ISO/IEC JTC 1/SC 17
Cards and personal identification
Secretariat: BSI (United Kingdom)

Document type:	Text for PDTR ballot or comment
Title:	Notification of Ballot: ISO/IEC PDTR - Identification cards - Contactless integrated circuit cards - Proximity cards - Multiple PICCs in a single PCD field.
Status:	This ballot has been posted to the ISO Electronic balloting application and is available under the Balloting Portal, Committee Internal Balloting.
Date of document:	2012-04-13
Expected action:	VOTE
Action due date:	2012-07-14
No. of pages:	15
Email of secretary:	chris.starr@ukpayments.org.uk
Committee URL:	http://isotc.iso.org/livelink/livelink/open/jtc1sc17

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ISO/IEC JTC 1/SC 17 N XXX

Date: 2011-09-30

ISO/IEC PDTR TBD

ISO/IEC JTC 1/SC 17/WG 8

Secretariat: DIN

Identification cards — Contactless integrated circuit cards — Proximity cards — Multiple PICCs in a single PCD field

Cartes d'identification — Cartes à circuit intégré sans contact — Cartes de proximité — Multiples PICC dans le champ d'un PCD

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Document type: Technical Report
Document subtype:
Document stage: (30) Committee
Document language: E

C:\Documents and Settings\PR452\Local Settings\Temporary Internet Files\OLK20A\wg8n1863_PDTR_xxxxx_TR_Multiple_PICCs_V3.doc STD Version 2.1c2

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ISO/IEC TR TBD, which is a Technical Report of type 3, was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 17, *Cards and personal identification*.

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Introduction

Experience from the field has shown that the presence of multiple PICCs in a field can have unexpected results in terms of all PICCs being seen by the PCD and the quality of the communications. This report seeks to assemble the collective knowledge of the engineering principles involved.

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Identification cards — Contactless integrated circuit cards — Proximity cards — Multiple PICCs in a single PCD field

1 Informative text

In order that multiple PICCs can be reliably presented to a reader, the following should generally be achieved:

a) PICCs presented (within the reader's operating field) need to receive sufficient power to operate

b) The communications interface between each PICC and the PCD needs to operate reliably (for all PICCs within the PCD operating field)

c) The PCD should perform its intended functionality in a manner such that the cardholder experience is reliable and consistent.

In an operational contactless interface, there are a number of components that have a mutual interaction. The most dominant of these is the inductive coupling between the coil of the PCD antenna and that of the PICC, plus further interaction between all the PICC antennas if there are multiple PICCs within the field. The interaction is multi-faceted and depends on the coupling factor k between each inductance, the resonant frequency f of the individual PICCs and the quality factor Q of all of the inductive components. Other factors which also have an impact are the size of antenna, separation distance, spatial overlap, PICC loading and the dynamic movement of PICCs through the PCD field.

With so many degrees of freedom, it is not possible to describe the definitive outcome for any particular combination of PICCs presented to an individual reader. However, it is possible to quantify certain aspects with the objective of gaining an improved understanding of the mechanisms involved. This is expected to lead to recommendations and/or requirements that will ultimately improve the acceptance of multiple cards presented to a single reader. The main items that can be addressed are:

— The PICC interaction such that the resulting resonant frequency of the set of PICCs is lower compared to the resonant frequency of an individual PICC.

— The uneven sharing of power between the PICCs in the field, such that some may receive insufficient power to operate correctly.

— The influence on PCD modulation caused by close coupled PICCs, such that collectively, multiple PICCs in the field will receive a modified modulation signal shape.

In order that contactless products continue to have practical application, the reliability and consistency of the user experience needs to be addressed in the following areas:

— The PCD should be able to reliably build a list of applications available on the presented PICCs and determine in a consistent manner an order for which it will attempt to undertake its intended function.

— This process should be easy to understand by the general public and consistent across PCDs such that the user feels in control.

— The user interface on the PCD should provide simple feedback to the user, such that they understand when the intended function is completed, or if an issue has occurred.

— Overall performance (speed of operation) shall not be reduced significantly when multiple cards are presented such that the usability of the functionality is compromised.

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2 Physical effects of multiple PICCs

2.1 Resonant frequency

When operating within an electro-magnetic field of given frequency, then maximum power coupling would occur if PICCs are tuned to have a resonant frequency equal to the operating frequency of the field. However, typical PICCs are manufactured to have a resonant frequency higher than the operating frequency (13,56 MHz) to limit the loading effect on PCDs.

