8PSK8:* *fc*/(8/3) (~5,09 Mbit/s)	*16PSK8:* *fc*/2 (~6,78 Mbit/s)
1 etu ≅ 4/*fc* (~295 ns)	*2PSK4:* *fc*/4 (~3,39 Mbit/s)	*4PSK4:* *fc*/2 (~6,78 Mbit/s)	*8PSK4:* *fc*/(4/3) (~10,17 Mbit/s)	
1 etu ≅ 2/*fc* (~147 ns)	*2PSK2:* *fc*/2 (~6,78 Mbit/s)	*4PSK2:* *fc* (~13,56 Mbit/s)		

Table 11 — PSK mode Bit rates

11.2 PSK signal parameters for Modulation

11.2.1 PSK modulation parameters

In PSK mode, communication from PCD to PICC shall use the modulation principle of PSK of the RF carrier of the operating field.

The transmitted PSK constellation (see Annex A) can be characterized by two main parameters:

M: PSK modulation order. This equals the number of constellation points. It is a power of 2.

Φ_{Seg}: The portion of the circle used for modulation. It is the angle between the outermost constellation points.

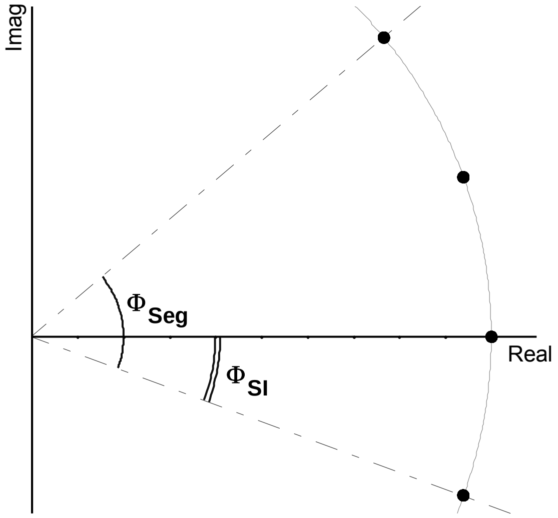


Figure 20 — PSK modulation parameter illustration

The symbol interval Φ_{SI} is defined by these parameters as:

$$\Phi_{SI} = \Phi_{Seg} /(M-1)$$

Figure 20 illustrates the definition of parameter Φ_{Seg} and the derived parameter Φ_{SI}.

For communication modes involving PSK modulation, the PCD shall generate a signal with IQ segment as specified by Table12.

Table 12 — PCD transmission IQ segment parameters for all PSK modes

PSK order M	Parameter	Min	Max
2, 4, 16	Φ_{Seg}	58	62
8	Φ_{Seg}	54	58

For communication modes involving PSK modulation, the PICC shall be able the receive signals with IQ segment as specified by Table 13

PSK order M	Parameter	Min	Max
2, 4, 16	Φ_{Seg}	56	64
8	Φ_{Seg}	52	60

Table 13 — PCD reception: IQ segment parameters for all PSK modes

11.2.2 ISI parameters

The effect of bandwidth limitations, for example originating from the PCD antenna, is to introduce inter-symbol interference (ISI), resulting in ISI clouds around each constellation point. See also Annex B.

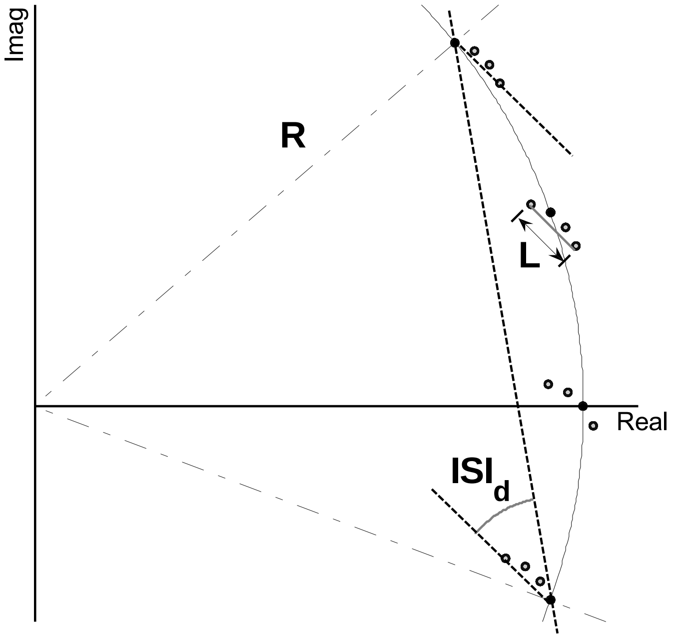


Figure 21 — ISI parameters illustration

Such inter-symbol interference is defined by the following two parameters:

ISI_m: the ISI magnitude normalized to the symbol interval Φ_{SI}.

