08 Testbench for contactless characterization

8th unit in course 451.417, RFID Systems, TU Graz

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*rfid-Systems.at*
Advancing Technology

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- Setup for Reader Test – Hardware components and considerations

- Setup for Reader Test – Measurement methods

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- Other test benches – EMVCo and NFC Forum

Overview

3 relevant test benches for Proximity

Contactless near-field communication testing
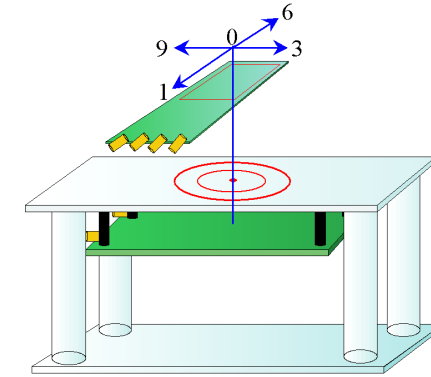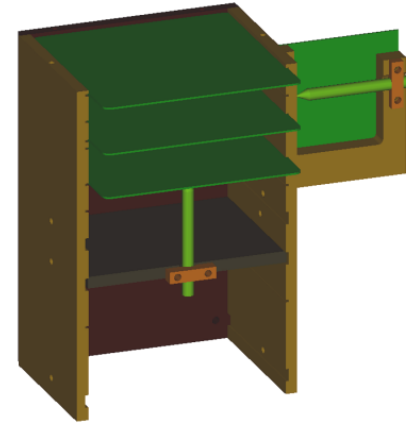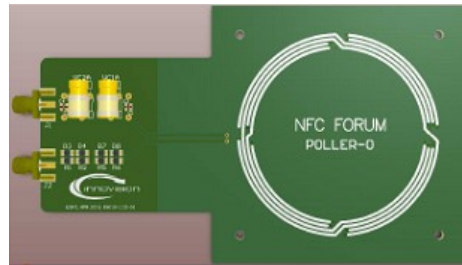
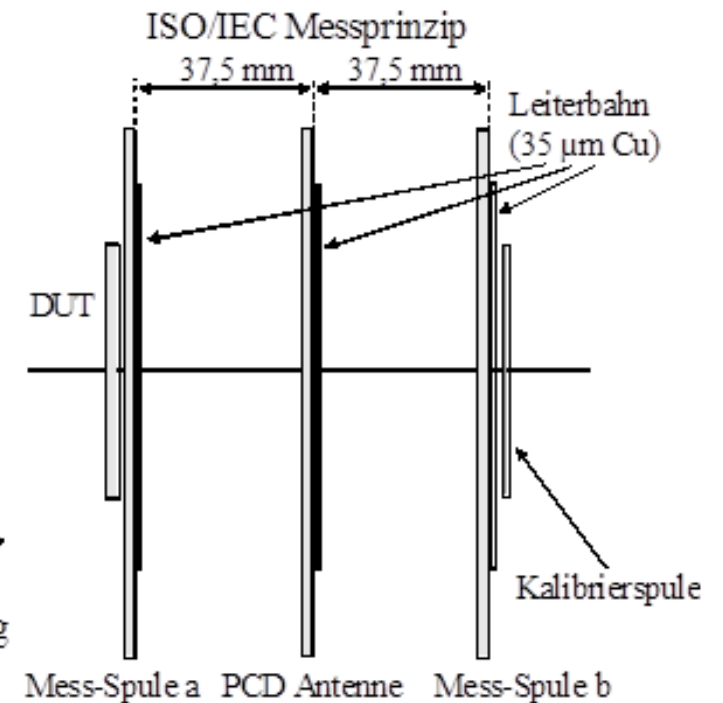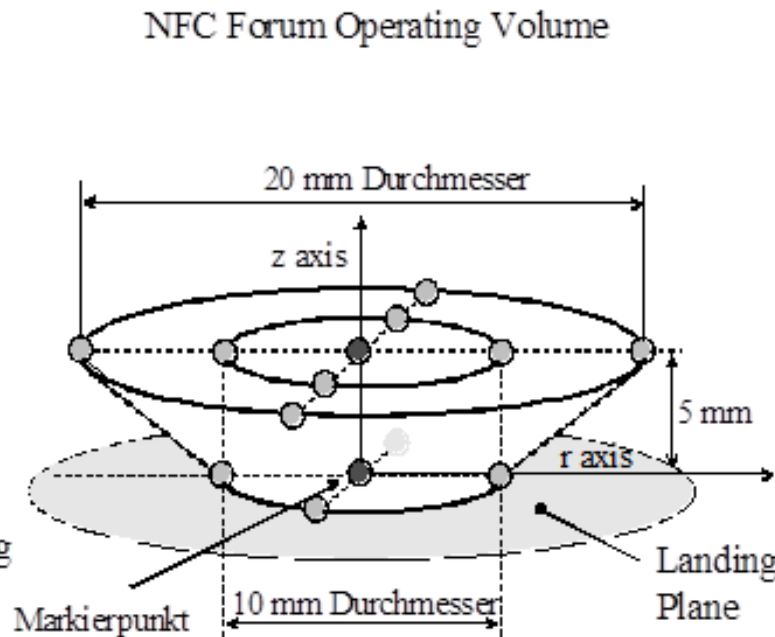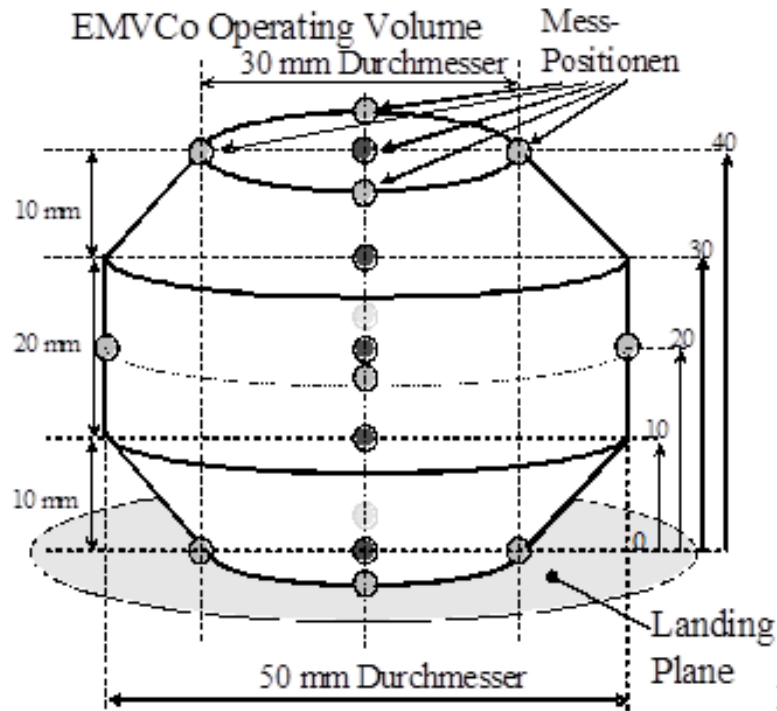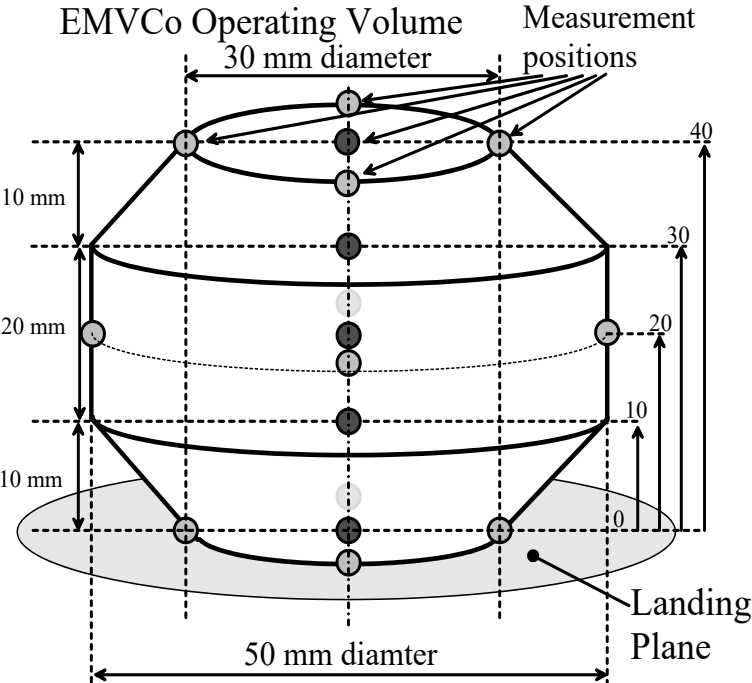|	**NFC Forum**	**ISO/IEC**	**EMVCo**
Coverage	RF to logical link	RF & Protocol	RF to App
Protocols	NFC-A, NFC-B, NFC-F. In progress NFC-V and ACM	Type A, B, V	Type A, B (106 kbit/s only)
Application	All	All	Payment only
NFC Forum	Primary focus	Complementary	Complementary
Mutability	Continuous evolution	Stable	Evolution depedent on payment needs

3 test benches and concepts

- Other test benches for contactless HF measurements are…

- EMVCo test bench, related to contactless payment

- NFC Forum test equipment.

- Main concept difference: Application oriented vs. individual parameter char.

EMVCo Contactless Testbench Overview

distance 0, 1, 2, 3, 4 cm to Landing Plane

radius 0, 1, 2 means 0 – 1.5 – 2.5 cm

angle (0), 1, 3, 6, 9 means (---), 0°, 90°, 180°, 270°

z	r	φ

EMVCo Reference PICC

EMVCo Reference PCD

EMVCo Operating Volume
30 mm diameter

Measurement positions

10 mm

20 mm

10 mm

40

30

20

10

0

50 mm diamter

Landing Plane
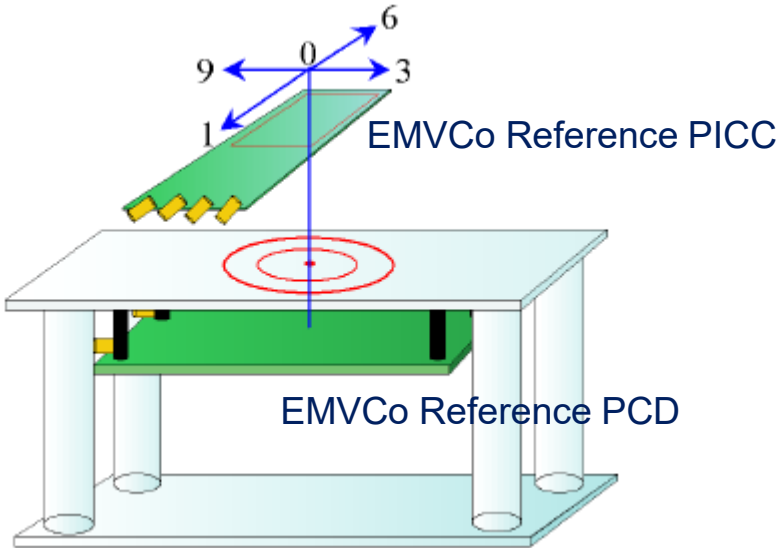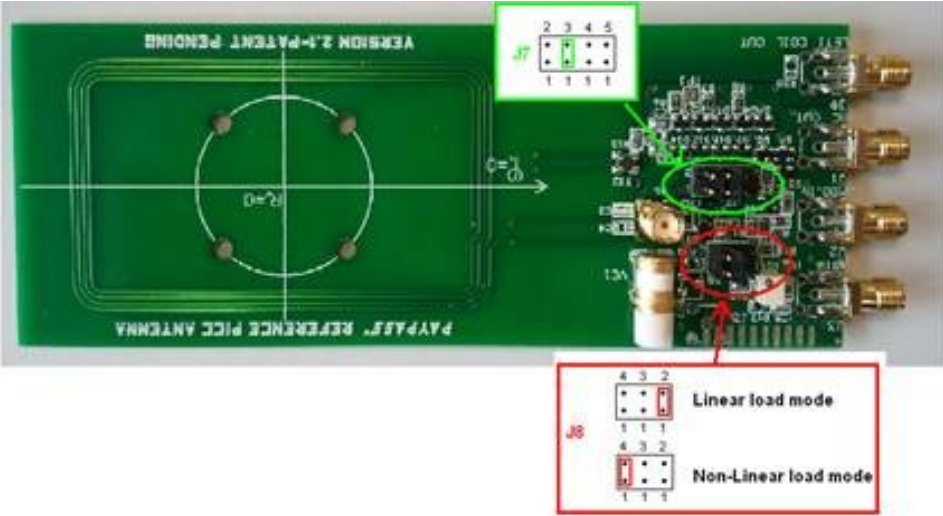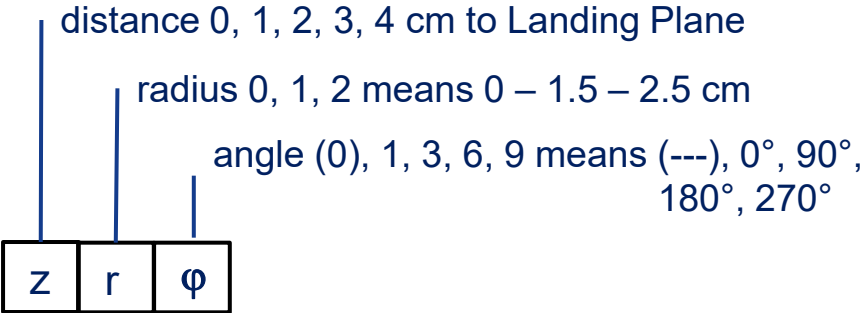
NFC Forum testing

- Varied positions in an Operating Volume

  – 0 ... 5 mm on z axis

  – 0 ... 5 mm radius in z = 0 plane

  – 0 ... 10 mm radius in z = 5 mm plane

- Different reference point for every antenna category possible (< 20 mm)

- Environment: Free guard distance of 150 mm

- Defined resonance frequency and DC voltages (~ Q-factor)
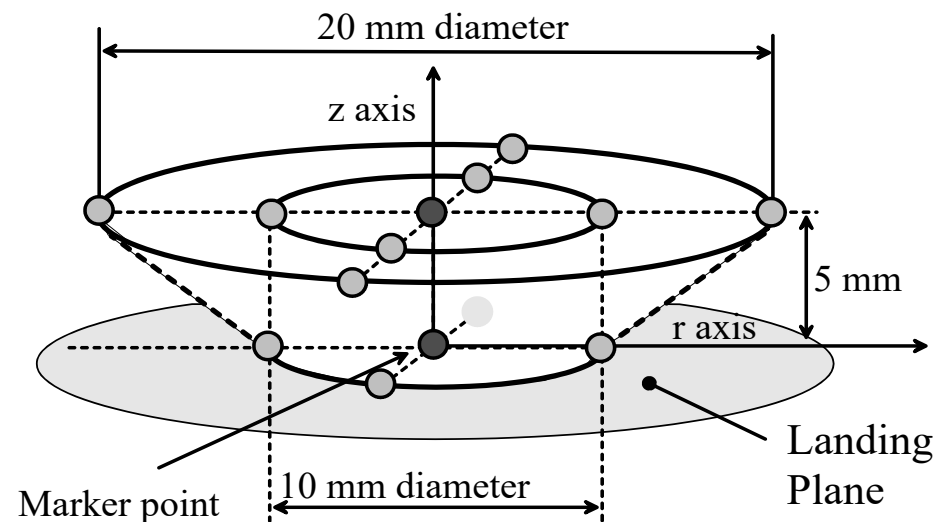
Reader Mode Testing: Listener device
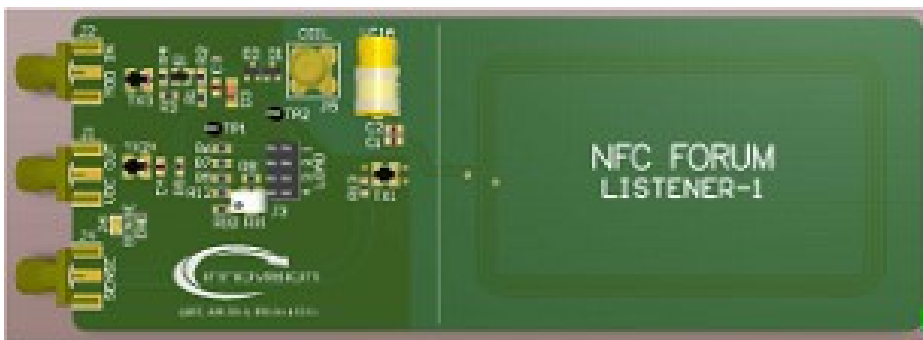
Card Mode Testing: Poller device

Practical implementation of an ISO/IEC test bench

Remote control bus interface

Remote control bus interface

External command trigger

Reader Rx path

Helmholtz bridge signal

Load Modulation

Digital Lab Reader & arbitrary waveform generator

Reader signal

Modulated carrier

Reader signal

Modulated, amplified carrier

Lab Amplifier
0,01 - 250 MHz, 75 W

10373-6 antenna arrangement

Calibration Coil signal

H-field amplitude, Envelope shape

Digital Sampling Osc.
2 GS/s,
8 bit ampl. res.