When the antenna of a PICC is close to another antenna there will be mutual inductive and capacitive coupling that results in a drop in its resonant frequency. Both the antenna in the PCD and the antennas of other PICCs in the field will cause this effect. Generally the coupling to a physically adjacent PICC (or PICCs) will be more than that to the PCD antenna.

Figure 1 and Figure 2 show this effect as evaluated experimentally for ISO/IEC 14443 operation using multiple PICCs all having an individual resonance frequency of about 20 MHz.

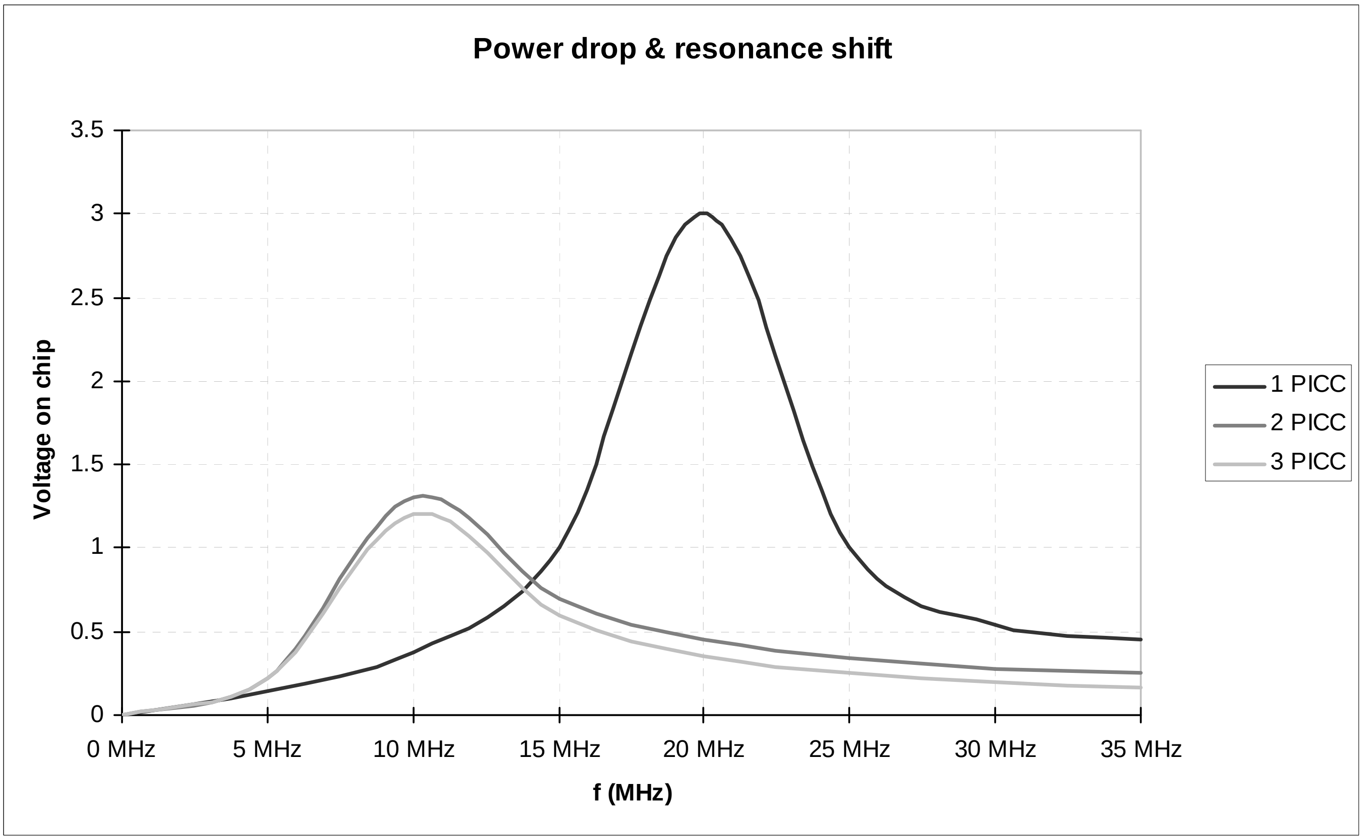

Figure 1 — Power drop and resonant shift

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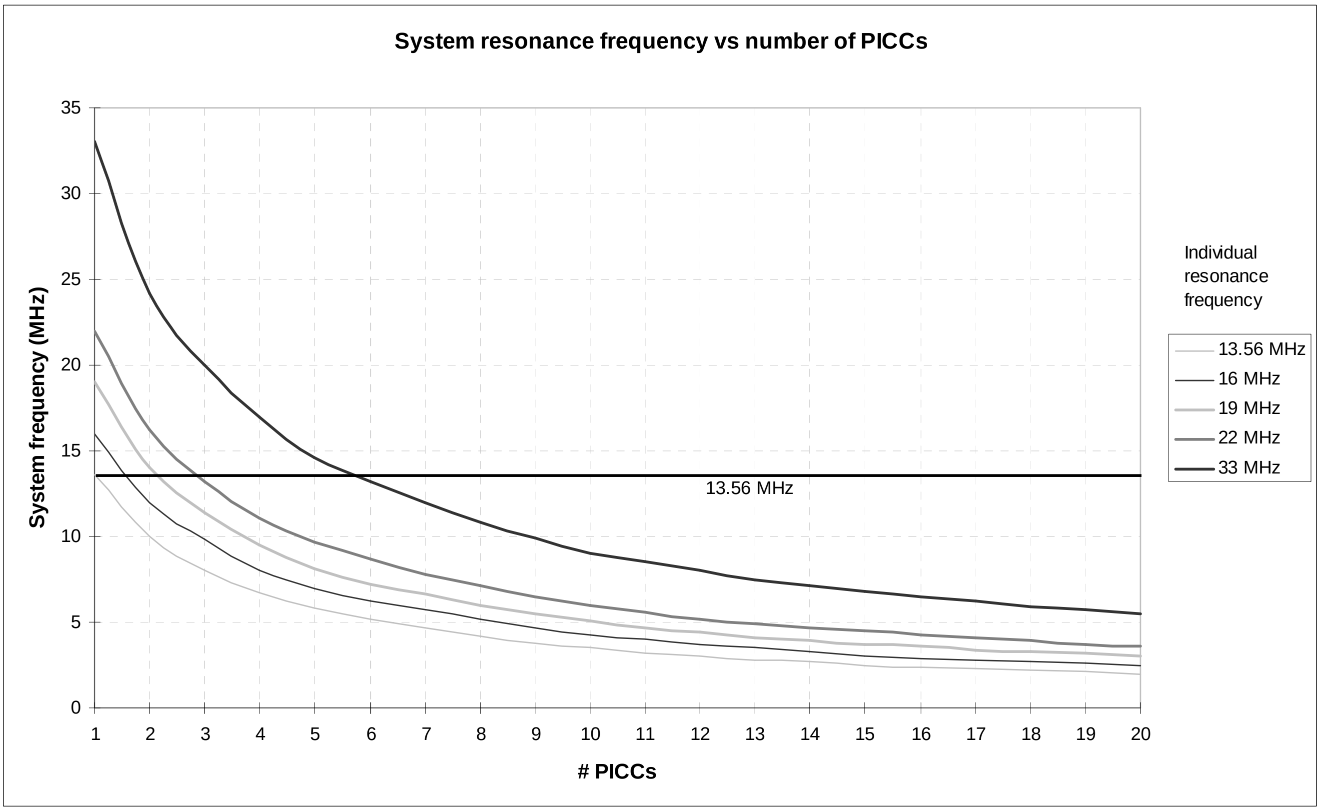

Figure 2 — Collective resonant frequency vs number of PICCs

Figure 1 and Figure 2 curves are from a simulation based on the ISO10373-6 Test PCD Assembly with a distance between PICCs: Δx = 1 mm and using the test PCD antenna and PICCs with Class 1 antenna size as shown in Figure 3.