ISI_d: the ISI rotation.

Instead of observing ISI_m directly, one can measure distance between the two outermost points of an ISI cloud L and then calculate the corresponding ISI_m as:

$$ISI_m = \arcsin(L/R)/\Phi_{SI}$$

where R is the amplitude of the original constellation points. A visual clarification can be found in Figure .20

The ISI magnitude ISI_m generated by the PCD shall be as specified in Table 14 Parameter $ISI_{d,lim}$ is used in the condition field.

Table 14 — PCD transmission: ISI parameters

Parameter	PSK order M	Condition	Min	Max
ISI_m	2	-	0	0.50
	4, 8, 16	$abs(ISI_d) > ISI_{d,lim}$		
		$abs(ISI_d) \leq ISI_{d,lim}$	0	1.8
$ISI_{d,lim}$	2	-	N/A	N/A
	4, 8, 16	-	20°	

The PICC shall be able to receive an amount of ISI as specified in Table 15.

Table 15 — PICC reception ISI parameters

Parameter	PSK order M	Condition	Min	Max
ISI_m	2	-	0	0.52
	4, 8, 16	$abs(ISI_d) > ISI_{d,lim}$		
		$abs(ISI_d) \leq ISI_{d,lim}$	0	1.9
$ISI_{d,lim}$	2	-	N/A	N/A
	4, 8, 16	-	21°	

11.2.3 Phase noise

Any physical signal will in practice be contaminated by noise. In the case of a PSK modulated signal, it is the noise in the phase component of the signal (also known as the phase noise) that could affect reliable data recovery and should therefore be within limits. Similar to ISI, such phase noise would be visible in a constellation diagram as clouds around the wanted constellation points. It is possible to distinguish the two due to the fact that ISI can be modelled by a linear filter response of the transmitted signal, whereas noise, of course, cannot.

The amount of noise added to the PSK signal (on top of the ISI) is defined by the following parameter:

PN_{RMS}: The root-mean-square phase component of the noise present in the PSK signal, normalized to a symbol interval Φ_{SI}.

Normalizing to the symbol interval means that when the measured RMS phase noise is expressed in degrees, this number has to be divided by the symbol interval Φ_{SI} (also expressed in degrees) to yield PN_{RMS}.

The amount of phase noise by which the PCD signal is contaminated shall be as specified in Table16.

Table 16 — PCD transmission: Phase noise parameters for all PSK rates

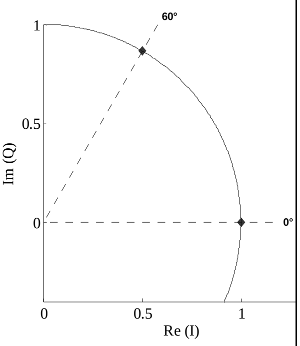
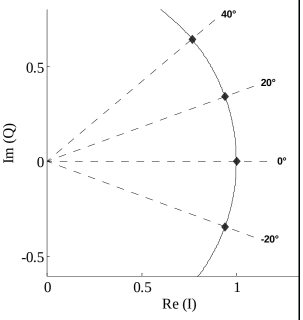
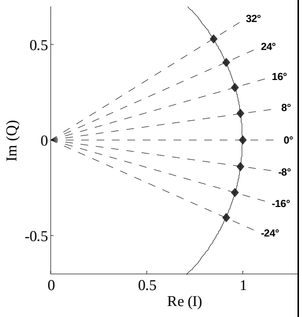
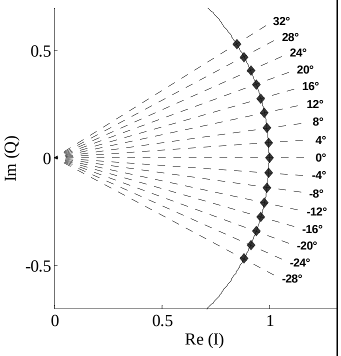
Parameter	Min	Max
PN_{RMS}	0	0.030

The PICC shall be able to receive an amount of noise as specified in Table 17.