Aspects of the Analogue Air Interface

Reader

- *Test under Card Loading*
- *H*-field (emitted) @ 13,56 MHz
- Modulation Envelope
- Sensitivity to Load Modulation
- EMD / Noise reception

Card

- Card Loading
- *H*-field (required) @ 13,56 MHz
- Modulation reception
- Load Modulation Emission
- EMD / Noise Emission
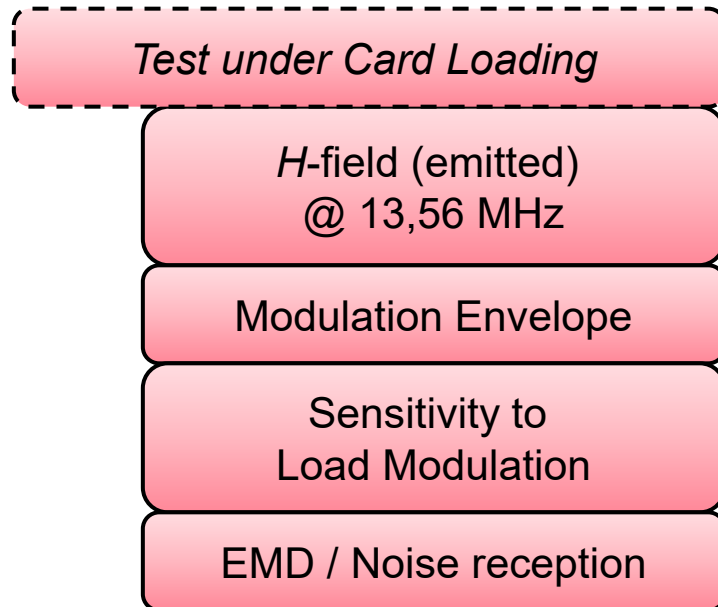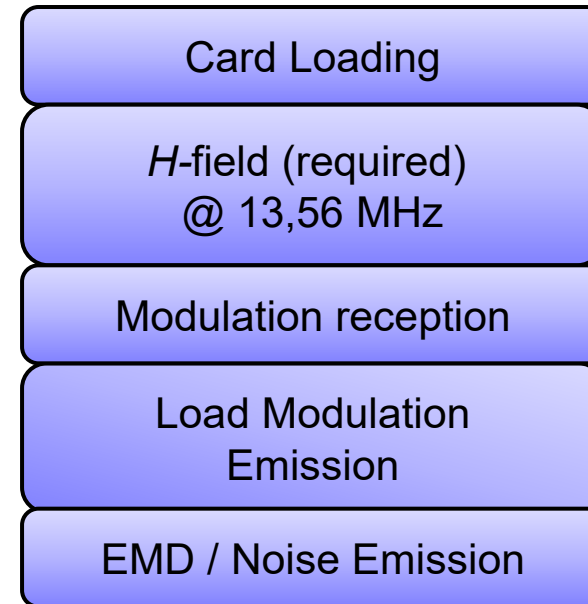
● To be checked according to

– **Interoperability** (with cards / readers available on market)

– **Standard compliance** (with contactless test benches according ISO/IEC, EMVCo, NFC Forum)

ISO/IEC Test bench

Overview and general considerations

Test Standard ISO/IEC 10373-6 specification

- The Proximity Test Standard specifies
  - a specific setup based on a coaxial antenna arrangement (to emulate a reader) for card measurement, and a test card (to emulate a transponder card) for reader measurement.
  - measurement methods, to verify the parameter values specified in the base standard.
- This is mainly related to ISO/IEC14443-2, the power and radio-frequency signal air interface.
- Only the antenna arrangement for contactless measurement at the air interface is specified in detail, the instrumentation which is connected, is up to the laboratory or test house.
- The idea is, to measure aspects separately (not in combination, like in application) and to get absolute (comparable) values.

Consider: Concept for a modular test bench

To cover complete Standard Conformance tests, a modular test bench may consist on the following principle:

● Interchangeable modules, which include:

 – command set and state transitions (**digital part**),

 – modulation characteristics at the air interface (**analogue part**),

 – antenna arrangement (**contactless part**).

All modules are controlled by a PC.
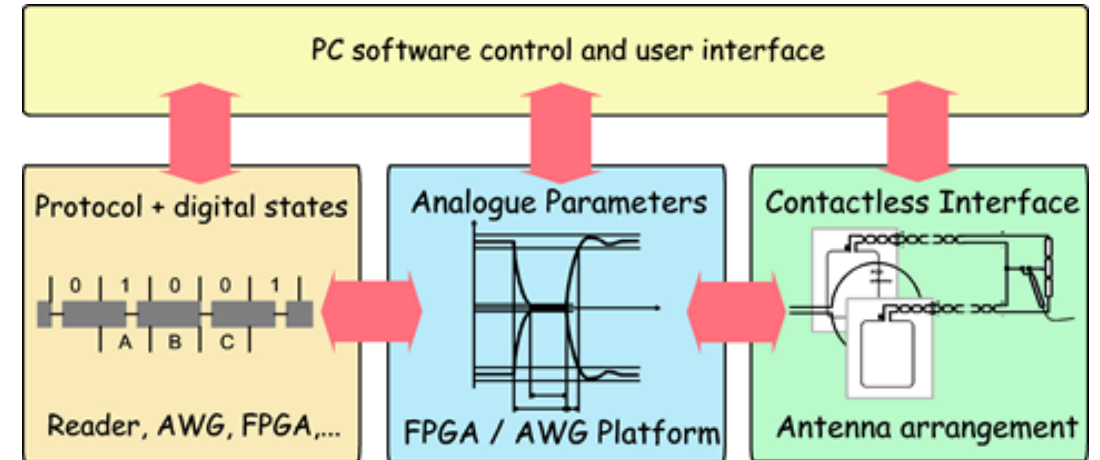
→ Pre-defined test profiles can be run automatically, as well as manual „debug"-tests,

→ Quick checks with standard parameters are possible as well as deep investigations, and

→ **Combined effects** can be tested (wide analogue parameter variation combined with specific command flow).

→ This is the specific challenge for passive RFID transponders!

Testable parameters

▶ Analogue Signal parameters
- ▶ *Amplitude*
  - ▶ *H-field range*
  - ▶ *Load Modulation (DFT of Subcarrier)*
  - ▶ *Card Loading*
- ▶ *Timing*
  - ▶ *Modulation pulse edge steepness,*
  - ▶ *modulation index / residual carrier,*
  - ▶ *reset time / start up time / delay time*
- ▶ *Disturbances*
  - ▶ *Overshoots / ringing effects*
  - ▶ *Noise / EMD*

▶ Functional test cases
- ▶ *(intended) state transitions,*
- ▶ *Complete and correct response,*
- ▶ *Security functions,*
- ▶ *Regression tests,*

← **testable parameters**

Parameters to set (require additional components)

▶ Ambient Conditions
- ▶ Temperature
- ▶ Movement
- ▶ Coupling (metal / multi label)

▶ Transponder / Device
- ▶ Resonance frequency
- ▶ Quality factor
- ▶ Supply voltage

Chip Characterization and Evaluation

Regarding the measurement, we differentiate…

- **Evaluation** of standard conformance

  - **The Standard** / a certification requirement is in the main focus. Specified measurement methods and parameter values are the reference. Typically a final end product is measured, and it is checked, if the result is within standard specified limits.

  - For the test bench this means, accuracy must be sufficiently high to get significant / reliable results for the (known) parameter limits.

- **Characterization**

  - **The chip** is in the main focus. Properties are characterized up to chip limits, which can be inside, or outside the standard specification. Usually this is done during chip development on engineering samples, or prototypes of the final product.

  - For the test bench this means, accuracy of results must be judged for every result individually, requirements can be much higher, than for compliance tests.
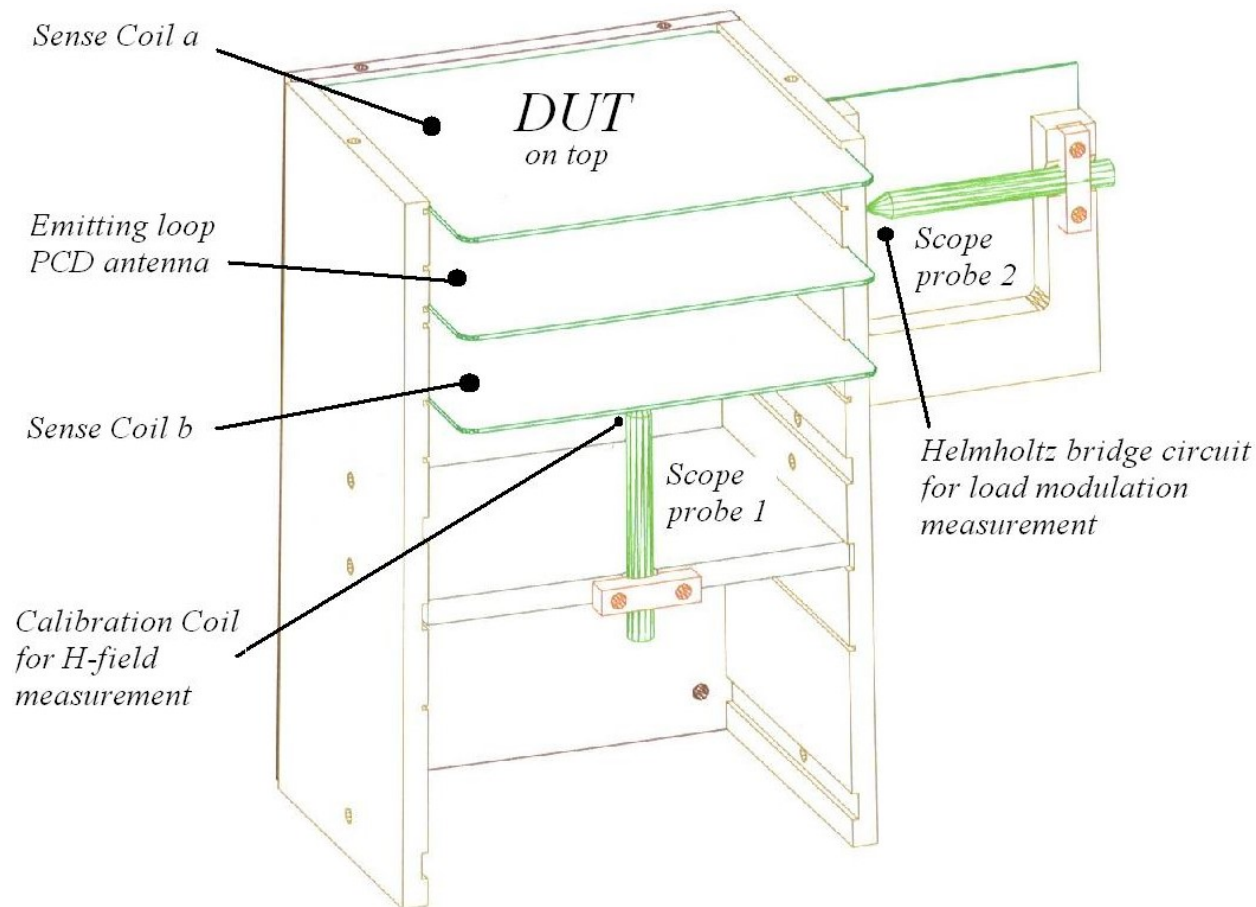
ISO/IEC Setup for Card test

Proximity Test Concept
Hardware components and the considerations behind

Coaxial antenna arrangement – overview

- An implementation of the coaxial antenna arrangement is shown.

- **PCD antenna** emits an alternating *H*-field and reader modulation
- **Calibration coil** allows to measure *H*-field and envelope shape
- 2 **Sense coils** signals combined in a Helmholtz bridge allow to measure card emission and to compensate coupling to PCD antenna

PCD antenna *H*-field and choice of a dedicated distance

- The ISO-setup is a coaxial arrangement of TX loop antenna and transponder loop antenna (DUT).

- The distance of 37,5 mm to the transponder is chosen in a way, that an area of about ID-1 (credit card) size gets a homogenous *H*-field strength.

  - The driver power for the required *H*-field strength is given by…

$$P_D \approx \frac{I_A^2 \cdot \omega_C \cdot L_{AM}}{N^2 \cdot Q_C}$$

…which results in about 0,13 .... 3,5 W for the specified antenna Q35 and *H*-field range of 1,5 – 7,5 A/m (rms)
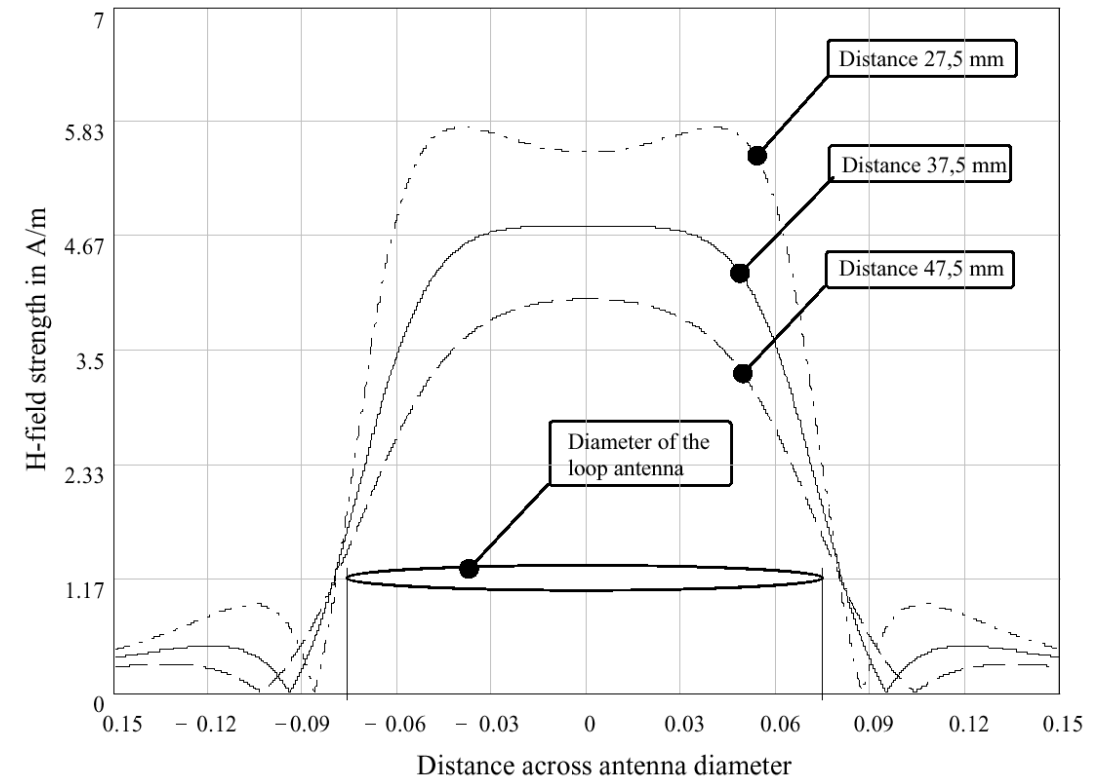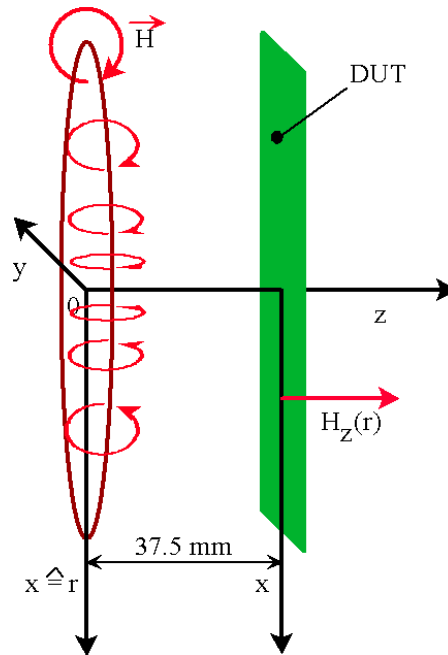
H-field calculation using extended Biot-Savart law

- The vector from the circular PCD transmit antenna conductor (circumference) to a receiving point in space can be described by

$$r_{SR}(\Phi, x_R, y_R, z_R) = \sqrt{\left(x_S + a \cdot \cos(\Phi) - x_R\right)^2 + \left(y_S + a \cdot \sin(\Phi) - y_R\right)^2 + \left(z_S - z_R\right)^2}$$

S.....source point (PCD antenna center point)

R.....receiving point (field measurement)

a.....antenna conductor radius

- In the coaxial arrangement of the ISO-Setup with the transponder card placed as DUT the z-component of the *H*-field is important, as it is perpendicular to the card antenna. This component H_z can be calculated for any receiver point in space according to

$$H_z(x_R, y_R, z_R) = \left| \frac{I_A \cdot a}{4 \cdot \pi} \cdot \int_0^{2\pi} \left\{ \frac{e^{-i \cdot \beta \cdot r_{SR}}}{r_{SR}^2} \cdot \left(i \cdot \beta + \frac{1}{r_{SR}} \right) \cdot \left[a + \left(x_S - x_R\right) \cdot \cos(\Phi) + \left(y_S - y_R\right) \cdot \sin(\Phi) \right] \right\} d\Phi \right|$$

β.....phase constant, $\quad \beta = \dfrac{2\pi f}{c}$

H-field measurement with Calibration Coil

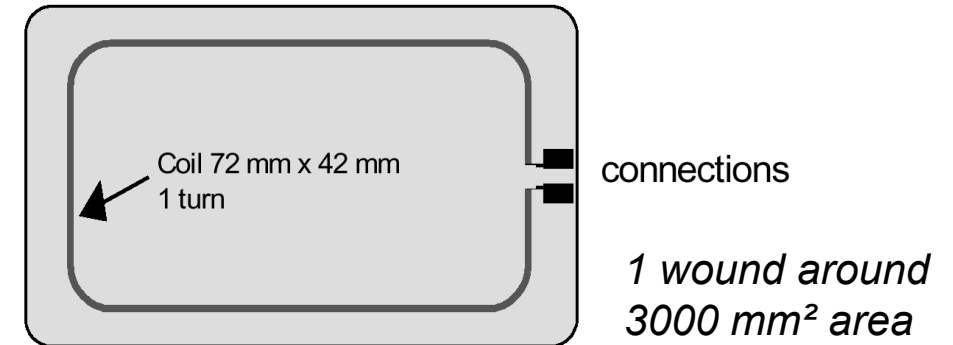– **Michael Faraday´s** law of magnetic induction $u_i = -\dfrac{d\Phi}{dt}$

ISO/IEC 7810 ID-1 outline

– As we have a harmonic sine-wave signal, this can be simplified to $u_i = \Phi \cdot \omega$

Coil 72 mm x 42 mm
1 turn

connections

1 wound around
3000 mm² area

– According to the Ohm law of the magnetic field

$$\Phi = B \cdot A \quad = \quad \mu_R \mu_0 \cdot H \cdot A$$

– For H = 1 A/m$_{\text{rms}}$

$$u_i = -\frac{d\Phi}{dt} \quad = \quad \Phi \cdot \omega \quad = \quad 2\pi \, f_C \cdot \mu_R \mu_0 \cdot H \cdot A$$

$$U_i = 2\pi \cdot 1.356 \cdot 10^7 s^{-1} \cdot 4\pi \cdot 10^{-7} VsA^{-1}m^{-1} \cdot 1\, Am^{-1} \cdot 3 \cdot 10^{-3} m^2 \quad \cong \quad 0.32\, V_{RMS}$$

– Or peak-to-peak value with crest factor

U_P U_{PP} U_{RMS}

$$U_{i,PP} = 2\sigma \cdot U_{i,RMS} \cong 910\ mV_{PP}$$
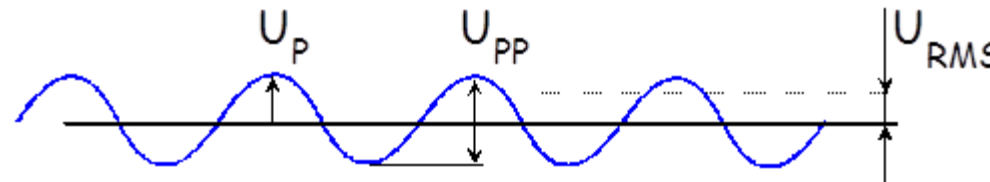
RMS values for time-discrete signals

- The root – mean – square value is the power-equivalent DC value.