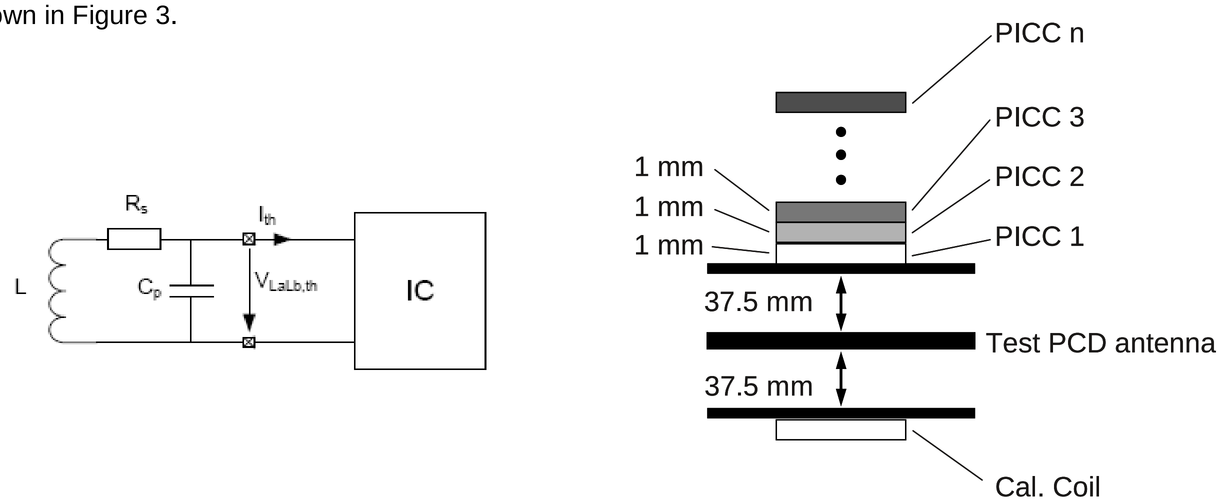

Figure 3 — Simulation set-up

Virtual simulation of the coupling indicates that the capacitance between two resonant circuits has a strong influence on the measurable effects of the two circuits being coupled. With coupling between only the inductances, then the frequency response shows that the uncoupled resonant frequency separates into two new peaks spaced equally higher and lower than the uncoupled frequency. The result of including the capacitance that will exist between the circuits in a real system, is that the higher frequency peak is suppressed, resulting in the appearance of the system resonant frequency being lowered. Figure 4 shows this effect.

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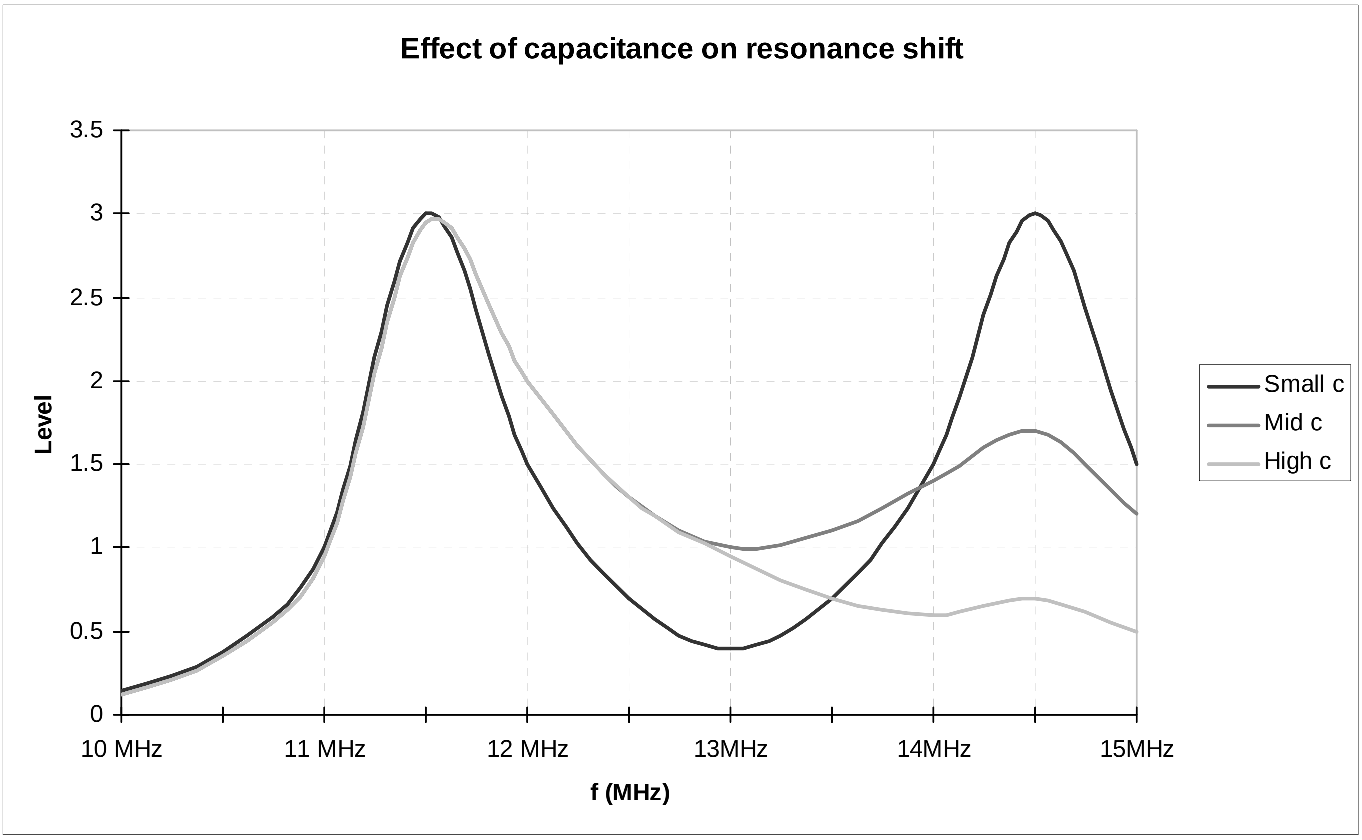