Table 17 — PICC reception: Phase noise parameters for all PSK rates

Parameter	Min	Max
PN_{RMS}	0	0.032

Table 18 — PSK mode symbols

Modulation	2PSK	4PSK	8PSK	16PSK
Symbols in the IQ plane				

NOTE on the 8PSK modulation. The IQ segment for this data rate is 56 °

11.3 Bit representing and coding

For very high bit rates of and above fc/16 the complete information chain is as shown in .Figure 22

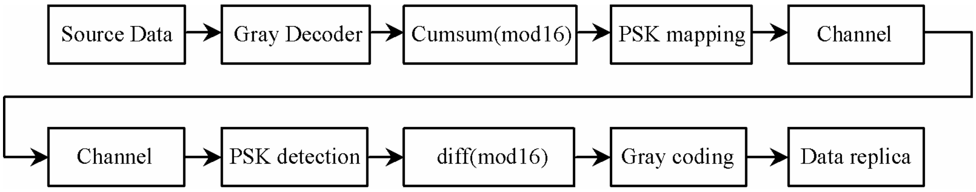


Figure 22 — Complete information chain for VHBR

Data is transmitted in symbols. Every bit rate is related to an individual symbol alphabet.

For 2PSK binary information is encoded in 2 symbols allowing an information content of 1 bit per symbol.

For 4PSK binary information is encoded in 4 symbols allowing an information content of 2 bits per symbol.

For 8PSK binary information is encoded in 8 symbols allowing an information content of 3 bits per symbol.

For 16PSK binary information is encoded in 16 symbols allowing an information content of 4 bits per symbol.

The following subclauses define the complete information chain for every bit rate.

11.3.1 Bit representation and Coding for 2PSK

Step 1, the source data to Gray decoding process is described in Table 19.

Table 19 — Source data to Gray decoding.

Source data	Gray decoder output
0	0
1	1

Step 2, the cumsum operation (differential encoding) is described according to: out(n) = (out(n-1) + in(n))mod2

Step 3, mapping to 2PSK is described in Table 20.

Table 20 — Phase states for the symbols, represented by binary information content.

Cumsum out	Phase state
0	$\phi_0 + 60\ °$
1	ϕ_0

NOTE These phase states are transmitted by the PCD over the channel, and received by the PICC.

Step 4, PSK detection by the PICC and mapping to binary information is done according to Table 20.

Step 5, the diff operation is defined as out(n) = (in(n) – in(n-1)) mod2

Step 6, a replica of the source data is restored by Gray coding according to table 21.

Table 21 — Data replica by Gray coding.

Diff out	Data replica
0	0
1	1

11.3.2 Bit representation and Coding for 4PSK

Step 1, the source data to Gray decoding process is described in table 22.

Table 22 — source data to Gray decoding.

Source data	Gray decoder out
00	00
01	01
10	11
11	10

Step 2, the cumsum operation is described according to:

out(n) = (out(n-1) + in(n))mod4

Step 3, mapping to 4PSK is described in table 23.

Table 23 — Phase states for the symbols, represented by binary information content.

.Cumsum out	Phase state
00	ϕ_0 + 40 °
01	ϕ_0 + 20 °
11	ϕ_0
10	ϕ_0 - 20 °

These phase states are transmitted by the PCD over the channel, and received by the PICC.

Step 4, PSK detection by the PICC and mapping to binary information is done according to table 23.

Step 5, the diff operation is defined as out(n) = (in(n) – in(n-1)) mod4

Step 6, a replica of the source data is restored by Gray coding according to table 24.

Table 24 — Data replica by Gray coding.

Diff out	Data replica
00	00
01	01
10	11
11	10

11.3.3 Bit representation and Coding for 8PSK

Step 1, the source data to Gray decoding process is described in table 25.

Table 25 — Source data to Gray decoding.

Source data	Gray decoder out
000	000
001	001
010	011
011	010
100	111
101	110
110	100
111	101

Step 2, the cumsum operation is described according to: out(n) = (out(n-1) + in(n))mod8

Step 3, mapping to 8PSK is described in table 26.

Table 26 — Phase states for the symbols, represented by binary information content.

