TECHNICAL REPORT

ISO/IEC TR 18268

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

Cartes d'identification — Cartes à circuit(s) intégré(s) sans contact — Cartes de proximité — Multiples PICCs dans le champ d'un seul PCD

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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.

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

In exceptional circumstances, when the joint technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide to publish a Technical Report. A Technical Report is entirely informative in nature and shall be subject to review every five years in the same manner as an International Standard.

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.

ISO/IEC TR 18268 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 17, *Cards and personal identification*.

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 Technical Report seeks to assemble the collective knowledge of the engineering principles involved.

This Technical Report is relevant to the standards listed in the Bibliography and an understanding of these is useful in placing this Technical Report in context.

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

1 Scope

This Technical Report presents a collation of industry experience of technical issues resulting from the presence of multiple PICCs in the field of a PCD. It describes how resonance frequencies may shift, how individual PICCs may see a reduced field strength, how multiple PICCs load the PCD, how they may change the local modulation signal and how PICCs should manage their identities to aid support of simultaneous usage. Scenarios for electronic passports with multiple visas and wallets containing multi-industry cards are explored.

2 Symbols and abbreviated terms

f_r	resonant frequency
H_{low}	lowest magnetic field strength
Q	quality factor
PCD	proximity coupling device
PICC	proximity card or object

3 General

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

a) PICCs presented (within the PCD'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_r 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 PCD. 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 potential revisions to the standards that will ultimately improve the acceptance of multiple PICCs presented to a single PCD. 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) should not be reduced significantly when multiple PICCs are presented such that the usability of the functionality is compromised.

4 Physical effects of multiple PICCs

4.1 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 a drop in its resonant frequency (f_r). This is due to the capacitive coupling and mutual inductance that forms between the turns of the coils of the two antennas. From the formula $f_r = 1/(2\pi\sqrt{LC})$, if either the capacitance or inductance increases, then the frequency will drop. 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.