Figure 4 — Effect of capacitance on resonance shift

Observations that can be drawn include:

— Higher field strength may be required to enable multiple PICCs to operate correctly.

— The collective resonant frequency shifts downwards as the number of PICCs increases.

— The collective Q factor decrease as the number of PICCs increases.

— Influence of additional PICCs decreases with increasing distance between them.

It may be noted that PICC resonant frequency is not specified in the current standard, although it is a significant system parameter for multiple PICC systems.

2.2 Minimum operating field strength H_{min}

PCDs provide sufficient power into the operating volume (100s mW) that it is not a limiting factor in how many PICCs can be powered (5 – 10 mW each).

If in close proximity to each other, multiple PICCs will be tightly coupled, have a low collective Q factor and therefore will receive less power for a given local field strength. Consequently, the field strength at the location of the PICCs will need to be higher than for a single PICC if they are all to operate correctly. In some circumstances the shift of resonance frequency as described in 2.1 may compensate to some extent for the change of Q factor.

The effects of increasing the number of PICCs (with individual resonance frequencies higher than 13,56 MHz) compared to the minimum field strength required to operate them can be generalised into a model with three regions as shown in Figure 5.

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— Region I: the collective resonance frequency decreases with an increasing number of PICCs until it reaches 13,56 MHz (lowest H_{min}) after which the collective resonance frequency continues to decrease and H_{min} required to operate all PICCs starts to increase.

— Region II: H_{min} increases approximately linearly with increasing number of PICCs.

— Region III: The influence of additional PICCs decreases due to the physical dimensions of the PICC stack and the necessary increase in H_{min} starts to decline. From a practical perspective, Region III is unlikely to be reached.