Cumsum out	Phase state
000	ϕ_0 + 32 °
001	ϕ_0 + 24°
010	ϕ_0 + 16 °
011	ϕ_0 + 8 °
100	ϕ_0
101	ϕ_0 - 8 °
110	ϕ_0 - 16 °
111	ϕ_0 - 24 °

NOTE These phase states are transmitted by the PCD over the channel, and received by the PICC.

Step 4, PSK detection by the PICC and mapping to binary information is done according to table 26.

Step 5, the diff operation is defined as out(n) = (in(n) – in(n-1)) mod8

Step 6, a replica of the source data is restored by Gray coding according to table 27.

Table 27 — Source data to Gray decoding.

Diff out	Data replica
000	000
001	001
010	011
011	010
100	110
101	111
110	101
111	100

11.3.4 Bit representation and Coding for 16PSK

Step 1, the source data to Gray decoding process is described in table 28.

Table 28 — Source data to Gray decoding.

Source data	Gray decoder out
0000	0000
0001	0001
0010	0011
0011	0010
0100	0111
0101	0110
0110	0100
0111	0101
1000	1111
1001	1110
1010	1100
1011	1101
1100	1000
1101	1001
1110	1011
1111	1010

Step 2, the cumsum operation is described according to: out(n) = (out(n-1) + in(n))mod16

Step 3, mapping to 16PSK is described in table 29.

Table 29 — Phase states for the symbols, represented by binary information content.

Cumsum out	Phase state
0000	$\phi_0 + 32\,°$
0001	$\phi_0 + 28\,°$
0010	$\phi_0 + 24\,°$
0011	$\phi_0 + 20\,°$
0100	$\phi_0 + 16°$
0101	$\phi_0 + 12\,°$
0110	$\phi_0 + 8\,°$
0111	$\phi_0 + 4\,°$
1000	ϕ_0
1001	$\phi_0 - 4\,°$
1010	$\phi_0 - 8\,°$
1011	$\phi_0 - 12\,°$
1100	$\phi_0 - 16\,°$
1101	$\phi_0 - 20\,°$
1110	$\phi_0 - 24\,°$
1111	$\phi_0 - 28\,°$

NOTE These phase states are transmitted by the PCD over the channel, and received by the PICC.

Step 4, PSK detection by the PICC and mapping to binary information is done according to table 29.

Step 5, the diff operation is defined as out(n) = (in(n) – in(n-1)) mod16

Step 6, a replica of the source data is restored by Gray coding according to table 30.

Table 30 — Data replica by Gray coding.

Diff out	Data replica
0000	0000
0001	0001
0010	0011
0011	0010
0100	0110
0101	0111
0110	0101
0111	0100
1000	1100
1001	1101
1010	1111
1011	1110
1100	1010
1101	1011
1110	1001
1111	1000

11.3.5 SOF

For very high bit rates, the standard frame contains a start of frame (SOF) field and an end of frame (EOF) field. The frame size of the SOF depends on the PSK order. For 2PSK the SOF consists of 48 etu, for 4PSK, 8PSK and 16PSK the SOF consists of 76 etu.

The SOF consists of

- calibration sequence CAL (44 etu),
- synchronization sequence SYNC (4 etu),
- and only for PSK orders > 2 a training sequence TSC.

CAL	SYNC	TSC
44 etu	4 etu	92 etu

The constitution of the calibration sequence and the synchronization sequence is generic; the same principle is applied to all VHBR PSK modes.

The calibration sequence consists of 2 symbols of the IQ segment, depending on the PSK order. A portion of 2 equal symbols is alternating with a portion of 2 other equal symbols. This sequence is transmitted 8 times, resulting in 32 etu in total.

For 2PSK the sequence starts with 2 symbols of 60° followed by 2 symbols of 0°.

For 4PSK the sequence starts with 2 symbols of 20° followed by 2 symbols of – 20°.

For 8PSK the sequence starts with 2 symbols of 24° followed by 2 symbols of – 24°.

For 16PSK the sequence starts with 2 symbols of 28° followed by 2 symbols of – 28°.

The synchronization sequence consists of the same 2 symbols as the calibration sequence. The sequence starts with the symbol of positive phase. One symbol alternating with the other symbol is transmitted 2 times. This results in 4 etu in total.

The training sequence is specific for every PSK order.

For the 1st frame transmitted for PSK orders > 2, the training sequence consists of 92 etu, for all following frames the training sequence consists of 28 etu. The concept is a pseudo-random sequence; a definition for every data rate is given in Tables 31 to 34.