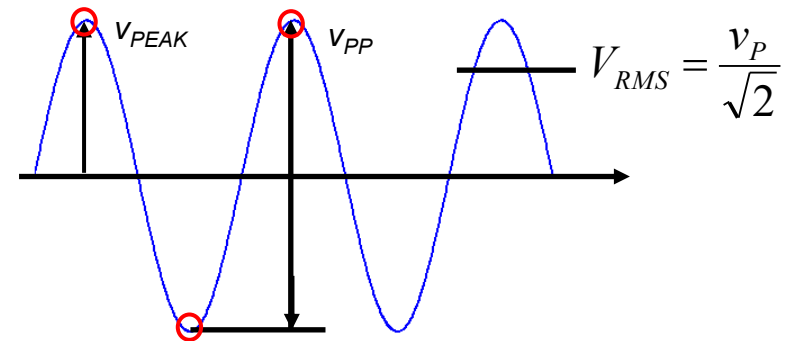Root $\sqrt{(\quad)}$ Mean $\dfrac{1}{n}\sum_{i=1}^{n}x_i$ Square $(\quad)^2$

- If we have a time series of discrete amplitudes (sampling values) and equal time steps, the rms value is given by
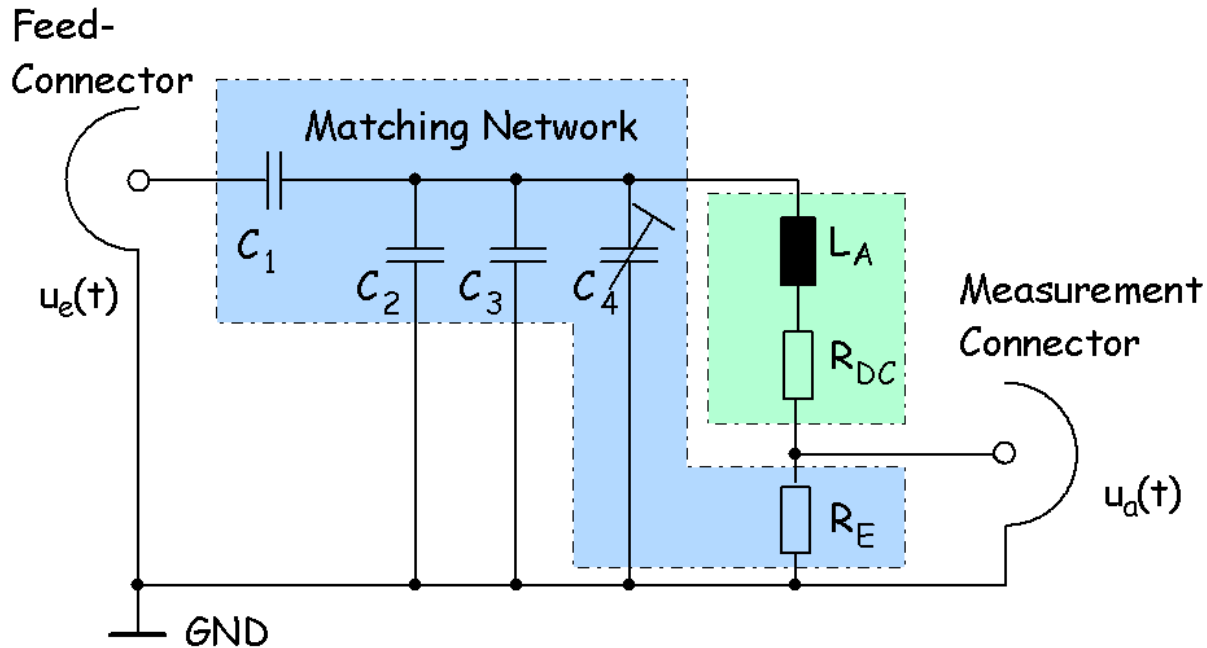
$$U_{RMS} \cong \sqrt{\frac{1}{n}\sum_{i=1}^{n}u_i^2} = \sqrt{\frac{1}{n}\left(u_1^2 + u_2^2 + \ldots + u_n^2\right)}$$

- For sine-wave voltage signals, it is related to other values by...

$$V_{RMS} = \frac{v_P}{\sqrt{2}}$$

v_{PEAK} v_{PP}

- The **signal amplitude** is related to the **peak** value of the voltage!

Example: *H*-field signal of the ISO/IEC10373-6 PCD

Component values

PCD loop antenna eq. circuit

L_A....480 nH

R_{DC}....0,14 Ohm

Matching network

C_1.....47 pF

C_2.....180 pF

C_3.....33 pF

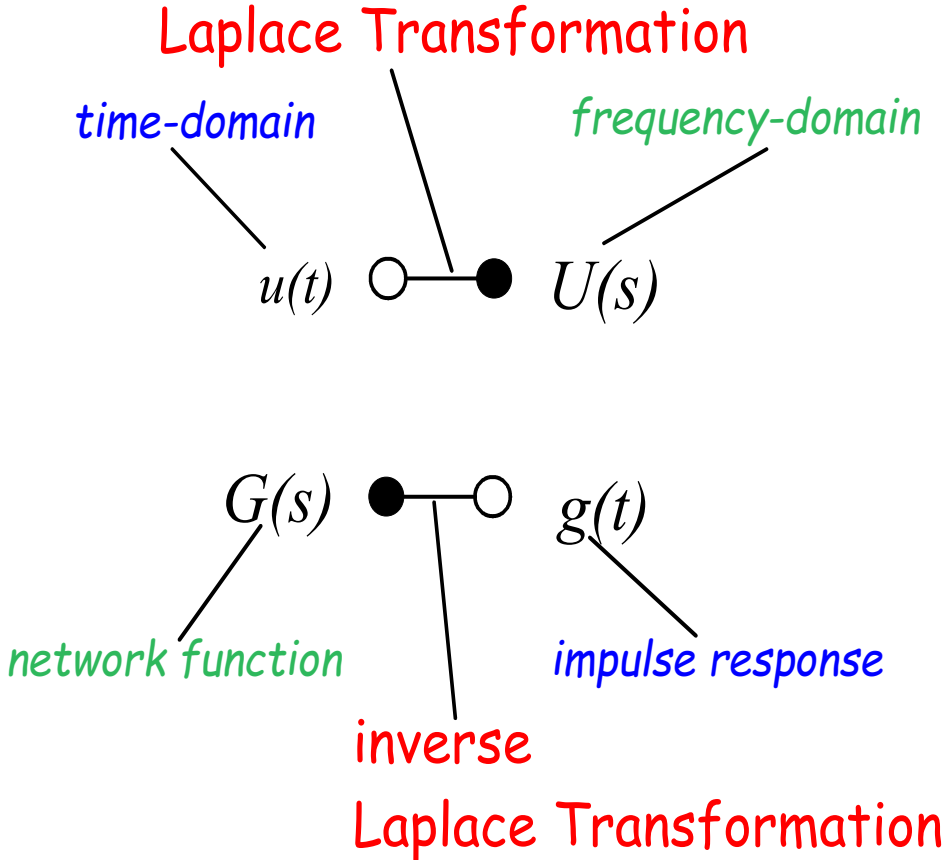C_4.....3 - 30 pF (selected 17 pF)

R_E.....0,94 Ohm

Driver amplifier

R_D.....Driver impedance (50 Ohm)

$$G(s) = \frac{R_E + R_{DC}}{sL_A + R_E + R_{DC}} \cdot \frac{\dfrac{sL_A + R_E + R_{DC}}{(sL_A + R_E + R_{DC})(C_2 + C_3 + C_4) + 1}}{\dfrac{1}{sC_1} + \dfrac{sL_A + R_E + R_{DC}}{(sL_A + R_E + R_{DC})(C_2 + C_3 + C_4) + 1} + R_D}$$

Laplace-Transformation

- The Laplace transformation corresponds between time-domain and complex frequency domain. Can be applied on signals and networks.

Laplace Transformation

time-domain   frequency-domain

$u(t)$ ○—● $U(s)$

$$F(s) = L\{f(t)\} = \int\limits_0^\infty f(t) \cdot e^{-st}\, dt$$

$G(s)$ ●—○ $g(t)$

$$f(t) = L^{-1}\{F(s)\} = \frac{1}{2\pi} \cdot \int\limits_{-\infty}^{+\infty} F(s) \cdot e^{st}\, d\omega$$

network function   impulse response

inverse Laplace Transformation

Example: *H*-field signal of the ISO/IEC10373-6 PCD

Arbitrary Waveform Gen. *RF signal in*

PCD

Calibration Coil signal

Digital Sampling Osc.

H-field, Mod. Envelope shape

$$u_a(t) = L^{-1}\{G(s) \cdot L\{u_e(t)\}\}$$

$$i_A(t) = R_E \cdot u_a(t)$$

Input signal (command modulated on RF carrier)

Output signal, distorted by resonant antenna

Note: current corresponds to *H*-field
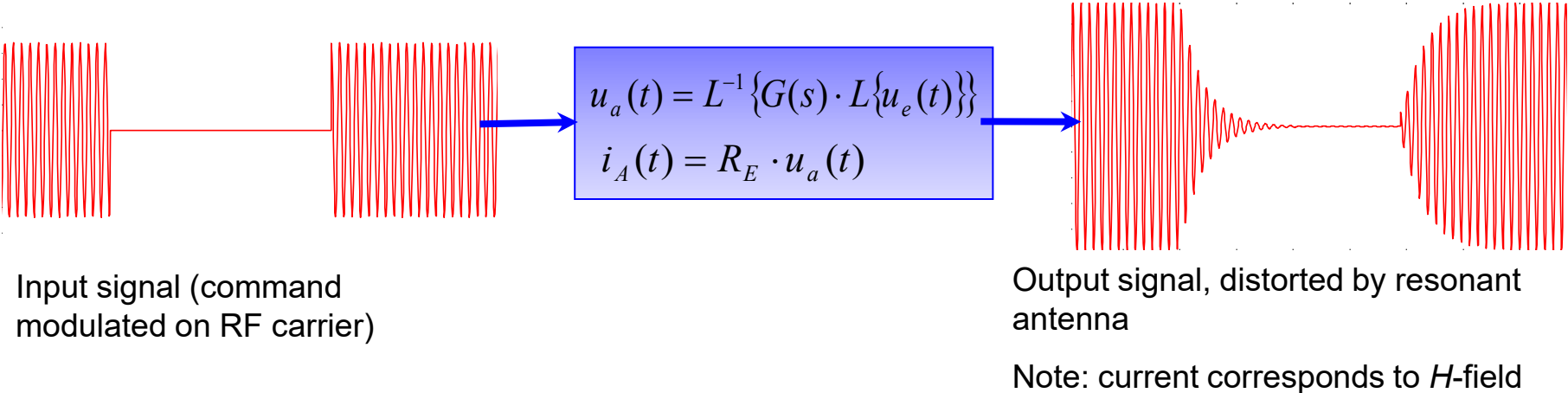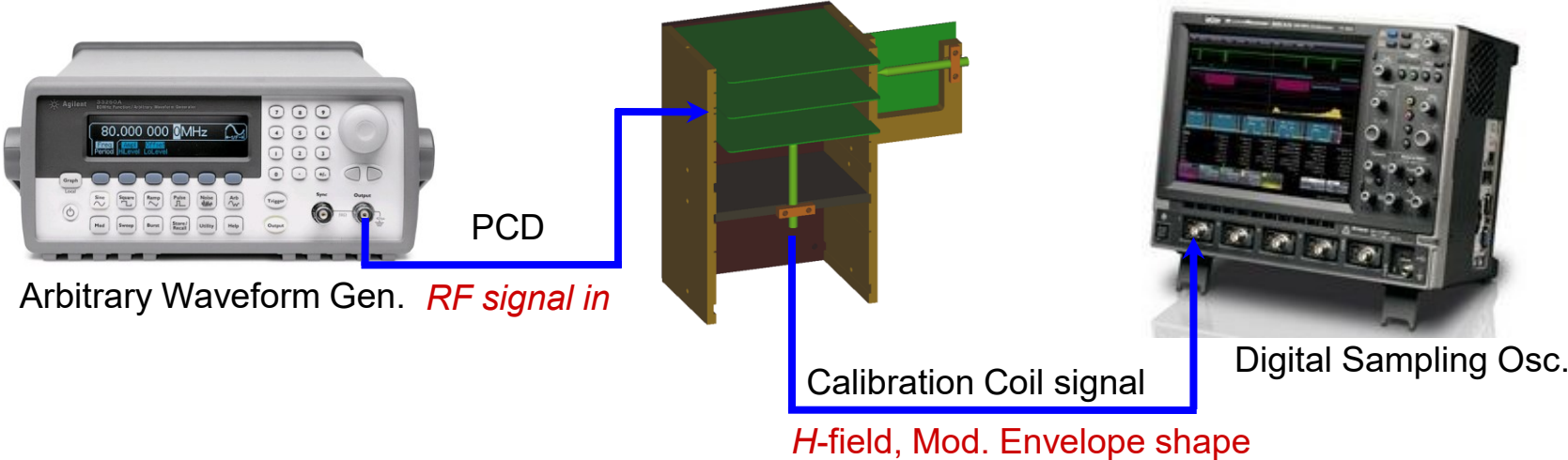
Modulated *H*-field in Time Domain

● In time domain, the amplitude envelope of a second-order resonant circuit in load matching can be described by an exponential function. τ is the time constant, after which the amplitude has decreased from 1 to 1/e (~ 37% of initial value).

Falling edge

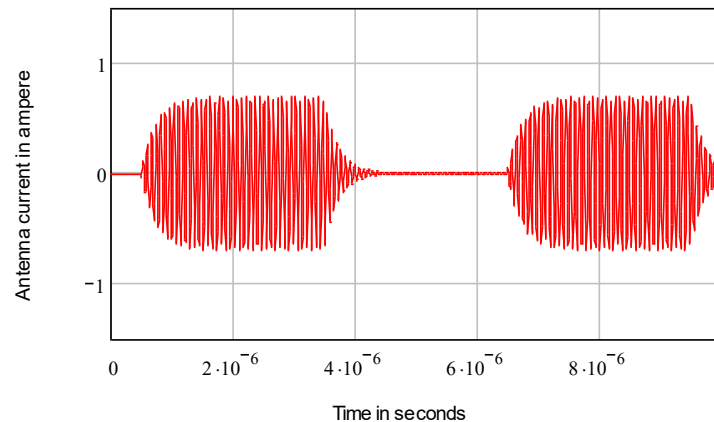$$u_F(t) = e^{-t/\tau} = e^{-t \cdot \frac{f_C \pi}{Q}}$$

Rising edge:
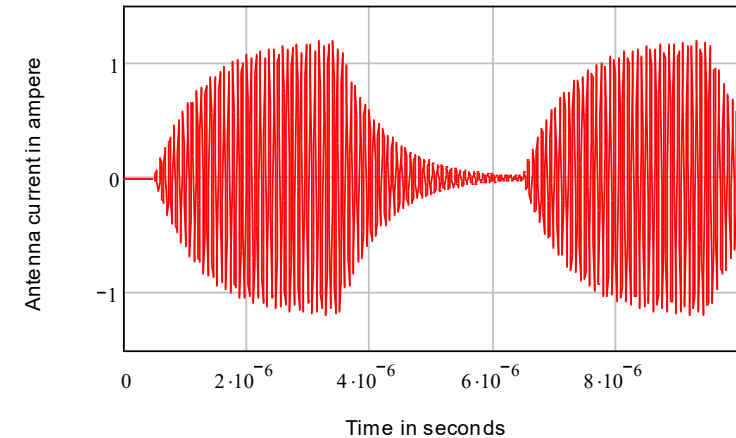
$$u_R(t) = 1 - e^{-t \cdot \frac{f_C \pi}{Q}}$$

$$Q_{SYS} = \tau \cdot \pi \, f_C$$

As a practical example, pulse shapes for two different antenna Q-factors

Q ~ 10

Q ~ 30:

Modulated *H*-field in Time Domain

● This allows to relate the time and amplitude parameters specified in the Proximity base standard for RF Interface, ISO/IEC14443-2, to the „natural" envelope distortion by the PCD antenna Q-factor operated in 50 Ohm load matching to the lab amplifier. For example, these relations are given for the Type A modulation pulse parameters specified for 106 kbit/s.
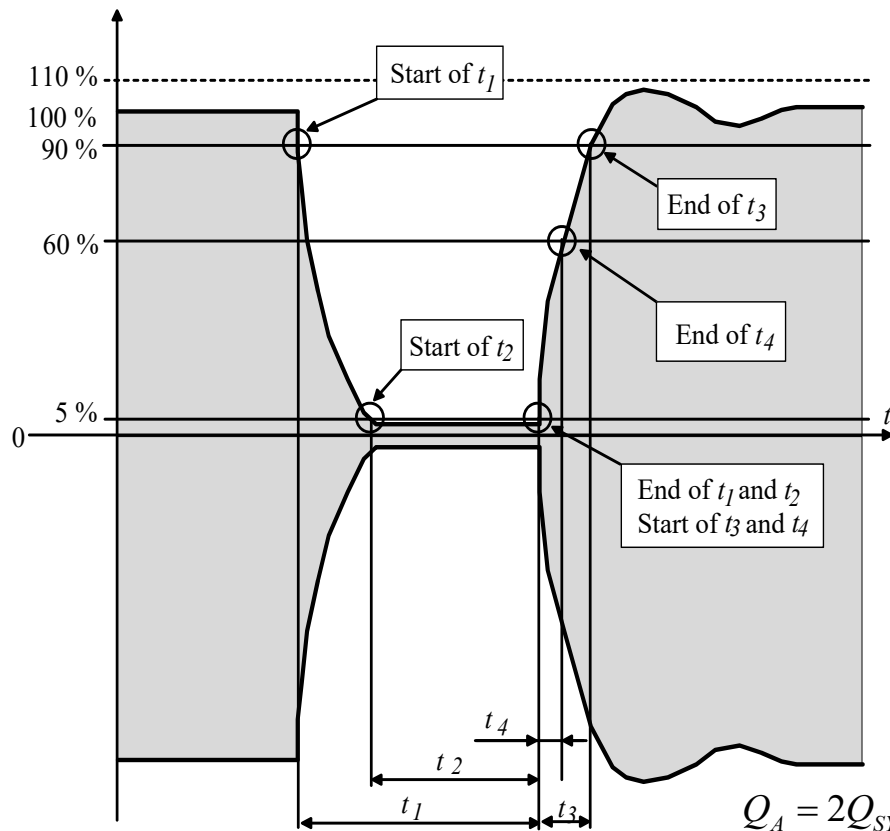
$$(t_1 - t_2) = \frac{Q_{SYS}}{\pi f_C} \cdot [\ln(0.9) - \ln(0.05)]$$

$$t_3 = \frac{Q_{SYS}}{\pi f_C} \cdot [\ln(0.95) - \ln(0.1)]$$

$$t_4 = \frac{Q_{SYS}}{\pi f_C} \cdot [\ln(0.95) - \ln(0.4)]$$

$$a = u_F(t_1) = e^{-t_1 \cdot \frac{\pi f_C}{Q_{SYS}}}$$

$$Q_A = 2Q_{SYS} \text{ for load matching}$$

Type A	Time in µs		Time in carrier cycles	
	$Q_A = 10$	$Q_A = 35$	$Q_A = 10$	$Q_A = 35$
$t_1 - t_2$	0.339	1.187	4.6	16.1
t_3	0.264	0.925	3.6	12.5
t_4	0.102	0.355	1.4	4.8
a ($t_1 = 2$ µs)	0	0.008	0	0.008

# Channel characterization and signal equalization

Channel estimation

↓

Impulse response

↓

Pre-equalization filter

↓

Signal generation

Test execution
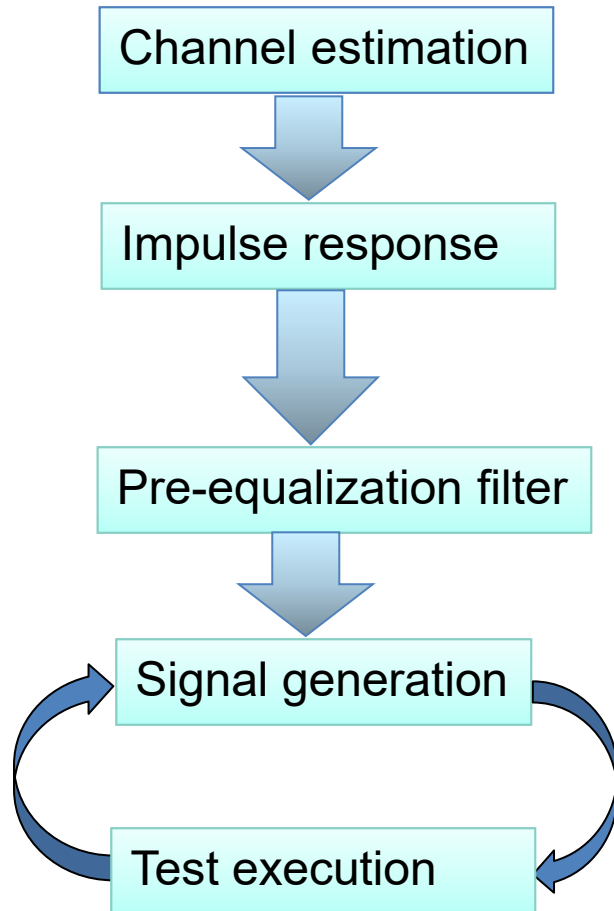
– ...by transmission of a maximum length sequence signal of 218 bits (full memory size of FPGA) over the emitting loop antenna, and receiving the Calibration coil signal.

– A cross-correlation of the received signal with the transmitted signal allows to estimate the impulse response (based on an assumption for the network).

– Coefficients of an IIR filter are calculated, which allows to pre-distort signals with the inverse of the system.

– A 13,56 MHz HF carrier modulated by an NF signal with intended time parameters is generated as time series (7 points per carrier cycle), fed trough the pre-distortion filter, then transmitted via amplifier by the emitting loop antenna.

– The intended *H*-field modulation envelope parameters for reader commands appear at the air interface, as defined in the standard.

Channel characterization and signal equalization

Channel estimation

Impulse response

Pre-equalization filter

Signal generation

Test execution

MLS signal
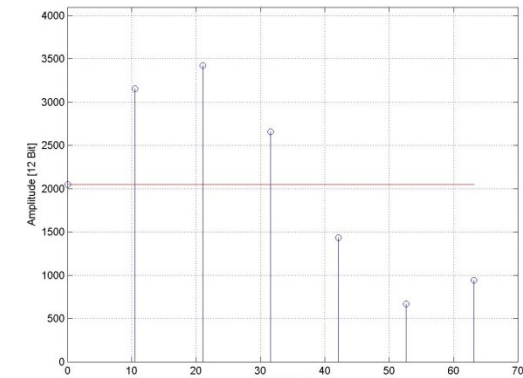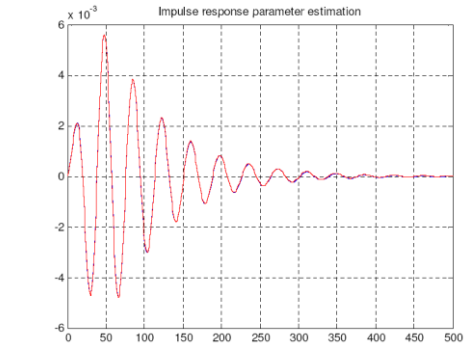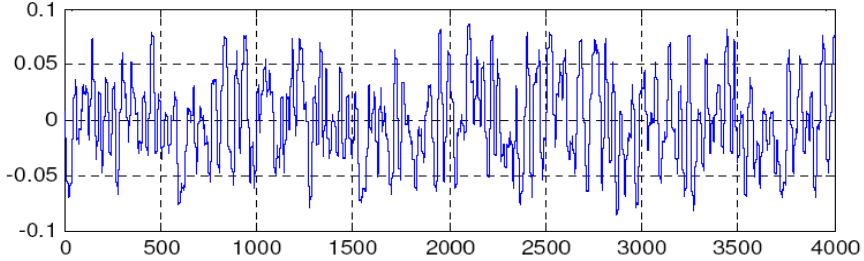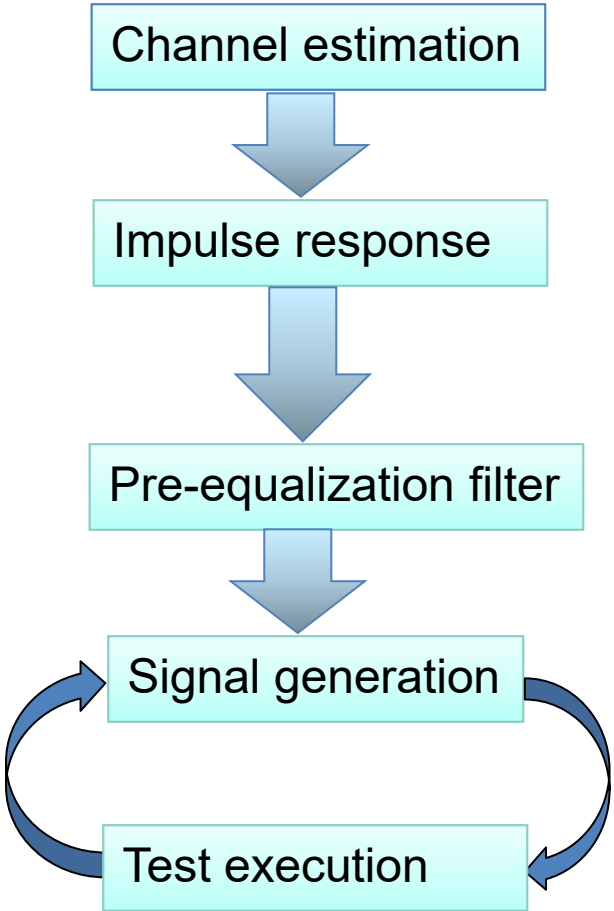
Impulse response
parameter estimation

(almost) any envelope shape
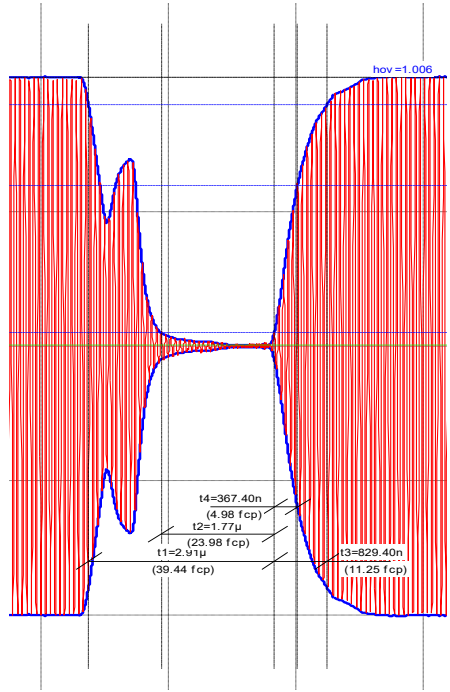
Helmholtz arrangement

- In the distance, chosen to have homogenous *H*-field distribution, there are two equal **Sense coils** in the coaxial antenna arrangement. These are connected to a **Helmholtz-bridge**.
- It the PCD antenna emits the 13,56 MHz carrier, the same voltage is induced in each Sense coil, if no transponder (loading) is near.
- So the induced voltage of the primary *H*-field is compensated (spatial filter).
- The secondary *H*-field of a transponder can be measured, this is…
  - quasi-static "Card Loading"
  - Load modulation
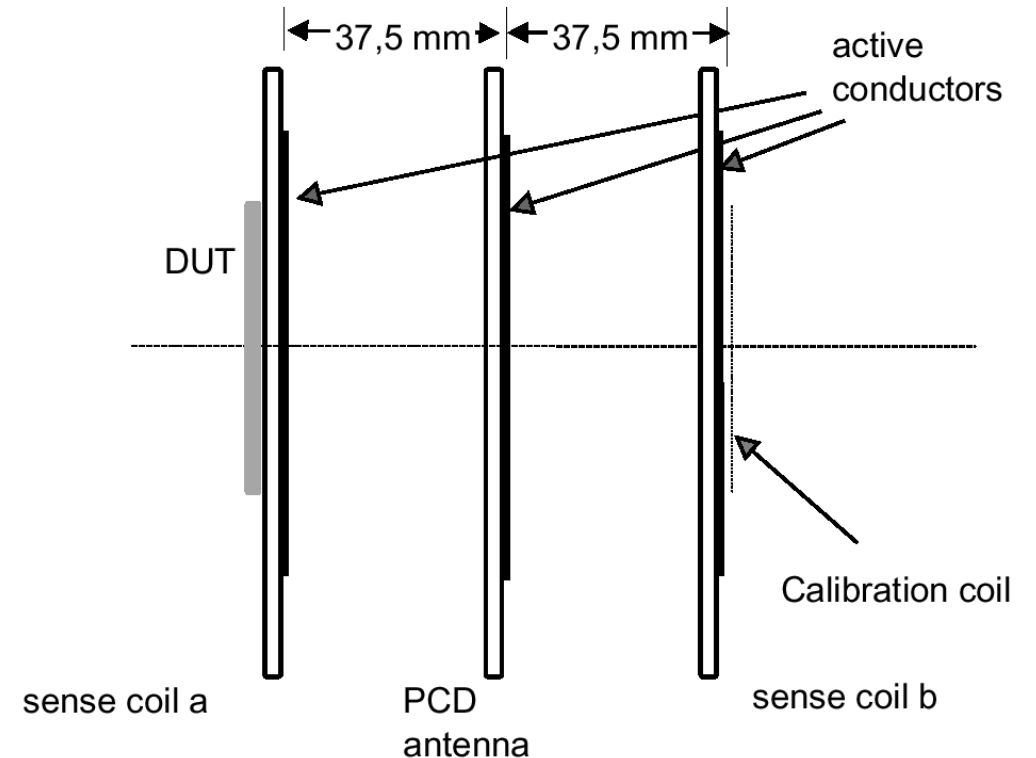
Simulation model for PCD antenna
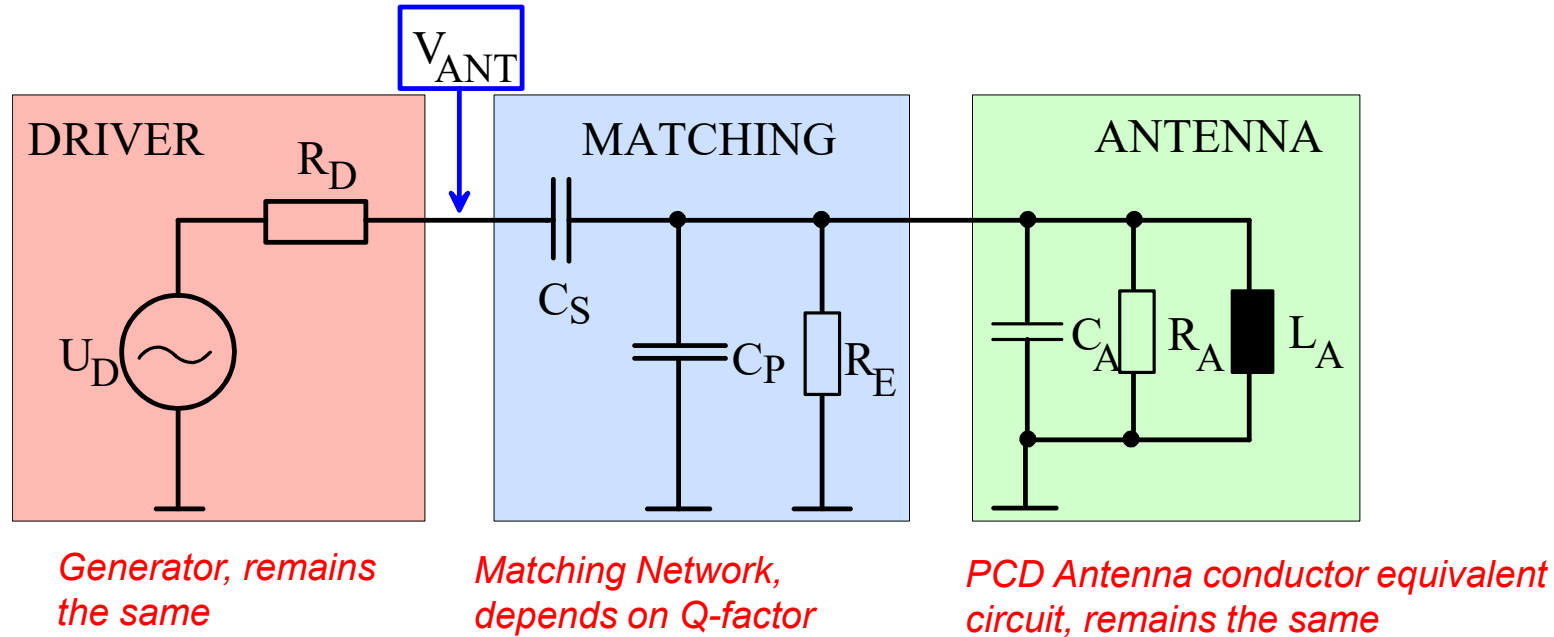
Generator:
- R_D = 50 Ohm

Matching Q12:
- R_E = 531,3 Ohm
- C_P = 200,9 pF
- C_S = 80,77 pF

Matching Q30:
- R_E = 2036,87 Ohm
- C_P = 229,2 pF
- C_S = 45,55 pF

Antenna conductor
- L_A = 0,462 µH
- C_A = 25,05 pF
- R_A = 4257 Ohm

Simulation model for Helmholtz arrangement (2 Sense coils)
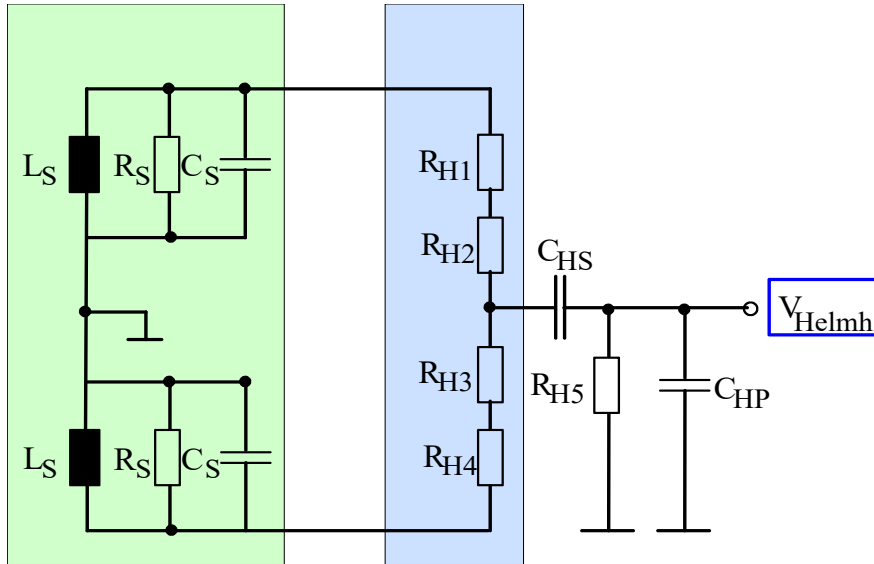
Antenna conductor equivalent circuit, remains the same