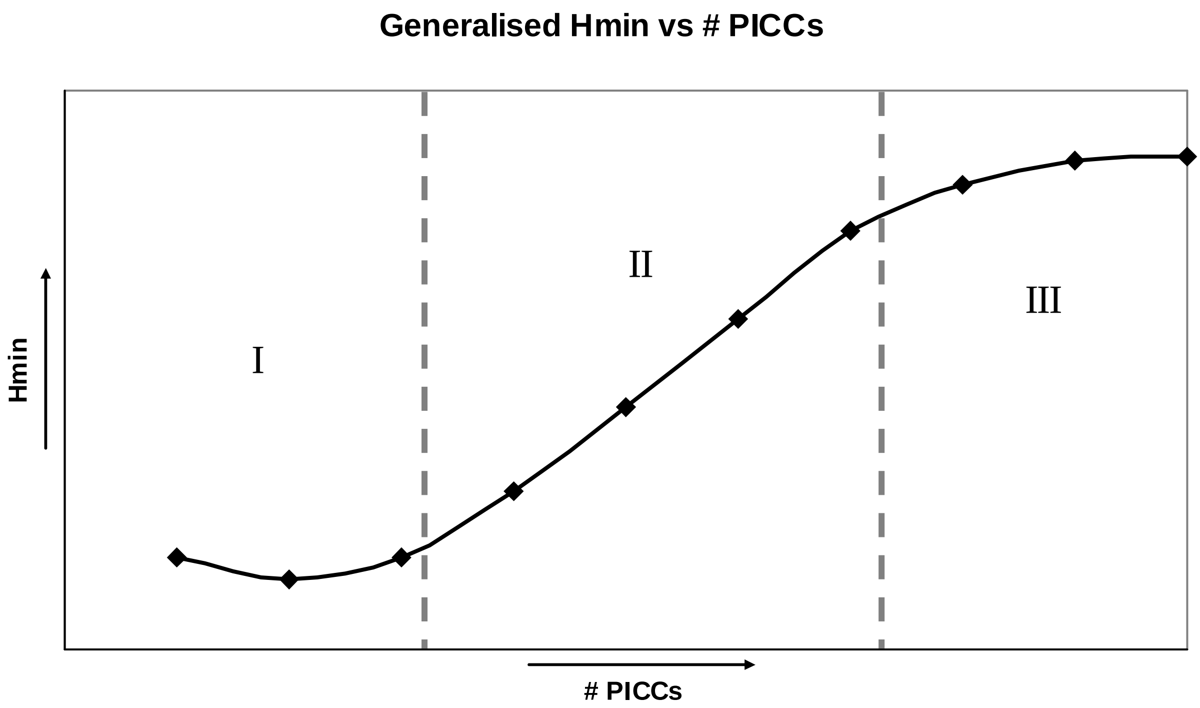

Figure 5 — Generalised Characteristics for Hmin vs #PICCs

Practical experience indicates that H_{min} (1,5 A/m) is sufficient to operate several PICCs only if they are of low power consumption.

2.3 Loading effect

Loading effect is defined as the change in PCD antenna current caused by the presence of the PICC(s) in the field. In the interests of maximum operating volume, most PCDs are designed with an antenna resonance frequency close to 13,56 MHz when no PICC is present. As PICCs are introduced, the effects of mutual coupling change the PCD antenna resonance frequency and Q factor and consequently the current in the antenna. The PCD antenna current will decrease (lower field strength) for both its resonance frequency moving away from the optimum of 13,56 MHz and its antenna Q factor decreasing. Consequently for PICCs of the same nature and location:

— The presence of a PICC will result in a reduction in PCD antenna current depending on the PICC resonance frequency, the PCD antenna current reduction being the greatest for a PICC tuned to 13,56 MHz.

— The presence of multiple PICCs will also result in a decrease in PCD antenna current, but smaller than for a single PICC tuned to the same collective resonance frequency because the PICC collective Q factor will be lower than the Q factor of a single PICC.

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2.4 PCD to PICC communication

The presence of multiple PICCs can distort the PCD signals they receive. In particular the close coupled shunt and demodulator activity of multiple PICCs can be such that collectively, individual PICCs in the field may receive a modified PCD waveform (e.g. modulation level, rise/fall time, ringing, etc).

Figure 6 shows an example of waveform distortion. The upper waveform represents a Type A pause as transmitted by the PCD. The lower waveform shows its appearance in the field local to the PICC. The modulation index is reduced with higher residual carrier and the fall time has increased.

Observations that can be drawn include:

— PICCs should minimise their impact on the local field waveform,

— PICC reception capabilities should be robust in terms of waveform shape,

— PCDs should transmit nominal waveforms that are not significantly impacted by loading effects.