Table 31 — Phase states of the training sequence for the 1st frame of 4PSK.

etu No	Phase state	etu No	Phase state	etu No	Phase state	Etu No	Phase state
1	40 °	24	20 °	47	-20 °	70	20 °
2	40 °	25	20°	48	40 °	71	0 °
3	-20 °	26	-20 °	49	-20 °	72	40 °
4	20 °	27	40 °	50	40 °	73	-20 °
5	-20 °	28	40 °	51	0 °	74	40 °
6	20 °	29	0 °	52	40 °	75	-20 °
7	-20 °	30	0 °	53	0 °	76	40 °
8	0 °	31	20 °	54	20 °	77	-20 °
9	40 °	32	0 °	55	-20 °	78	20 °
10	0 °	33	-20 °	56	20 °	79	40 °
11	0 °	34	20 °	57	20°	80	20 °
12	0 °	35	40 °	58	-20 °	81	0 °
13	20 °	36	40 °	59	-20 °	82	20 °
14	0 °	37	-20 °	60	-20 °	83	20°
15	0 °	38	20 °	61	0 °	84	-20 °
16	40 °	39	-20 °	62	20 °	85	40 °
17	20 °	40	40 °	63	-20 °	86	-20 °
18	40 °	41	20 °	64	0 °	87	20 °
19	20 °	42	-20 °	65	20 °	88	-20 °
20	0 °	43	40 °	66	0 °	89	-20 °
21	20 °	44	-20 °	67	-20 °	90	-20 °
22	0 °	45	0°	68	20 °	91	40 °
23	40 °	46	0 °	69	20 °	92	20 °

Table 32 — Phase states of the training sequence for the 1st frame of 8PSK.

etu No	Phase state	etu No	Phase state	etu No	Phase state	Etu No	Phase state
1	32 °	24	32 °	47	-24 °	70	24 °
2	32 °	25	-24 °	48	32 °	71	16 °
3	-24 °	26	16 °	49	-8 °	72	-16 °
4	8 °	27	8 °	50	-24 °	73	-24 °
5	-16 °	28	8 °	51	8 °	74	32 °
6	24 °	29	-24 °	52	-24 °	75	-24 °
7	-8 °	30	-16 °	53	8 °	76	32 °
8	8 °	31	0 °	54	32 °	77	-24 °
9	-16 °	32	-8 °	55	8 °	78	8 °
10	16 °	33	-16 °	56	-16 °	79	24 °
11	16 °	34	24 °	57	-16 °	80	16 °
12	16 °	35	-16 °	58	24 °	81	0 °
13	-24 °	36	-8 °	59	24 °	82	16 °
14	24 °	37	16 °	60	32 °	83	24 °
15	32 °	38	-16 °	61	-16 °	84	-8 °
16	8 °	39	24 °	62	0 °	85	-24 °
17	-8 °	40	8 °	63	32 °	86	0 °
18	16 °	41	0 °	64	-16 °	87	32 °
19	8 °	42	32 °	65	8 °	88	8 °
20	-8 °	43	16 °	66	-8 °	89	8 °
21	16 °	44	32 °	67	-16 °	90	16 °
22	8 °	45	-16 °	68	24 °	91	8 °
23	-16 °	46	-16 °	69	24 °	92	0 °

Table 33 — Phase states of the training sequence for the 1st frame of 16PSK.

etu No	Phase state	etu No	Phase state	etu No	Phase state	Etu No	Phase state
1	32 °	24	4 °	47	-4 °	70	-24 °
2	32 °	25	16 °	48	-12 °	71	-28 °
3	-28 °	26	-8 °	49	16 °	72	8 °
4	8 °	27	-16 °	50	4 °	73	-28 °
5	-12 °	28	-16 °	51	-28 °	74	32 °
6	32 °	29	16 °	52	8 °	75	-28 °
7	0 °	30	28 °	53	-20 °	76	32 °
8	16 °	31	-20 °	54	4 °	77	-28 °
9	-8 °	32	-28 °	55	-16 °	78	4 °
10	28 °	33	32 °	56	28 °	79	24 °
11	32 °	34	8 °	57	32 °	80	16 °
12	-28 °	35	-28 °	58	8 °	81	0 °
13	-4 °	36	-16 °	59	12 °	82	20 °
14	-20 °	37	12 °	60	20 °	83	32 °
15	-12 °	38	-16 °	61	-24 °	84	4 °
16	28 °	39	28 °	62	-4°	85	-12 °
17	16 °	40	16 °	63	32 °	86	12 °
18	-20 °	41	8 °	64	-16 °	87	-20 °
19	-24 °	42	-20 °	65	8 °	88	24 °
20	24 °	43	32 °	66	-8 °	89	28 °
21	-12 °	44	-12 °	67	-12 °	90	-24 °
22	-20 °	45	4 °	68	32 °	91	-28 °
23	20 °	46	4 °	69	-28 °	92	32 °