Helmholtz printboard equivalent circuit, remains the same

Sense coils:

- L_S = 422,3 nH
- C_S = 5,26 pF
- R_S = 5653,1 Ohm

Helmholtz-bridge:

- R_{H1} = 220 Ohm
- R_{H2} = 24 Ohm
- R_{H3} = 220 Ohm
- R_{H4} = 24 Ohm

Signal reception:

- C_{HS} = 100 nF
- R_{H5} = 300 kOhm
- C_{HP} = 3 pF

Simulation model for Calibration coil
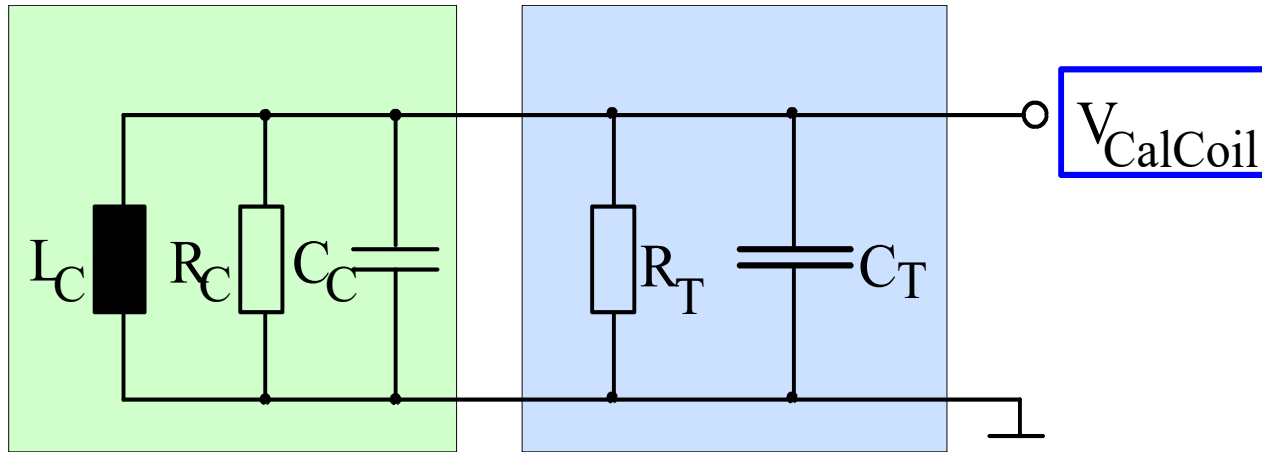
Antenna conductor equivalent circuit, remains the same

Probe equivalent circuit, remains the same

Calibration coil:

- L_C = 204 nH
- C_C = 9,0 pF
- R_C = 1767 Ohm

Probe:

- R_T = 1 MOhm
- C_T = 10 pF

Measured approximative coupling factors

PCD antenna to…

- CalCoil: 0,0841
- SenseCoil A: 0,1282
- SenseCoil B: 0,1282
- ID-1 DUT: 0,0834

Sense coil A to…

- CalCoil: 0,2392
- SenseCoil B: 0,0451
- ID-1 DUT: 0,2724

	L PCD in nH @ 3 MHz			
	Coil open	Coil short	stray factor	coupling factor
ID-1 Testcard	471,19	469,55	0,99652	0,0834
ID-1 Ref. PICC	471,07	469,54	0,99675	0,0805
Cal. Coil	471,37	469,70	0,99646	0,0841
Sense Coil a	471,31	467,42	0,99175	0,1282
Sense Coil b	471,31	467,42	0,99175	0,1282

	L Sense Coil in nH @ 3 MHz			
	Coil open	Coil short	stray factor	coupling factor
ID-1 Testcard	422,77	406,78	0,96218	0,2724
ID-1 Ref. PICC	422,36	408,85	0,96801	0,2509
Cal. Coil	427,15	414,75	0,97097	0,2392
Sense Coil b	422,14	421,71	0,99898	0,0451

PCD antenna arrangements for class 1 … 6

● For different card antenna size classes, 2 sets of coils are specified for the coaxial antenna arrangement:

PCD 1 antenna set
- class 1
- class 2
- class 3
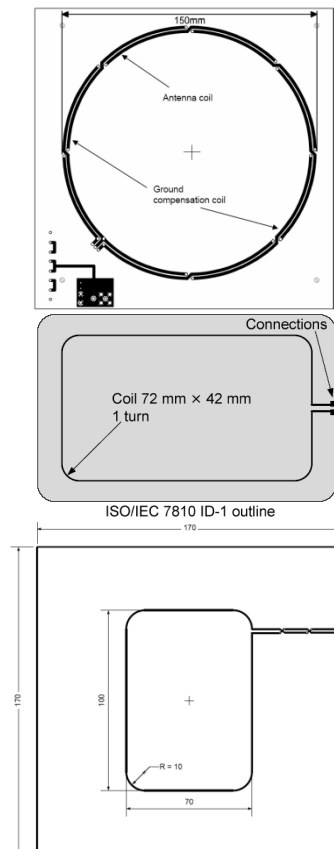
PCD 2 antenna set
- class 4
- class 5
- class 6
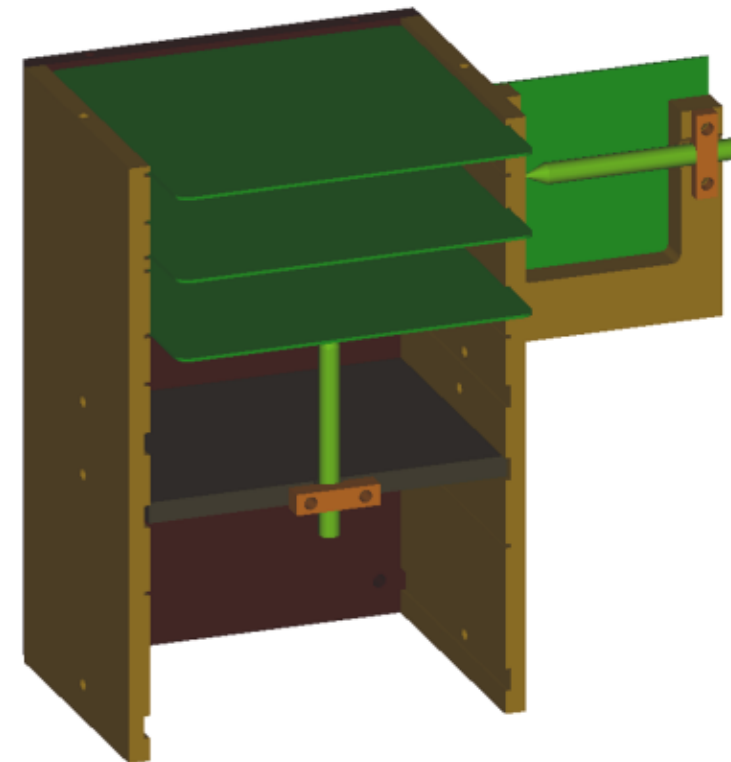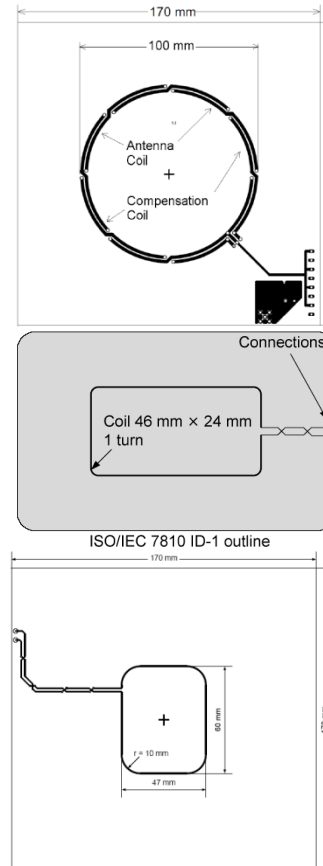
Practical implementation of an ISO/IEC test bench

Remote control bus interface

Remote control bus interface

External command trigger

Reader Rx path

Helmholtz bridge signal

Load modulation

Digital lab reader
& arbitrary waveform generator

Reader signal

Modulated carrier

Reader signal

Modulated, amplified carrier

Lab amplifier
0,01 - 250 MHz, 75 W

10373-6
antenna
arrangement

Calibration coil signal

H-field amplitude, Envelope shape

Digital sampling osc.
2 GS/s,
8 bit ampl. res.
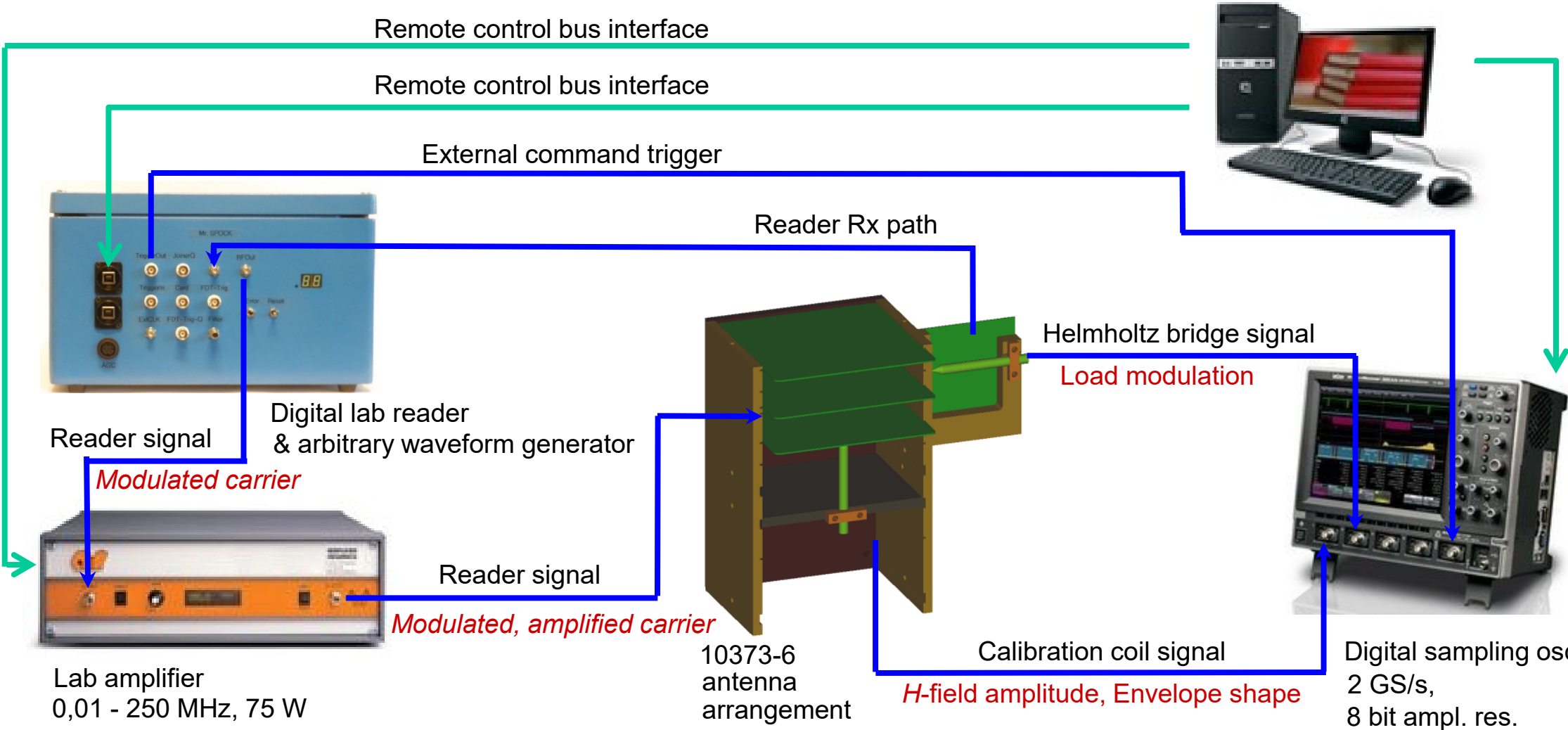
Setup for Card test

Measurement methods for Proximity card tests

Resonance frequency, f_{RES}

- **Explanation**

  – It shall be verified, that the card resonance frequency is in the expected range.

- **Test procedure**

  – Impedance analyzer with ISO/IEC CalCoil 1 as fixture, is compensated. The DUT card is placed in 10 mm distance, and the serial resistance is measured. The max. resistance value appears at the resonance frequency.

- **Criterion**

  – informative test, resonance should be in the specified range, else the card may be defect.

- **(possible) frame conditions**

  – temperature…

f_{RES} measurement using Agilent 4395A Analyzer

Procedure

- Compensate test fixture

  – Cal ➔ Fixture Compen ➔ Compen Menu

  – Use CalCoil as fixture with SMA connector

  – Short, Done

  – Check: Flat resistance trace over frequency

- Measure resonance frequency

  – Place transponder card in 10 mm distance to fixture

  – Adjust power level

  – Marker ➔ Search ➔ Max

  – Read out frequency of max. resistance
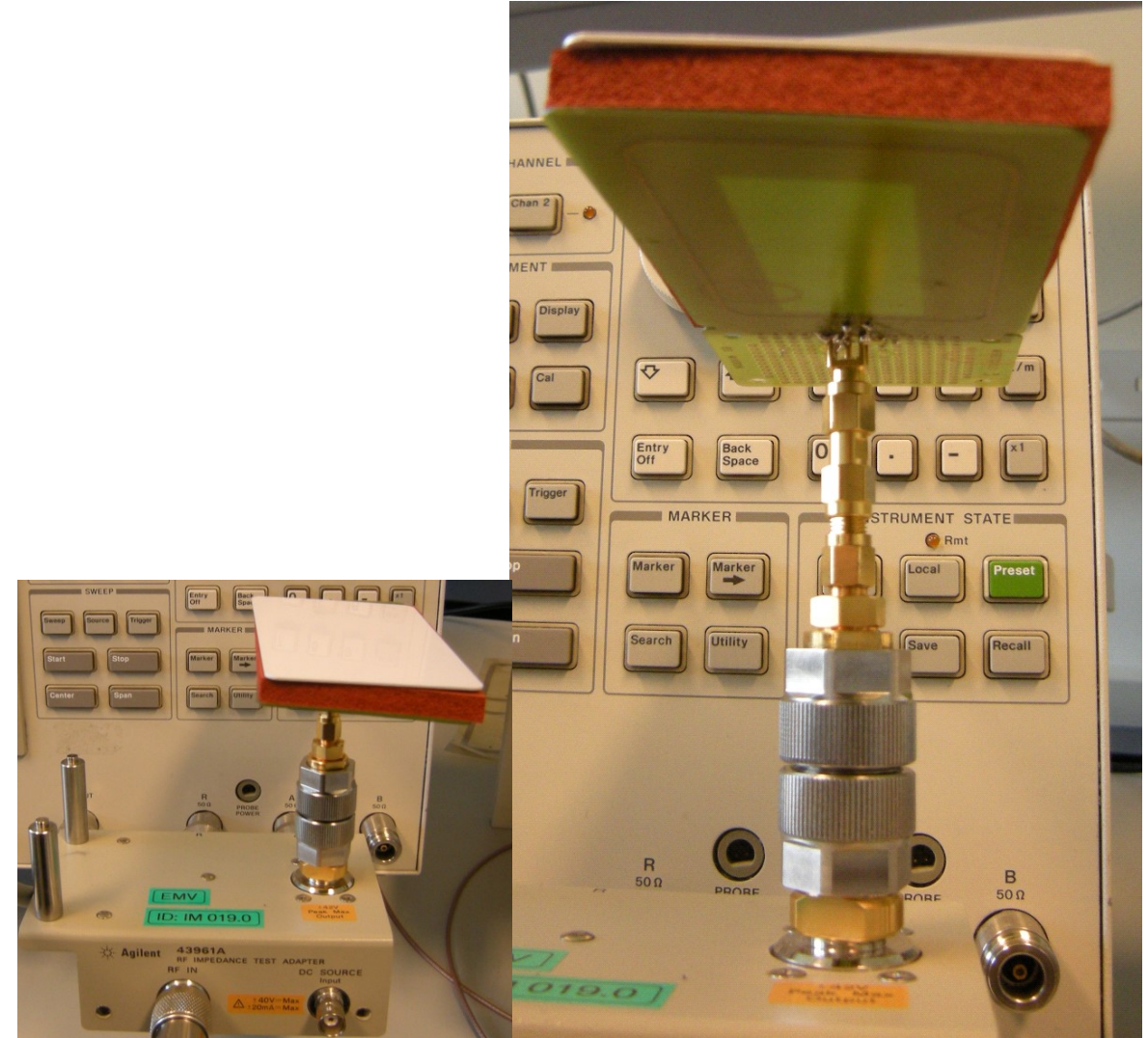
Transponder properties

- Measurement of resonance frequencies of a contactless transponder, using different *H*-field strength levels (indicated as instrument output power) shows the **variation of resonance frequency and Q**.