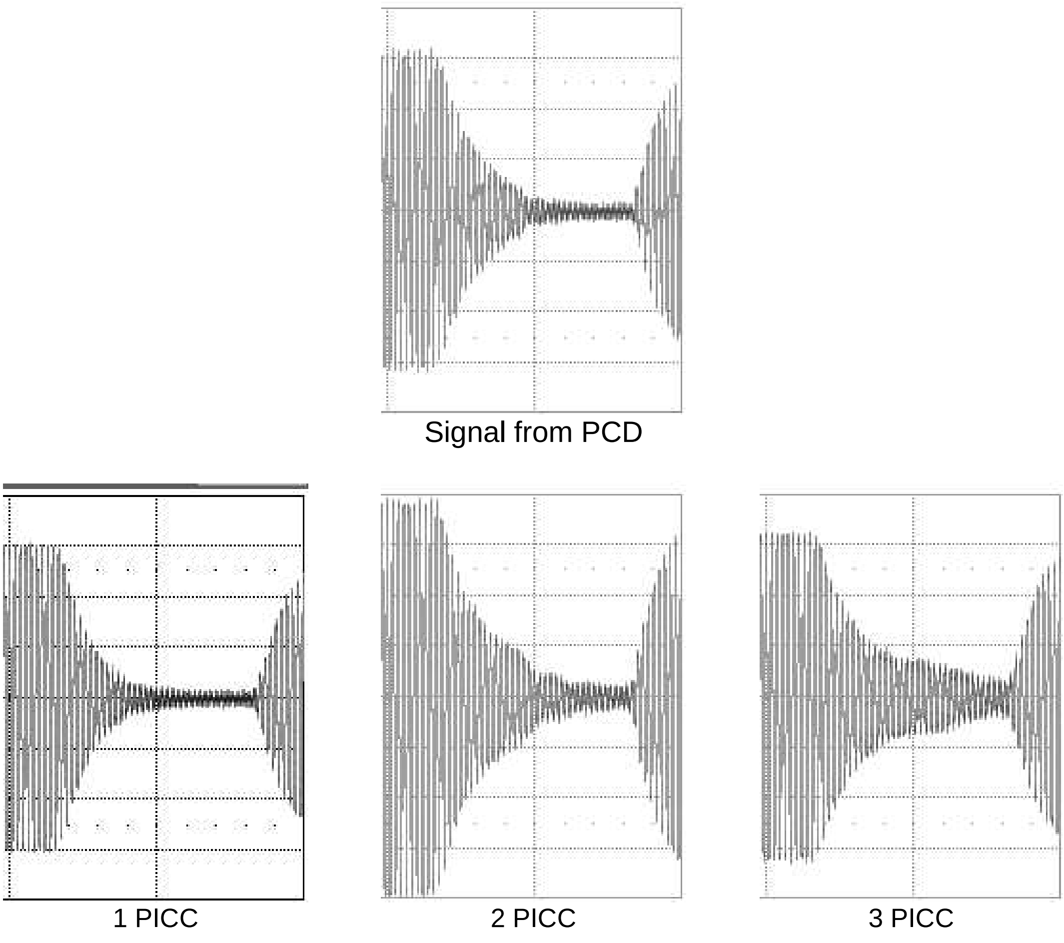

Figure 6 — PCD signal distortion

2.5 PICC to PCD communication

Whilst in theory it may be possible for the PICC signaling to be adversely impacted by the presence of multiple PICCs, experience has shown no significant problems with PCD reception with up to 12 PICCs in the field.

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3 Addressing multiple PICCs

3.1 CID support

If multiple PICCs need to be simultaneously in the PROTOCOL state (see ISO/IEC 14443-4, Annex A) then a CID should be attributed to each one. Logically, up to 15 PICCs could be simultaneously in the protocol state (CID from 0 to 14).

NOTE It is not advised to use the same CID values for PICCs Type A and for PICCs Type B to get up to 30 PICCs simultaneously in the protocol state.

PICCs not supporting CID are addressed with frames containing no CID. Once such a PICC is in PROTOCOL state, the CID value 0 shall not be used for any other PICC because this second PICC would then accept the commands sent to the first PICC. No other PICC not supporting CID may be simultaneously in the PROTOCOL state.

Consequently, once a PICC not supporting CID is in PROTOCOL state:

— other PICCs Type B can be activated, provided they support CID,

— no other PICC Type A may be activated (because the activation is done before knowing if the PICC supports CID).

It is therefore recommended that:

— all PICCs support CID,

— the CID=0 is not attributed to a PICC supporting CID, to keep it for a PICC not supporting CID.

3.2 Altering random UID or PUPI

PICCs using random UID/PUPI generate new random UID/PUPI only on state transition from POWER OFF to IDLE (see ISO/IEC 14443-3, 6.5.4 and 7.9.2). However, PICCs compliant with first edition of ISO/IEC 14443 may also change their random UID/PUPI when leaving the HALT state and/or in the IDLE state.

If the PCD put some PICCs in HALT state and then reactivate these PICCs then the PCD needs to be aware of the possible alteration of their UID/PUPI.

It is therefore recommended that all PICCs comply with latest edition of ISO/IEC 14443.

3.3 Receiving blocks of other type

PICCs of one type shall either go to IDLE state or be able to continue a transaction in progress after receiving any command of the other type (see ISO/IEC 14443-3, 5.2 and 5.3). However, PICCs compliant with the first edition of ISO/IEC 14443 may behave differently.

If the PCD alternates commands of Type A and commands of Type B then it needs to be aware of these possible different PICC behaviours.

It is therefore recommended that all PICCs comply with latest edition of ISO/IEC 14443 and preferably be able to continue a transaction in progress.

3.4 AFI management

The AFI mechanism was designed to allow the PCD to get answers only from PICCs of Type B with applications of the type indicated by the AFI in the REQB/WUPB command (see ISO/IEC 14443-3, 7.7.3).

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PICCs of Type B shall go to IDLE state:

— after receiving a WUPB command with unmatched AFI when in the HALT state,

— after receiving a REQB/WUPB command with unmatched AFI when in the READY-REQUESTED or READY-DECLARED state.

However, PICCs compliant with first edition of ISO/IEC 14443 may behave differently.

If the PCD uses AFI not equal to '00' then it needs to be aware of these possible different PICC behaviours.