Table 34 — Phase states of the training sequences for all following frames for VHBR PSK modes 4PSK, 8PSK and 16PSK

etu No	4PSK	8PSK	16PSK
1	20 °	8 °	8 °
2	-20 °	-16 °	-12 °
3	20 °	24 °	32 °
4	-20 °	-24 °	-28 °
5	40 °	32 °	32 °
6	-20 °	-24 °	-28 °
7	40 °	32 °	32 °
8	-20 °	-24 °	-28 °
9	40 °	32 °	32 °
10	-20 °	-24 °	-28 °
11	40 °	32 °	32 °
12	-20 °	-24 °	-28 °
13	20 °	16 °	12 °
14	0 °	0 °	0 °
15	20 °	24 °	28 °
16	0 °	16 °	24 °
17	-20 °	0 °	8 °
18	0 °	24 °	-28 °
19	-20 °	16 °	28 °
20	20 °	-8 °	4 °
21	0 °	-24 °	-12 °
22	0 °	-16 °	0 °
23	40 °	24 °	-24 °
24	20 °	16 °	32 °
25	20 °	16 °	32 °
26	-20 °	-16 °	-0 °
27	-20 °	-8 °	12 °
28	0 °	8 °	28 °

The EOF consists of 8 etu containing phase states outside of the IQ segment for the data rate. These phase states are ϕ_0 - 180 ° in the IQ plane.

Annex A
(INFORMATIVE)

Complex envelope and constellation diagram

In carrier-based transmission systems, it is convenient to represent the information-carrying component of the symbol $x(t)$ by the so-called complex envelope v:

$$x(\mathrm{t}) = \mathrm{v}(t)\cdot\exp(j\cdot 2\cdot\pi\cdot f_c\cdot t) + \mathrm{v}^*(t)\cdot \exp(-j\cdot 2\cdot\pi\cdot f_c\cdot t)$$

with $v(t)$ the complex envelope and $v^*(t)$ the complex conjugate of v. Furthermore, j is the imaginary unit and f_c the carrier frequency. For a purely ASK modulated signal, the argument (angle) of v would be constant over time and the information is coded in the magnitude of v. For a purely PSK modulated signal, the magnitude of v would be constant over time and the information is coded in the argument of v. Note that passing the signal $x(t)$ through a band-limited channel would affect the complex envelope of v. In some cases, a purely amplitude modulated signal might exhibit a varying phase component after the channel. Similarly, a purely phase-modulated signal generally exhibits some amplitude variations after passing though a band limited channel.