CH1 Rs   1 OHM / REF 4 OHM

Power	Rs	Frequency
- 20 dBm	8,0005 Ohm	17,4625 MHz
- 10 dBm	7,9983 Ohm	17,4750 MHz
- 5 dBm	7,3512 Ohm	17,3375 MHz
0 dBm	6,6344 Ohm	16,9875 MHz
5 dBm	4,4739 Ohm	16,9000 MHz
10 dBm	2,8075 Ohm	16,8375 MHz
15 dBm	2,0540 Ohm	16,6250 MHz
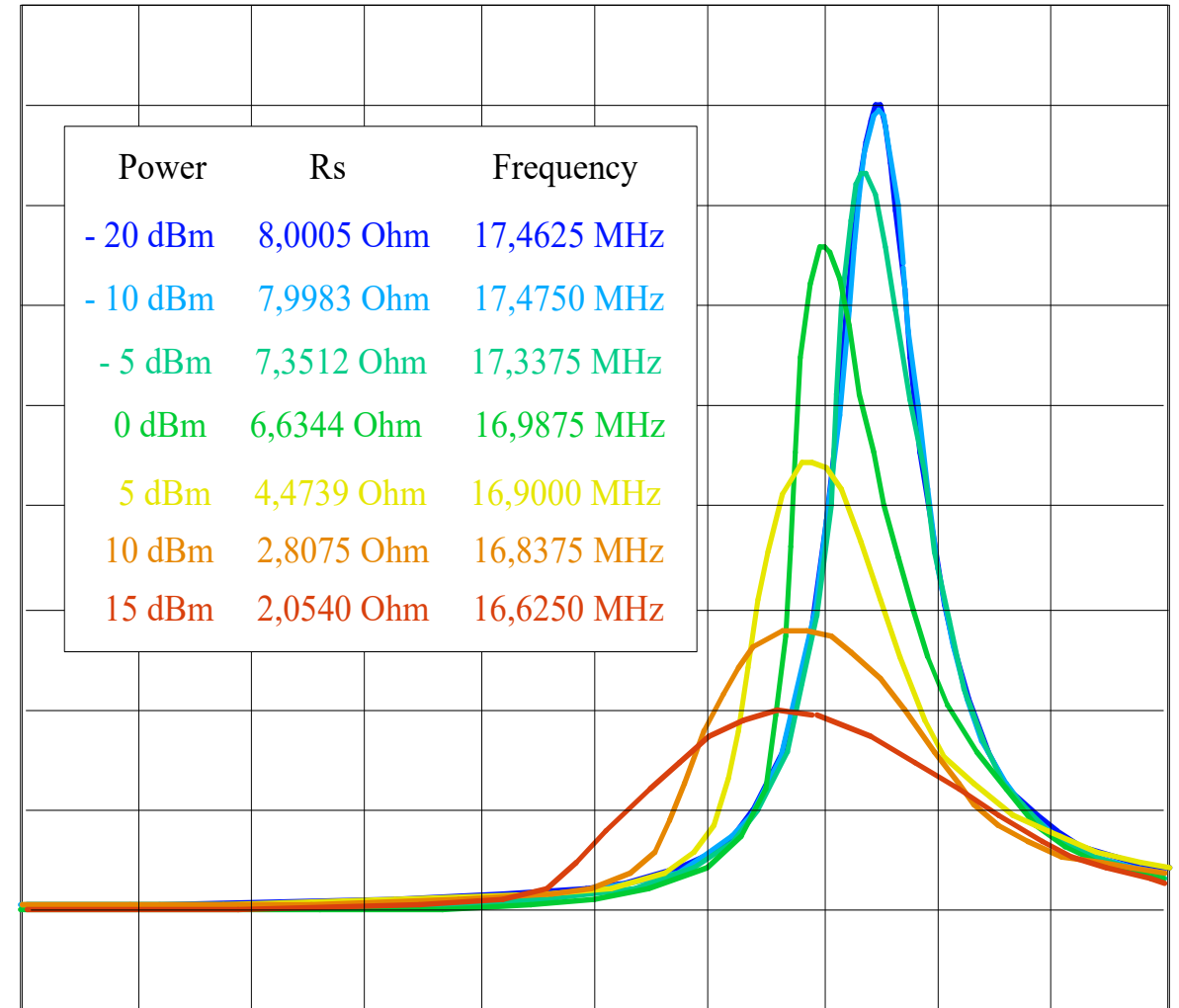
START 10 MHz   STOP 20 MHz

"Card Loading" of the Reader

- **Explanation**
  - Contactless reader implementations normally use resonant antenna networks, so all properties are affected by **Card loading**. This test shall assure, no card provides more loading to a reader as it is tested for (Ref PICC is adjusted to a defined maximum loading condition)

- **Test procedure**
  - A Proximity card is placed as DUT into the setup for card test. Min. H-field is adjusted. Then the card is removed (so the H-field increases). Then, the Ref PICC (of the appropriate class), adjusted to the defined max. loading is placed in the setup. Now, the H-field must drop below the specified minimum H-field, (for the card to pass the test).

- **Criterion**
  - H-field with Ref PICC set to maximum loading condition is lower than H-field with the tested card

- **(possible) frame conditions**
  - Resonance, temperature, operating condition

Minimum *H*-field for operation, H_{MIN}

- **Explanation**
  - The lowest *H*-field as measured on the setup, at which a transponder can operate.

- **Test procedure**
  - The RF carrier is switched on (for sufficient time, e.g. 5 ms), and then a reader command is transmitted iteratively. Starting from a higher *H*-field, the field amplitude is reduced in steps until the transponder stops to respond.

- **Criterion**
  - e.g. a correct response content, resulting in *pass / fail* verdict

- **(possible) frame conditions**
  - Resonance frequency…antenna resonance circuit
  - Modulation parameters…chip demodulator
  - Command (REQA/B, read or write commands)… chip current
  - Temperature…

Example: *H*-field for operation

Reader & Card Type: Pegoda-Type A
Test: Minimum Fieldstrength
23.08.2008   14:23:11
Pattern: 106_Q12_standard_7p_bin.txt
Temperature is: RT

Fieldstrength	Result	Pass	Repetitions	Failure Code
0.739	Fail	0	1	
0.755	Fail	0	1	
0.763	Fail	0	1	
0.775	Fail	0	1	
0.822	Fail	0	1	
0.822	Fail	0	1	
0.822	Fail	0	1	
0.831	Fail	0	1	
0.841	Fail	0	1	
0.855	Fail	0	1	
0.867	Fail	0	1	
0.881	Fail	0	1	
0.896	Fail	0	1	
0.909	Fail	0	1	
0.925	Fail	0	1	
0.933	Fail	0	1	
0.947	Fail	0	1	
0.968	Fail	0	1	
0.982	Fail	0	1	
1.002	Fail	0	1	
1.023	Fail	0	1	
1.045	Fail	0	1	
1.066	Fail	0	1	
1.093	Response	1	1	
1.114	Response	1	1	
1.135	Response	1	1	
1.160	Response	1	1	
1.185	Response	1	1	
1.220	Response	1	1	
1.251	Response	1	1	
1.283	Response	1	1	
1.314	Response	1	1	
1.351	Response	1	1	
1.429	Response	1	1	
1.463	Response	1	1	
1.511	Response	1	1	
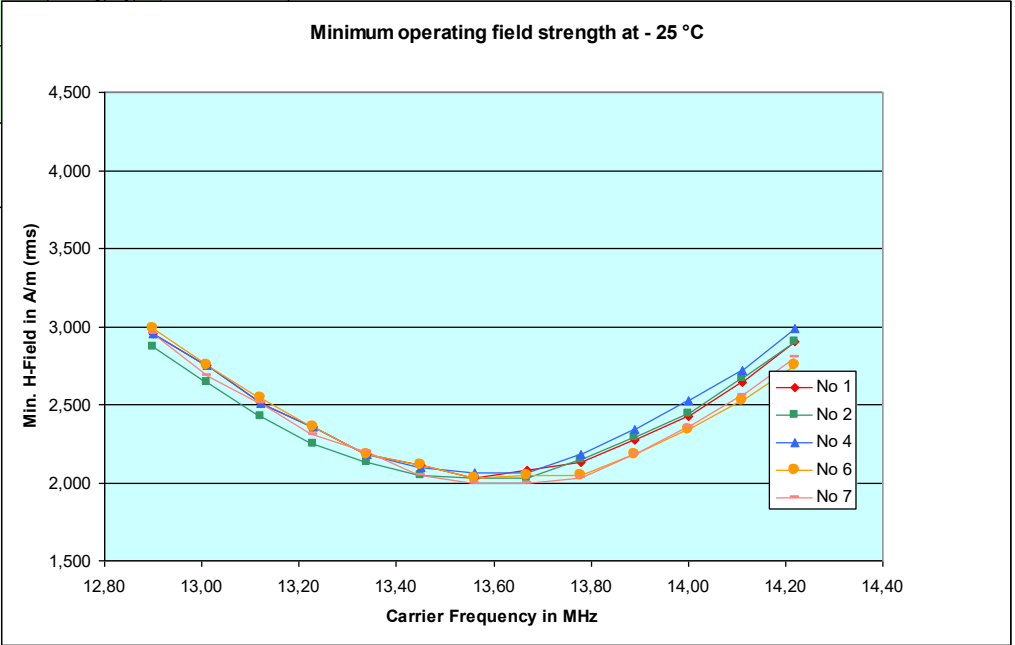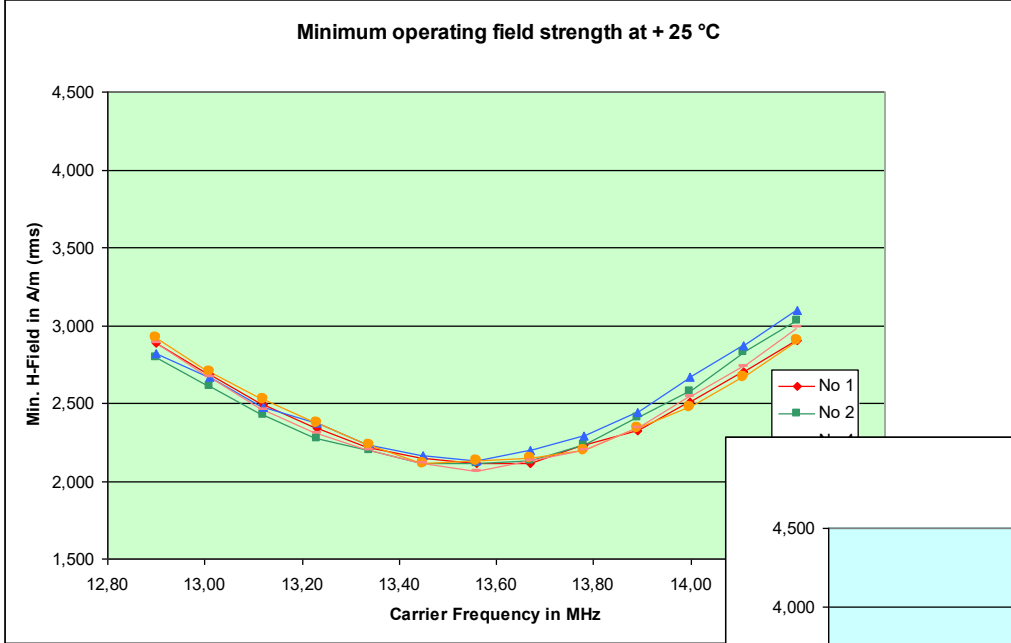
Reader Modulation / analogue demodulator

- **Explanation**
  - Reader modulation parameters are all varied (at least to the specified limit values) to see, if the analogue demodulator recognizes a command.
- **Test procedure**
  - A command, or a sequence of commands, sent with specific modulation parameters on carrier ("envelope wave shapes") is repeated iteratively. The *H*-field is varied from minimum (1,5 A/m) to maximum (7,5 A/m) value.
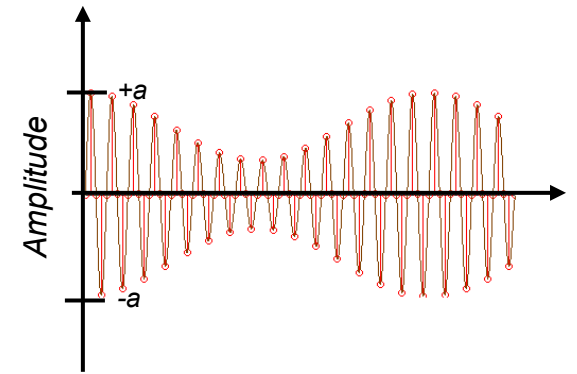- **Criterion**
  - …is a (content-wise) correct response of the transponder (verdict PASS / FAIL).
- **(possible) frame conditions**
  - Resonance frequency…
  - Command / State (Read-, Write process, Cryptography,…)
  - Temperature…

Reader command Envelope shape
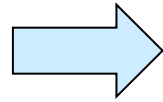## analysis based on Hilbert transform

AM of sine-wave signal

$$s(t) = [1 + m(t)] \cdot \cos(\omega_C t + \varphi_K)$$

Signal component in Time domain

$$v(t) \cdot \cos(\omega_c t + \varphi_0)$$

Signal group in Time domain

$$s_A(t) = [1 + m(t)] \cdot \sum_{k=0}^{n} A_k \cos(k\omega_c t + \varphi_k)$$

$$s_H(t) = [1 + m(t)] \cdot \sum_{k=0}^{n} A_k \sin(k\omega_c t + \varphi_k)$$

Base-band amplitude = envelope
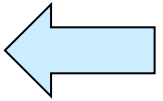
$$e(t) = \sqrt{s_A(t)^2 + s_H(t)^2}$$

Signal component in Frequency domain

$$\frac{e^{+j\varphi_0}}{2} \underline{V}(\omega - \omega_C) + \frac{e^{-j\varphi_0}}{2} \underline{V}(\omega + \omega_C)$$

Apply Hilbert operator (90 ° phase shift)

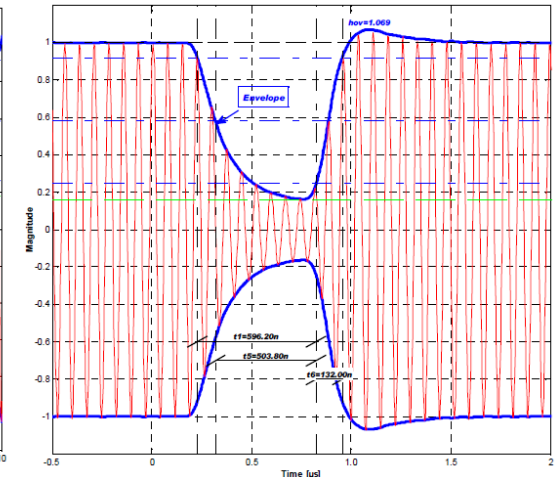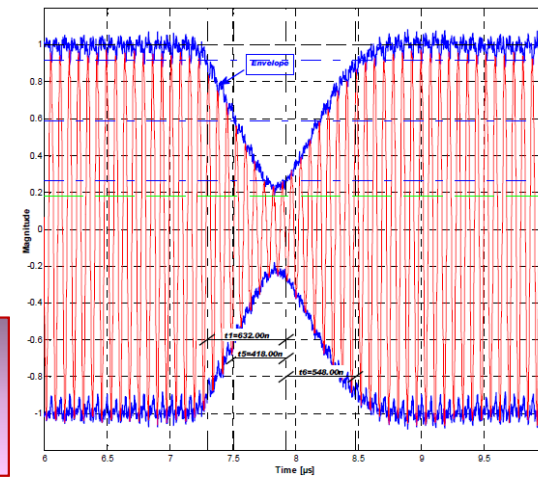$$e^{-j\frac{\pi}{2} \text{sgn}(\omega)}$$

$$\frac{e^{+j\varphi_0}}{2} \underline{V}(\omega - \omega_C) \cdot e^{j\frac{\pi}{2}} + \frac{e^{-j\varphi_0}}{2} \underline{V}(\omega + \omega_C) \cdot e^{-j\frac{\pi}{2}}$$

Noise and distortions cause ambiguities – base band filtering and signal pre-conditioning may affect time parameters.

ISO/IEC modulation envelope shape tool
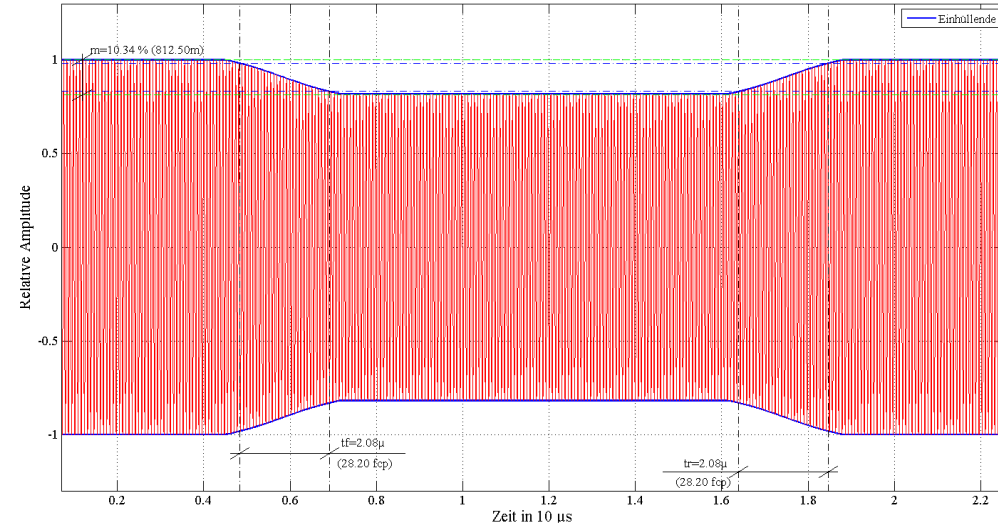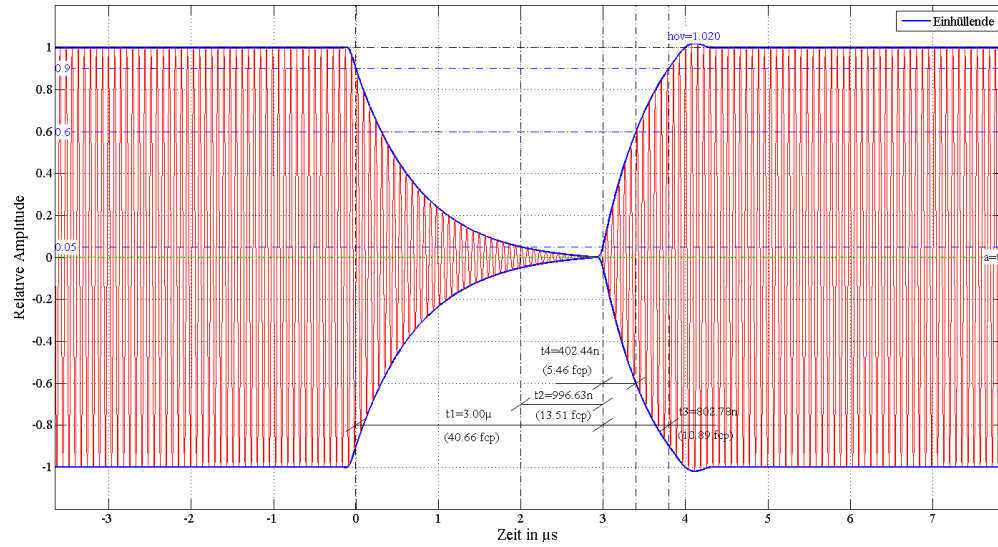
Problem Aspect: High residual carrier @ 106 kbit/s

The LDR demodulator for 106 kbit/s senses the envelope of the coil voltage.