It is therefore recommended that all PICCs comply with latest edition of ISO/IEC 14443.

4 Scenarios

4.1 Passport – multiple visas

Electronic passports carry the primary passport application in an ISO/IEC 14443 compliant module, usually carried on the back of the page with readable text and photograph. If visas are applied for and are electronic, then they will normally be affixed to other pages of the passport with the antenna and chip embodied in a sticker that carries the visible visa details. Typically enough room is left for immigration officers to apply entry and exit stamps to the page without striking the chip, but stamps may possibly be partially across the antenna.

If one or more visas are present and the passport is read as a complete booklet, then a “multiple PICCs in the field” situation arises. It is generally expected that physically the passport and visa modules will all be to a common form factor, have similar power requirements and use communication protocols of the same type. However, with a multi-leaf booklet it is possible to present only the primary passport page, or the individual page carrying a visa, to the reader antenna. Whether the presented item is the only PICC “seen” by the reader, or whether the other item(s) to the side, or orthogonal to the field are also “seen” or whether they may have an effect the field without being detected is at present unknown. An understanding of the interactions may allow recommendations on the design and use of passport readers and layout of visa pages to improve the contactless readability of electronic passports and readers.

4.2 Wallet – multi-industry

In the consumer sector it can be envisaged that several contactless cards may be carried in a single wallet or purse. They may be from the same industry sector (e.g. payments), or from multiple sectors (e.g. payment, transport and access control). If such a wallet is presented to a contactless reader, then a “multiple PICCs in the field” situation arises. Unlike passports, it should be expected that antenna sizes and construction will differ, that power requirements will vary considerably and that there may be a mixture of both Type A and Type B PICCs. Also, whilst some wallets and purses may have card slots that hold PICCs in a controlled spatial arrangement, consumers are unlikely to use such features consistently.

Clearly if two or more PICCs are presented to a reader that would be able to transact with more than one, then some kind of resolution is required and it is difficult to see how it could be resolved to the consumers satisfaction unless they are given a choice. Examples are a credit and a debit card for payment, two transport cards at a ticket gate, or one of each at a gate that accepts both tickets and payment cards. In the half second or so available for a contactless transaction, it will not be possible to display information and have the consumer make a choice, therefore such a wallet would need to be declined and the consumer requested to re-present with only the PICC of their choice. This needs a reliable collision detection mechanism across PICCs of different dimensions, power consumption and protocol types. Note that a priority system could help, but is unlikely to be practical across multiple cards from competing industry players.

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4.3 Possible scenarios

The following scenarios have been considered and the following conclusions drawn.

WARNING — Because of the many physical effects of multiple PICCs, a PCD can never be sure to detect all the PICCs which are simultaneously in its operating volume. The PCD can also not be sure that communication with any given card will be reliable.

4.3.1 Process the first PICC detected

This process allows a fast transaction with the first PICC detected when this PICC is relevant to the PCD application.

However, if the first PICC detected is not relevant to the PCD application then the PCD should:

— either ask the user to show only the PICC of his choice,

— or deselect the PICC detected and then try to detect another PICC until it finds a PICC relevant to the PCD application.

4.3.2 Check that only one PICC is present

This process prevents a transaction with a PICC relevant to the PCD application but not chosen by the user.

However, this process:

— is slower than "Process the first PICC detected",

— does not allow a transaction with a single PICC relevant to the PCD application when presented together with other PICCs not relevant to the PCD application; in this case the PCD should ask the user to show only one single PICC relevant to the PCD application.

4.3.3 Reader interrogates all PICCs presented (Application layer)

This process:

— allows a transaction with the PICC relevant to the PCD application when this PICC is the only one relevant to the PCD application,

— does not allow a transaction with any PICC relevant to the PCD application when more than one PICC is relevant to the PCD application; in this case the PCD should ask the user to show only one PICC relevant to the PCD application.

However this process is:

— as slow as "Check that only one PICC is present" when a single PICC is presented,

— slower than all other processes when several PICCs are presented.

4.4 Collision avoidance

Collision avoidance may be done by the AFI mechanism which is only available during Type B anticollision. This mechanism can be used in any of the processes described in 4.3 above and will improve their efficiency.

However, some PICCs may not answer to REQB/WUPB commands with AFI not equal to '00'. Such PICCs may be multi-application PICCs or PICCs which want to prevent an unprotected disclosure of their application. Consequently, PCDs should only use AFI equal to '00' if they are to process these multi-application PICCs.

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