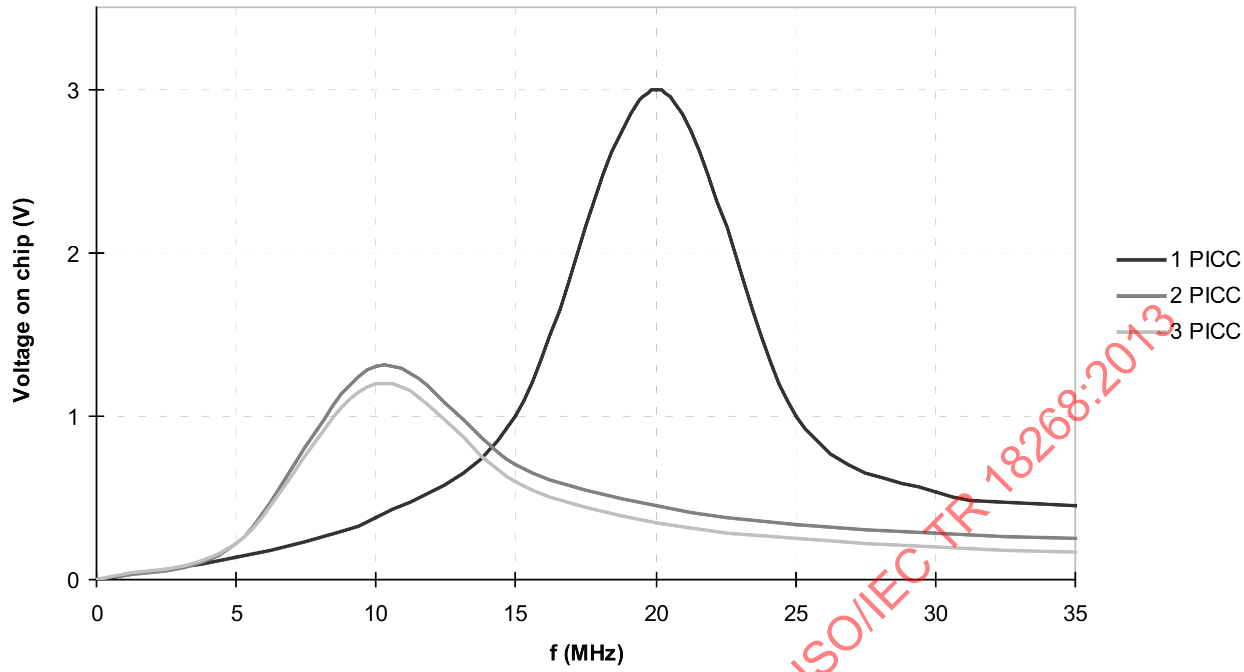


Figure 1 — Power drop and resonance shift

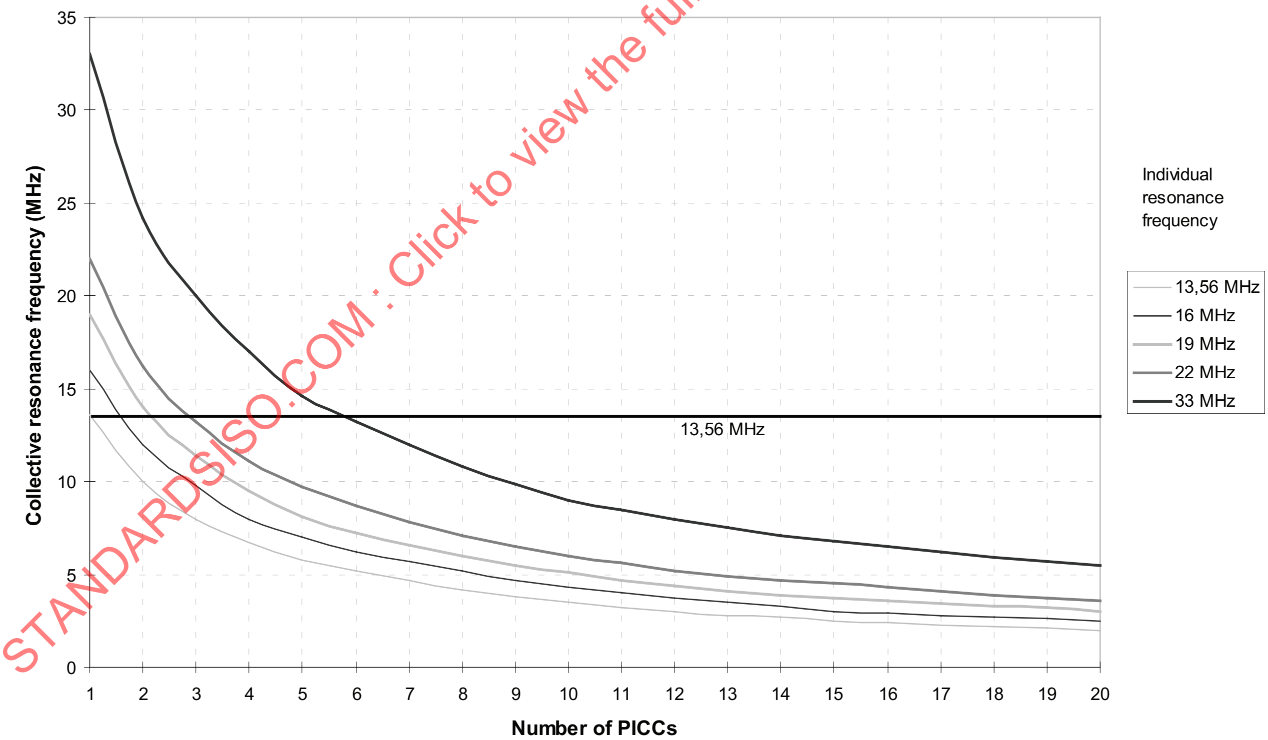
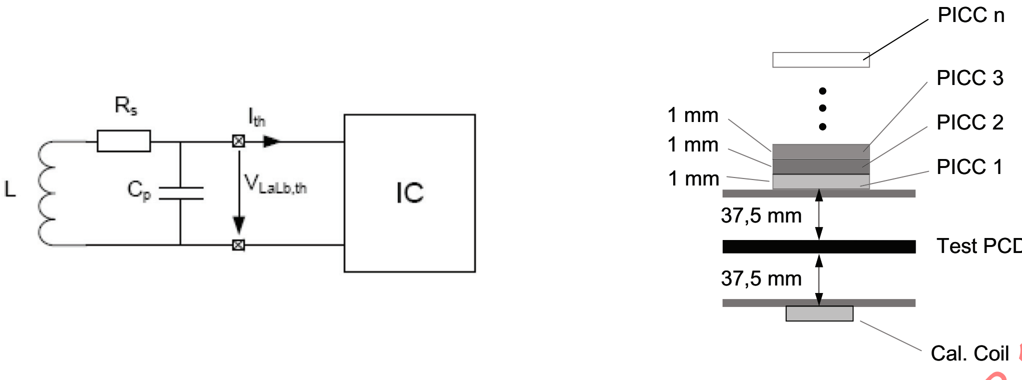