For higher H-field, the chip limiter is active so the shunt has lower resistance, which reduces the coil voltage and transponder Q-factor. According to the base standard, a residual carrier up to 5 % is allowed.

Depending on regulation of the chip current consumption during the modulation pause (time dependent behaviour), the modulation index on the coil voltage can be much reduced, so the demodulator may not be able to detect the pause for high energy (resonance close to carrier, large antenna area,…).
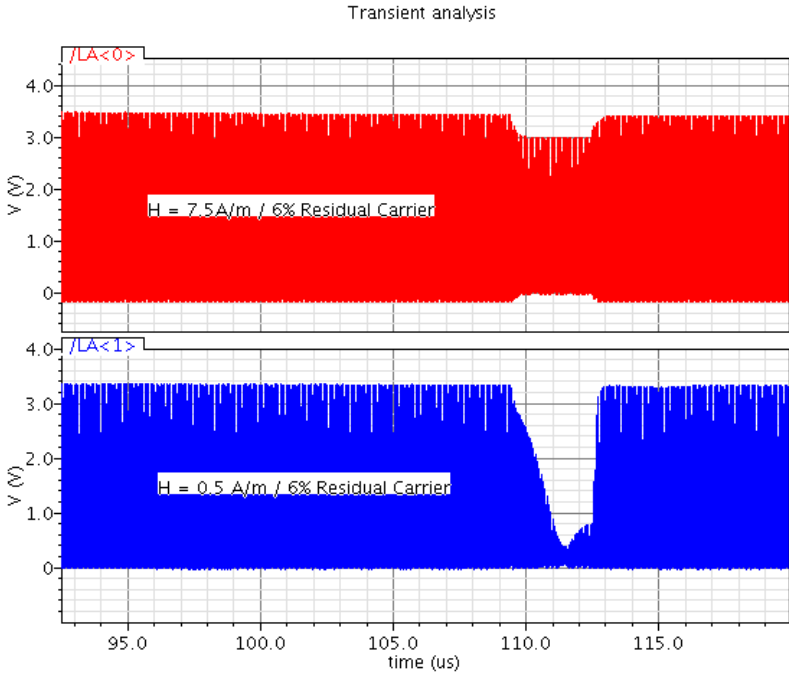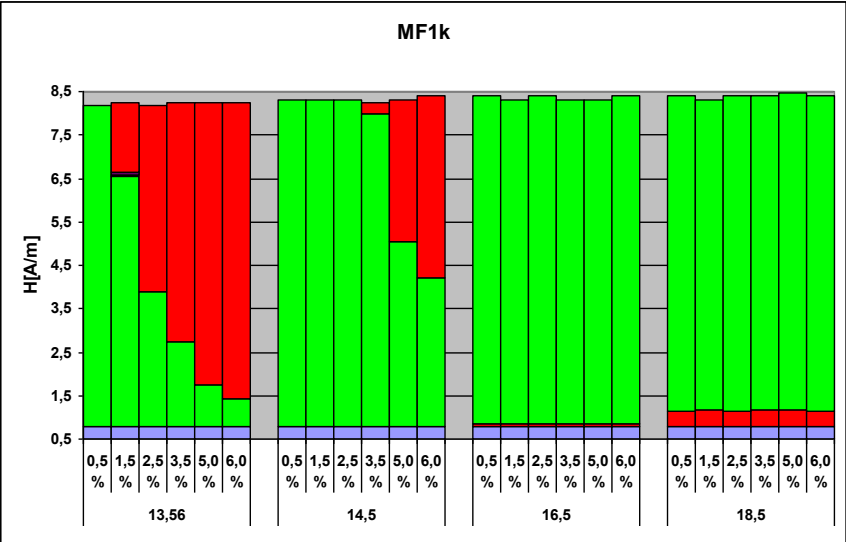
Problem Aspect: HDR envelope shapes and H_{MIN}

A set of pulse shapes is available for characterization of chip demodulator at any data rate.

The 232 pulse shapes (+ 8 ICAO + 8 BSI shapes) cover and exceed the base standard requirements.

Verification of the pulse parameters t1, t2, t3, t4, t5, t6 and a is done with the Matlab Software tool „ISOwaver V1.0", using the Hilbert Algorithm.
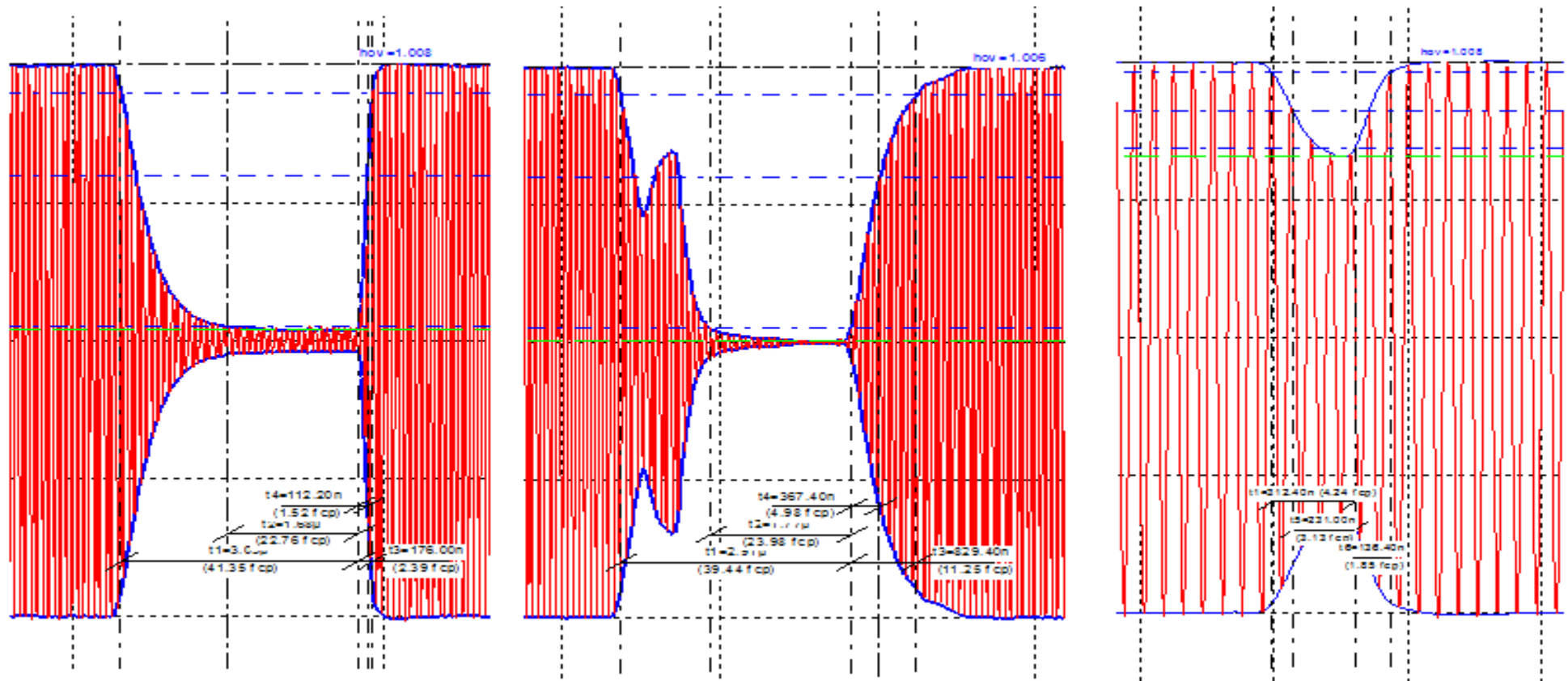
Problem Aspect: HDR envelope shapes and H_{MIN}

A matrix of measurements is performed automatically (temperature, data rate, pulse parameter).

Evaluation using the tool „ISO Waver" gives a quick graphical overview of tested H-field strengths (setup allows < 2 % tolerance) and Hmin / Hmax limits.

The concept sets warning limits with margin to the standard (1,2 A/m instead of 1,5 A/m, 8,0 A/m instead of 7,5 A/m) and allows detailed failure analysis for critical wave shapes.

- One sample is characterized over night (12 hours).

  This means

  – 24 (*H*-field strengths) x

  – 5 (repetitions) x

  – 232 (modulation envelope shapes) x

  – 3 (temperatures)

  = 1,6 million individual measurements typically.
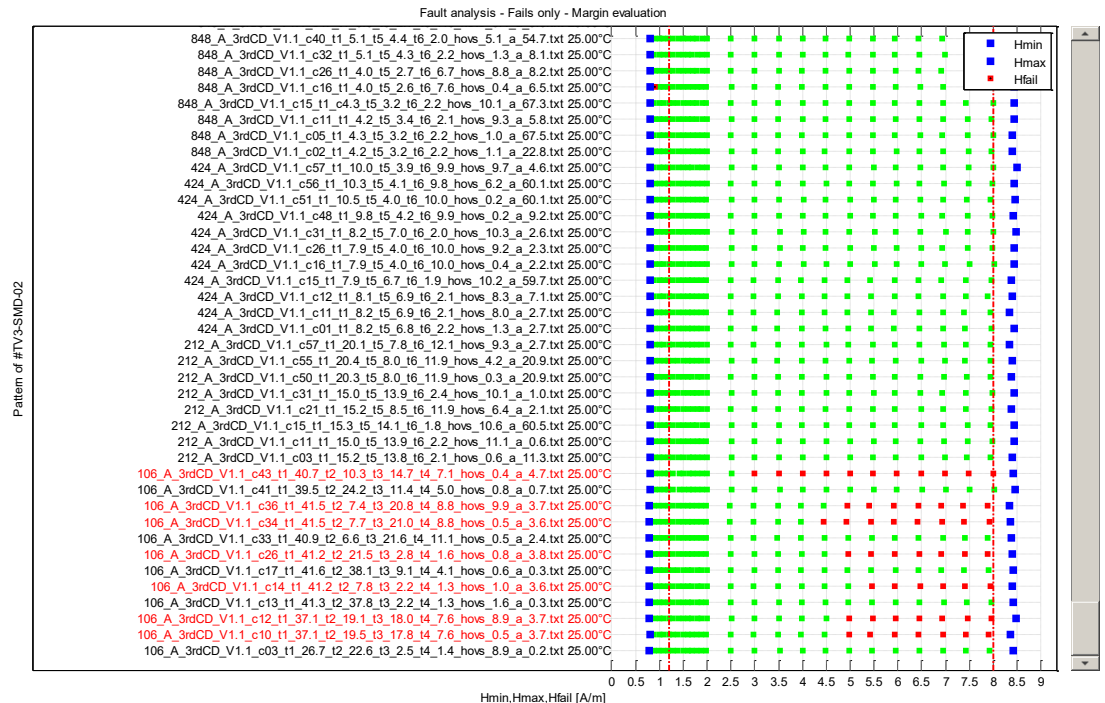
Load modulation (ISO/IEC side-band amplitudes)

- **Explanation**

  – Contactless transponder Load modulation is measured.

- **Test procedure**

  – A command is repeated iteratively. The response of the transponder is captured using the Helmholtz arrangement of the ISO/IEC setup for Card test. 2 sub-carrier cycles are Fourier-transformed, and the amplitudes at the upper side-band (13,56 + 0,8475 MHz) and lower side-band (13,56 – 0,8475 MHz) are evaluated versus the minimum limit in the standard. *H*-field strength is varied from minimum to maximum value (e.g. 1,5 A/m – 7,5 A/m).

- **Criterion**

  – For both side-band amplitudes to exceed the minimum limit specified in the base standard, results in a **pass**.

- **(possible) frame conditions**

  – Resonance frequency…antenna resonance circuit

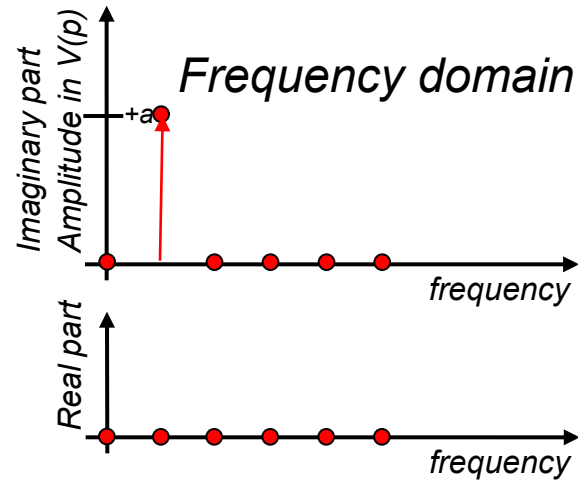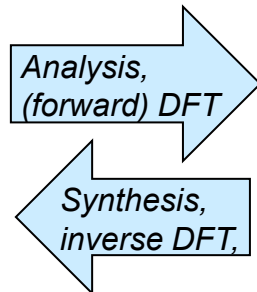 – State of the transponder (e.g. Read / Write to memory….)

  – Temperature…

Discrete signals in *time-domain, frequency-domain* and *Phasor view*

Time domain

Amplitude in Volts (peak)

+a

-a

time

Time series of discrete amplitudes

N samples

0   Index i   N-1

$$x_i \underset{i=0...N-1}{=} \sum_{k=0}^{N/2} \mathrm{Re}\{\overline{X}_k\} \cdot \cos\left(\frac{2\pi k i}{N}\right) +$$

$$+ \sum_{k=0}^{N/2} \mathrm{Im}\{\overline{X}_k\} \cdot \sin\left(\frac{2\pi k i}{N}\right)$$

e.g. 128 pt time-domain

Analysis, (forward) DFT

Synthesis, inverse DFT,

Frequency domain

Imaginary part
Amplitude in V(p)

+a

frequency

Real part

frequency

Frequency spectrum of discrete amplitudes

N/2 + 1 samples

Real part
(cos wave amplitudes)

0   Index k   N/2

N/2 + 1 samples

Imaginary part
(sine wave amplitudes)

0   Index k   N/2

$$\mathrm{Re}\{X_k\} = +\sum_{k=0}^{N-1} x_i \cdot \cos\left(\frac{2\pi k i}{N}\right)$$

$$\mathrm{Im}\{X_k\} = -\sum_{k=0}^{N-1} x_i \cdot \sin\left(\frac{2\pi k i}{N}\right)$$

65 pt frequency-domain x 2
2 pt contain no information: Im { X_0 } = 0 and Im { $X_{N/2}$ } = 0
Real part contains the DC component

Phasor view

108 °   72 °
144 °   36 °
180 °   0 °
216 °   324 °
252 °   288 °
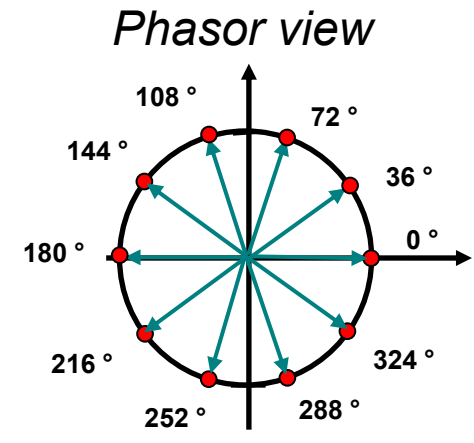
Phasors, the polar view
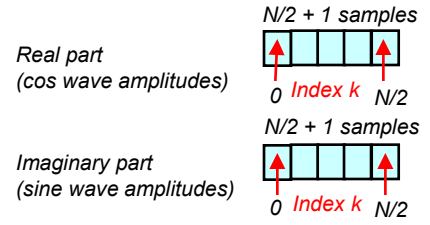
$$\mathit{Rotation\ speed} = \omega = 2\pi f_C$$

$$\mathit{Phasor\ radius} = \mathit{amplitude}\ a$$

Discrete signals in *time-domain, frequency-domain* and *Phasor view*

Time domain

Amplitude in Volts (peak)

$+a$

$-a$

time

Time series of discrete amplitudes

N samples

0   *Index i* $N-1$

Frequency domain

Imaginary part
Amplitude in V(p)

$+a$

frequency

Real part

frequency

Frequency spectrum of discrete amplitudes

$N/2 + 1$ samples

Real part
(cos wave amplitudes)

0 *Index k* $N/2$

$N/2 + 1$ samples

Imaginary part
(sine wave amplitudes)

0 *Index k* $N/2$

Phasor view

$+\omega_{SC}$ $-\omega_{SC}$

Phasors, the polar view

$$Rotation \; speed \;\; = \;\; \omega \;\; = \;\; 2\,\pi\,f_C$$

$$Phasor \; radius \;\; = \;\; amplitude\,a$$

Analysis, (forward) DFT

Synthesis, inverse DFT,

$$x_i \underset{i=0...N-1}{} = \sum_{k=0}^{N/2} \mathrm{Re}\{\overline{X}_k\} \cdot \cos\left(\frac{2\pi k i}{N}\right) \;\; +$$

$$+ \;\; \sum_{k=0}^{N/2} \mathrm{Im}\{\overline{X}_k\} \cdot \sin\left(\frac{2\pi k i}{N}\right)$$

e.g. 128 pt time-domain

$$\mathrm{Re}\{X_k\} \;\; = \;\; +\sum_{k=0}^{N-1} x_i \cdot \cos\left(\frac{2\pi k i}{N}\right)$$

$$\mathrm{Im}\{X_k\} \;\; = \;\; -\sum_{k=0}^{N-1} x_i \cdot \sin\left(\frac{2\pi k i}{N}\right)$$