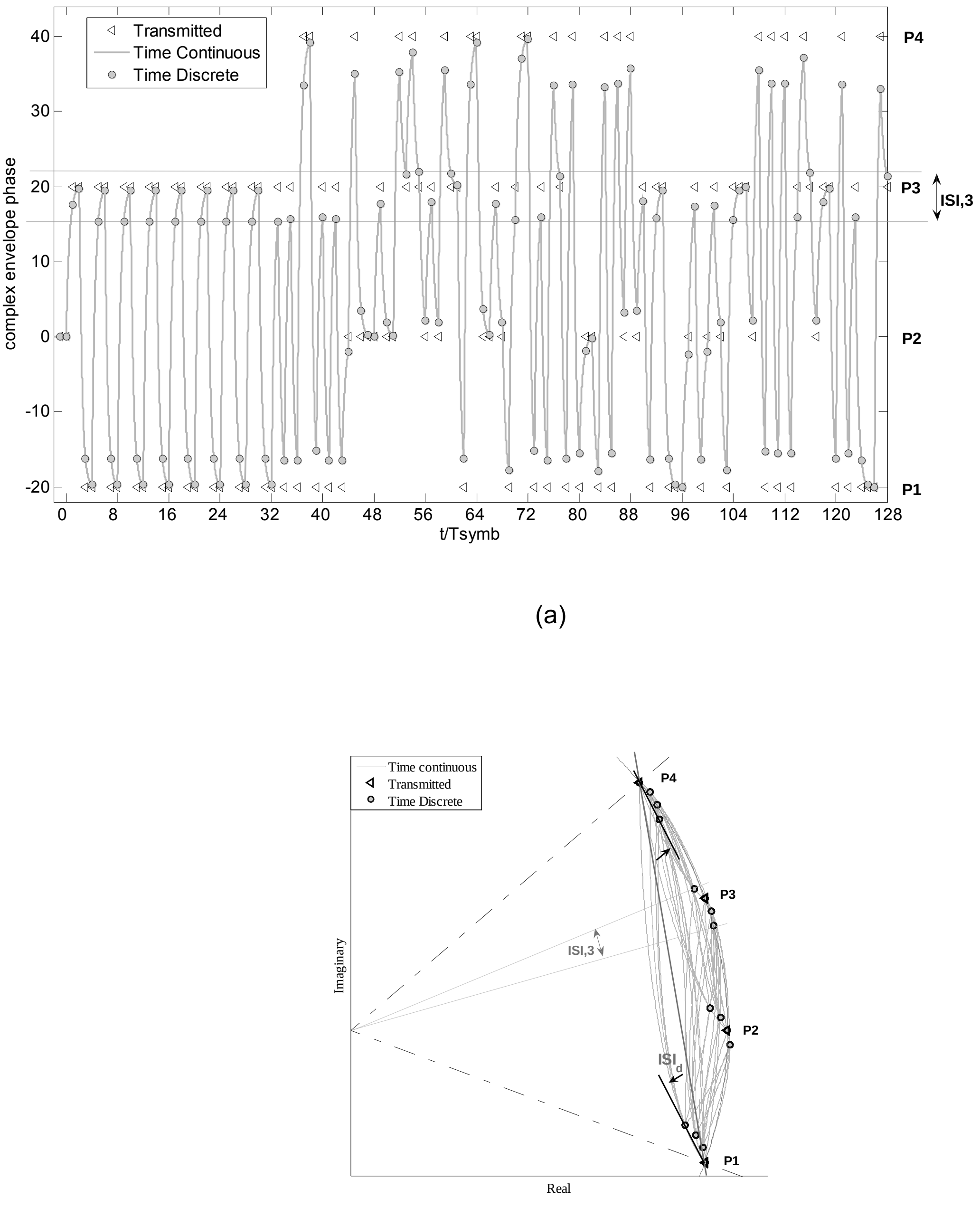
The complex envelope signal v is often conveniently plotted in the complex plane at the symbol sampling instants only, in what is called a constellation diagram. So, the complex values of $v(\mathrm{k}\cdot T_{\mathrm{symb}})$ are plotted (imaginary component versus real component), where k is a set of integer numbers and T_{symb} is the symbol time. All samples are plotted in the same diagram, without explicit time information. An example of such a diagram is found in Annex B.

Annex B

Inter-Symbol Interference

The bandpass characteristic of the PCD antenna resonator (inductive loop plus tuned matching network) affects the complex envelope of the transmitted signal and, thus, gives rise to inter-symbol interference (ISI). The effect of such ISI can be seen when observing the constellation diagram of the transmitted signal: the ISI spreads every constellation point into an *ISI cloud*, which has the same shape as the original constellation, a *size* depending on the channel bandwidth, and a *rotation* depending on the PCD tuning. These effects are depicted in **Error! Reference source not found.**.

By watching the Baud rate samples in **Error! Reference source not found.**a, one can identify intervals of ISI around the nominal (transmitted) phase values. Such intervals are a simplified view of the actual interference patterns which are visible two-dimensionally in **Error! Reference source not found.**b (the constellation diagram). The rotation of these clouds is caused by detuning of the PCD. In such detuned case, the line joining the extremes of these clouds form an angle ISId with respect to the line joining P1 and P4 (which correspond to the original transmitted constellation points before channel filtering).



(a)

(b)

Figure 23 — ***Example of inter-symbol interference due to a band-limited channel. (a) phase as a function of time. (b) the corresponding constellation diagram showing both amplitude and phase of the modulated carrier, in continuous time and at the symbol sample times.***