Figure 2 — Collective resonance frequency vs number of PICCs

Figure 1 and Figure 2 curves are from a simulation based on the ISO/IEC 10373-6 Test PCD Assembly with a distance between PICC antennas of 1 mm and using the test PCD antenna and PICCs with “Class 1” antenna size as shown in Figure 3.



a) Schematic **b) Physical**

Key

L antenna inductance

R_S series resistance

C_P parasitic capacitance

I_{th} chip input current

$V_{LaLb.th}$ chip threshold voltage

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. However, circuits in a real system will also have capacitance between them. This tends to suppress the higher frequency peak as the capacitance increases, with the result that the collective resonant frequency appears to be lowered. Figure 4 shows this effect.

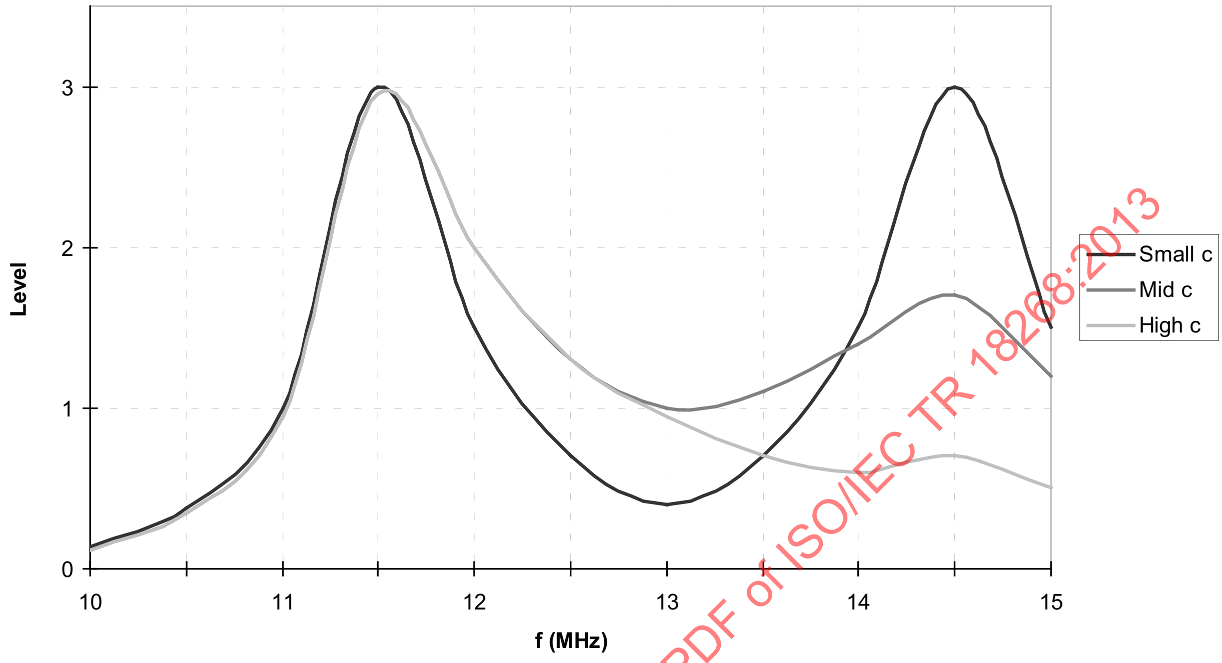


Figure 4 — Effect of capacitance on resonance shift

Observations that can be drawn include:

— A higher PCD field strength (compared to that for a single PICC) may be required to enable multiple PICCs to operate correctly.

— The collective resonant frequency shifts downwards due to mutual inductive coupling as the number of PICCs increases.

— The collective *Q* factor decreases due to the mutual inductive coupling as the number of PICCs increases.

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

— The PICC resonant frequencies are parameters of importance for multiple PICC systems.

4.2 Lowest operating field strength H_{low}

PCDs provide sufficient power in the range of 100 – 300 mW into the operating volume, such 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 4.1 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 lowest field strength required to operate them (H_{low})can be generalized into a model with three regions as shown in Figure 5.

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

— Region II: H_{low} 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_{low} starts to decline. From a practical perspective, Region III is unlikely to be reached.

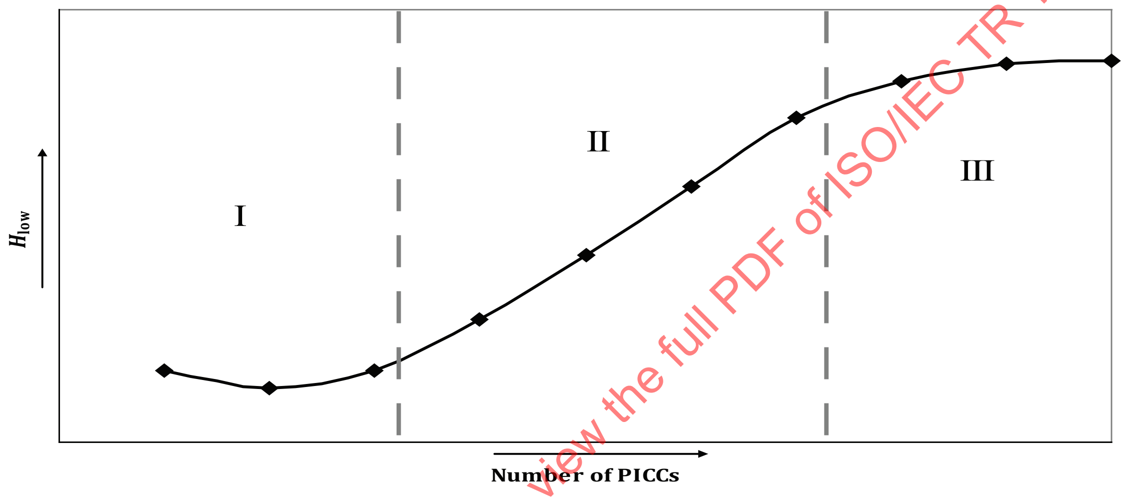


Figure 5 — Generalized Characteristics for H_{low} vs Number of PICCs

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

4.3 Loading effect

Loading effect is defined as the change in PCD antenna current caused by the presence of the PICC(s) in the field due to the mutual coupling modifying the PCD antenna resonance and quality factor. 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.

4.4 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 index, rise/fall time, ringing, etc.).

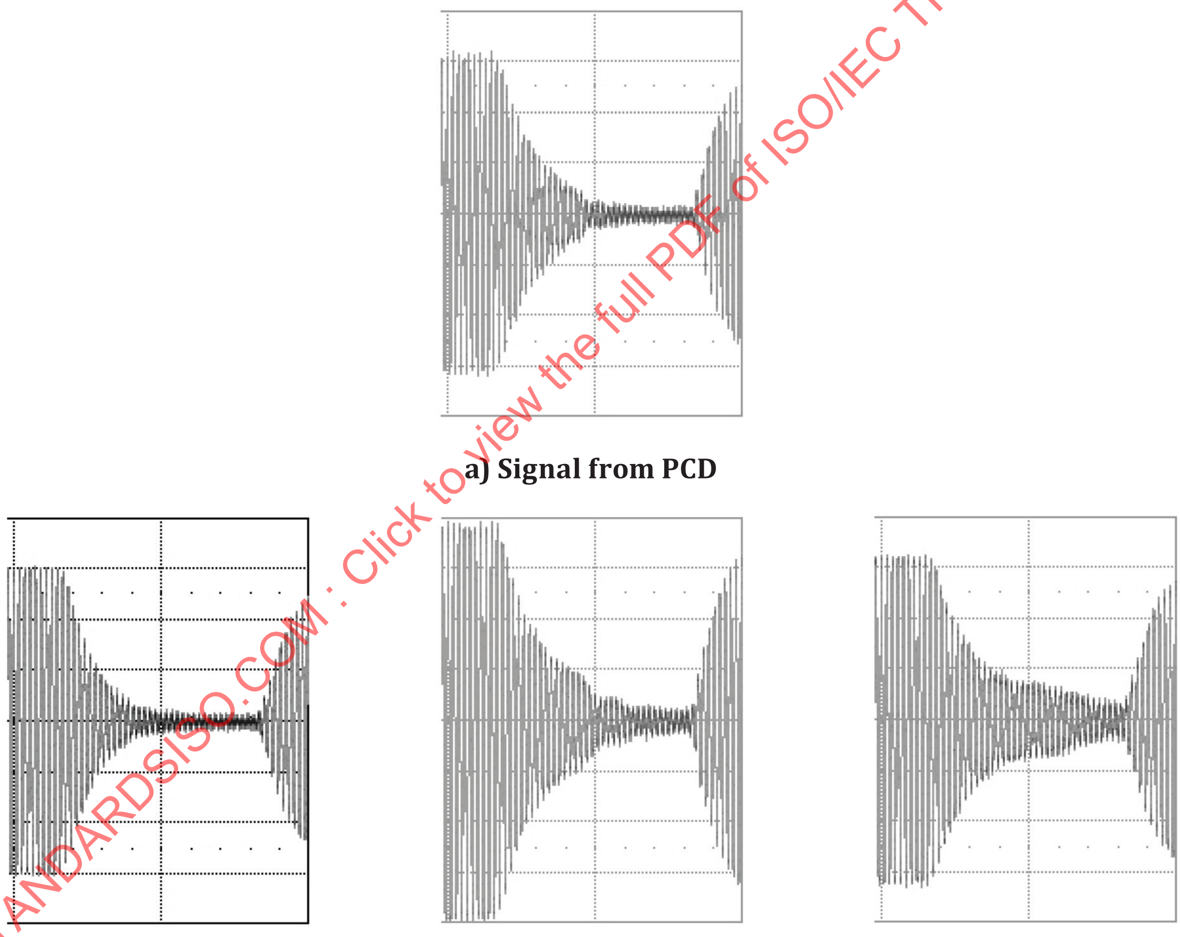
Figure 6 shows one example of waveform distortion. The upper waveform represents a Type A pause as transmitted by the PCD. The lower waveform shows its appearance in the field local to the PICC. The modulation index is reduced with higher residual carrier and the fall time has increased.

Observations that can be drawn include:

— PICCs should minimize 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.



a) Signal from PCD

b) 1 PICC

c) 2 PICCs

d) 3 PICCs

Figure 6 — PCD signal distortion

4.5 PICC to PCD communication

While in theory it may be possible for the PICC signalling 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.

5 Addressing multiple PICCs

5.1 CID support

If multiple PICCs need to be simultaneously in the PROTOCOL state (see ISO/IEC 14443-4,[4] Annex A) then a unique 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 should 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.

5.2 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,[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.

5.3 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,[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.

5.4 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,[3] 7.7.3).