65 pt frequency-domain x 2
2 pt contain no information: Im { X_0 } = 0 and Im { $X_{N/2}$ } = 0
Real part contains the DC component

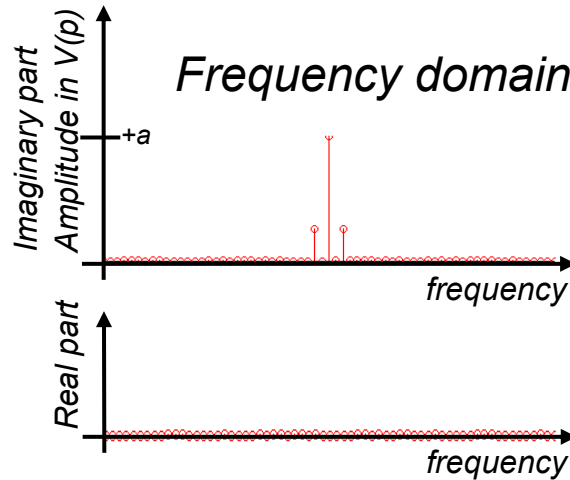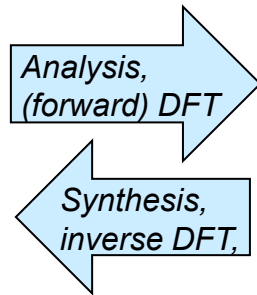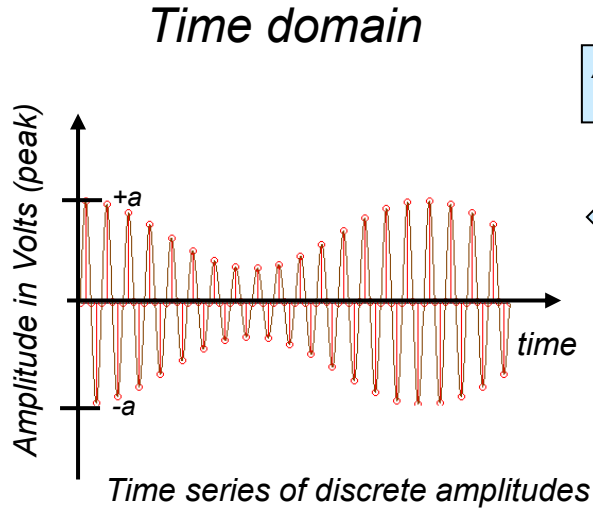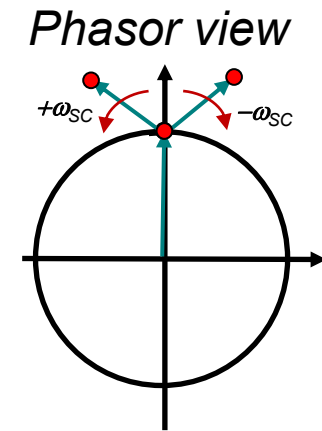# Discrete signals in *time-domain, frequency-domain* and *Phasor view*

Time domain

Amplitude in Volts (peak)

$+1.5\,a$

$+a$

$-a$

time

Time series of discrete amplitudes

Analysis, (forward) DFT

Synthesis, inverse DFT,

Frequency domain

Imaginary part Amplitude in V(p)

$+a$ — lower side band

upper side band amplitude

frequency

Real part

frequency

Frequency spectrum of discrete amplitudes

Phasor view
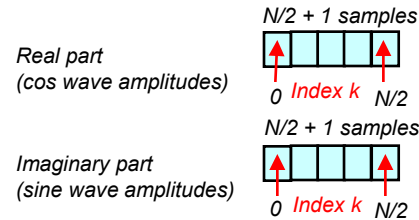
$+\omega_{SC}$ $-\omega_{SC}$

Phasors, the polar view

N samples

0   Index i   N-1

N/2 + 1 samples

Real part (cos wave amplitudes)

0 Index k N/2

N/2 + 1 samples

Imaginary part (sine wave amplitudes)

0 Index k N/2

$$Rotation\ \ speed\ \ =\ \ \omega\ \ =\ \ 2\,\pi\,f_C$$

$$Phasor\ \ radius\ \ =\ \ amplitude\ a$$

$$x_i \bigg|_{i=0...N-1} = \sum_{k=0}^{N/2} \mathrm{Re}\{\overline{X}_k\} \cdot \cos\left(\frac{2\,\pi\,k\,i}{N}\right) +$$

$$+ \sum_{k=0}^{N/2} \mathrm{Im}\{\overline{X}_k\} \cdot \sin\left(\frac{2\,\pi\,k\,i}{N}\right)$$

e.g. 128 pt time-domain

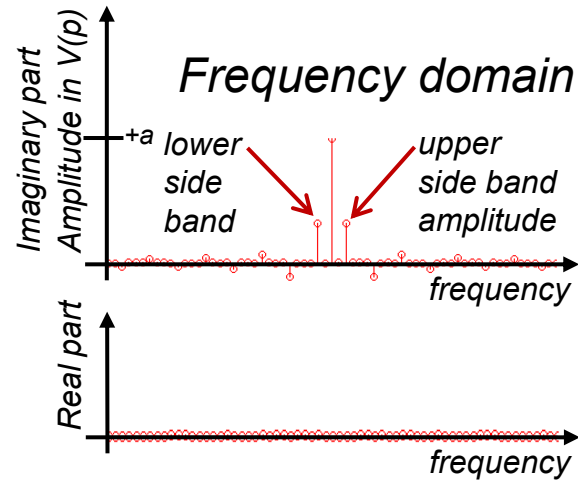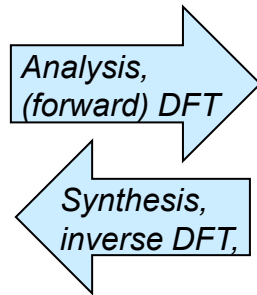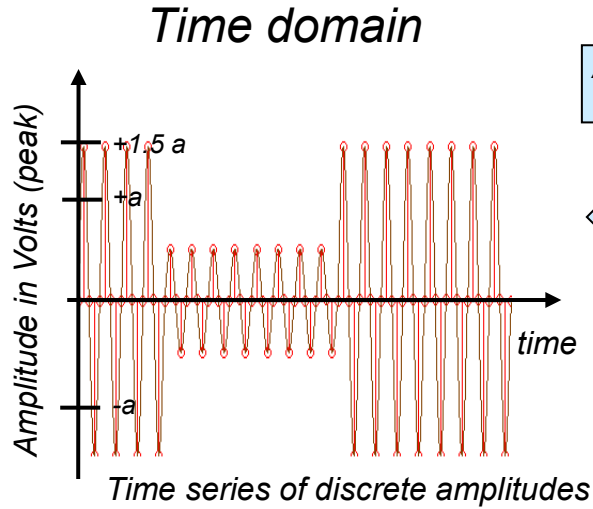$$\mathrm{Re}\{X_k\} = +\sum_{k=0}^{N-1} x_i \cdot \cos\left(\frac{2\,\pi\,k\,i}{N}\right)$$

$$\mathrm{Im}\{X_k\} = -\sum_{k=0}^{N-1} x_i \cdot \sin\left(\frac{2\,\pi\,k\,i}{N}\right)$$

65 pt frequency-domain x 2
2 pt contain no information: Im { X_0 } = 0 and Im { $X_{N/2}$ } = 0
Real part contains the DC component

Example for Load Modulation test

Loadmodulation for ISO14443A Chip and Etched Antenna

- 12,7125 MHz (lower Subcarrier)
- 14,4075 MHz (upper Subcarrier)
- ISO Minimum Limit

Side band levels in mV(p)

H-field in A/m(rms)
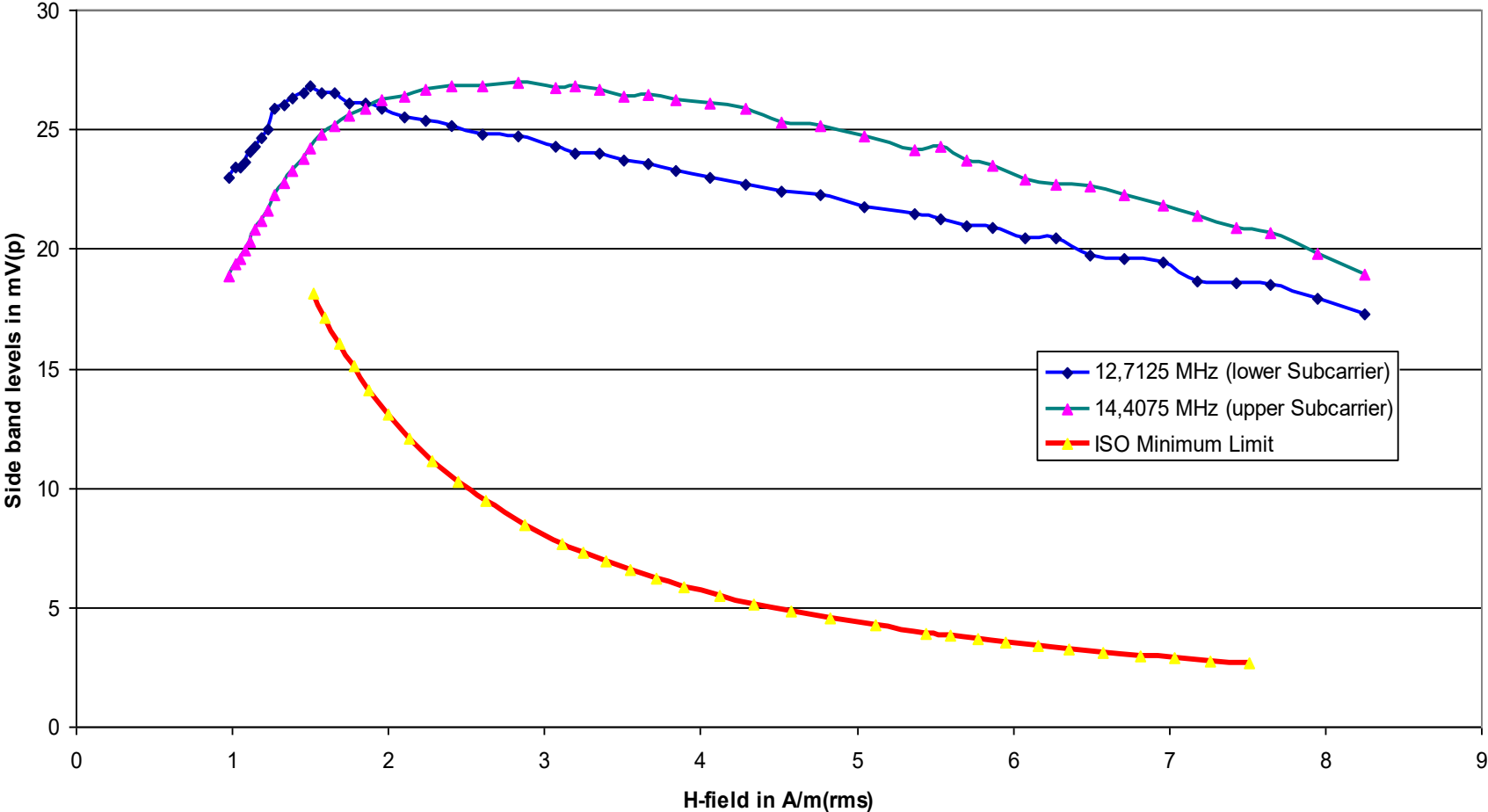
Problem Aspect: Load Modulation for small antennas

- Small antennas pick up less energy and produce less magnetic momentum, in addition they have less coupling to Sense coils. It is possible to compensate this (to some extent) by an increase of the transponder Q-factor. This can be achieved by higher blind current (increase of capacitance, decrease of inductance), or by higher limiter voltage.
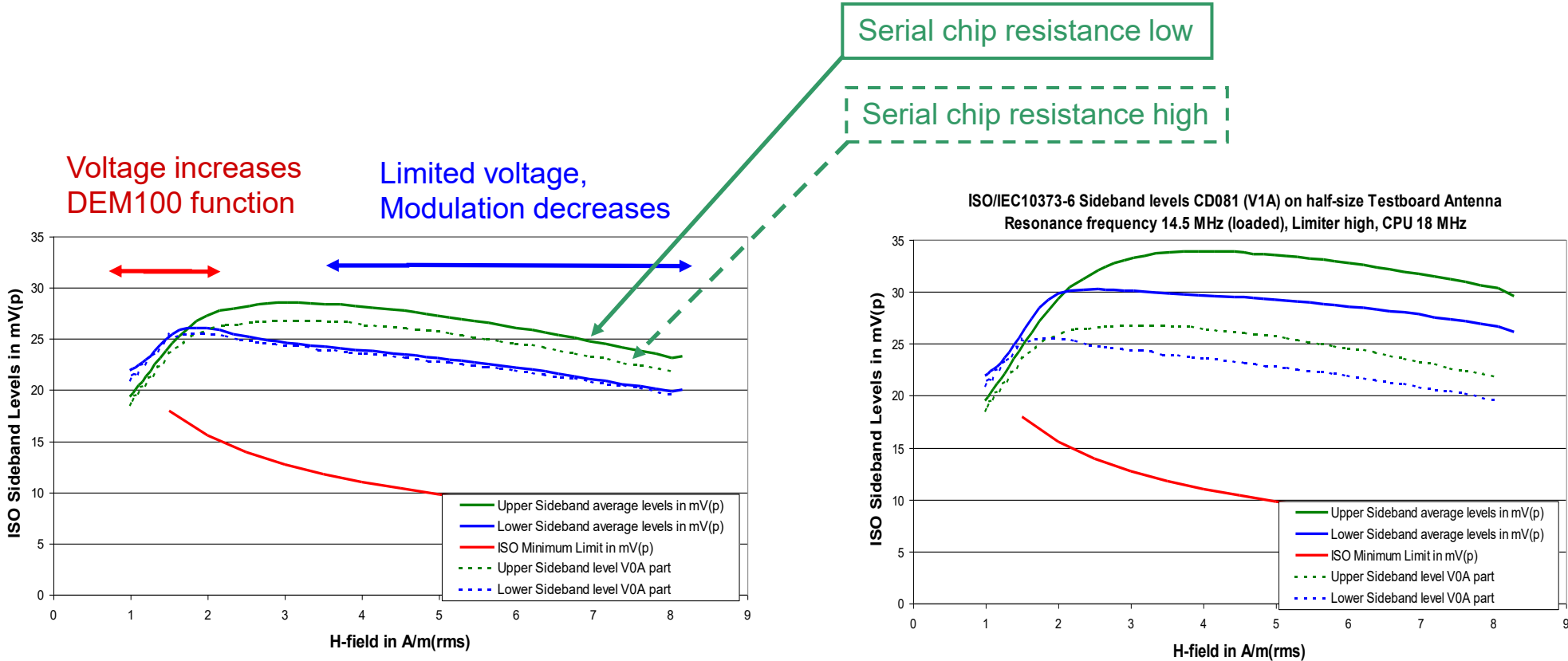
Frame Delay Time (PCD to PICC)

- **Explanation**
  - For Type A, anti-collision depends on the fact, that all transponders answer at the same time to REQA. So, the delay time from Reader command to Transponder response is measured accurately.
- **Test procedure**
  - Carrier reset, non-modulated carrier, and a command (or sequence of commands) is repeated iteratively. The exact time between end of Reader command and start of Transponder load modulation is measured with Oscilloscope. The H-field strength is at least varied from H_{MIN} to H_{MAX}.
- **Criterion**
  - to keep the delay variation in a specified time window (6 carrier cycles)..
- **(possible) frame conditions**
  - Resonance frequency…antenna resonance circuit
  - Command
  - Temperature…

Problem Aspect: Frame Delay Time PICC - PCD

- The Frame Delay time is specified in part 3 of the base standard and must be kept accurately. The HDR demodulator (DEM10) in comparison to the LDR demodulator (DEM100) shows significant change of FDT over *H*-field and practically uses the full allowed range in 1,5 …. 7,5 A/m. Reason is, the DEM10 depends more on power, so it also depends on resonance frequency, temperature, etc.

Room Temperature

Frame Delay Time (Reader to Card)
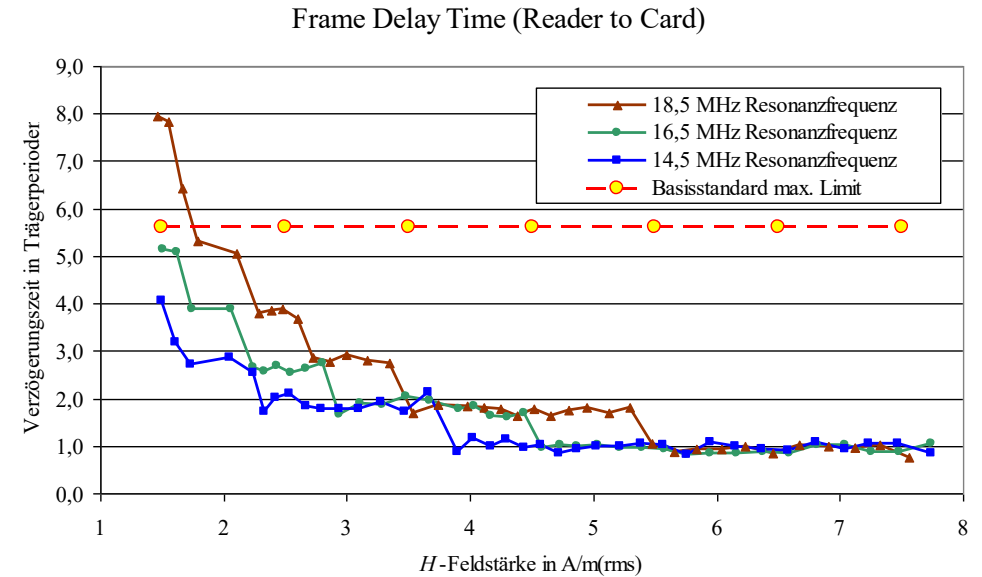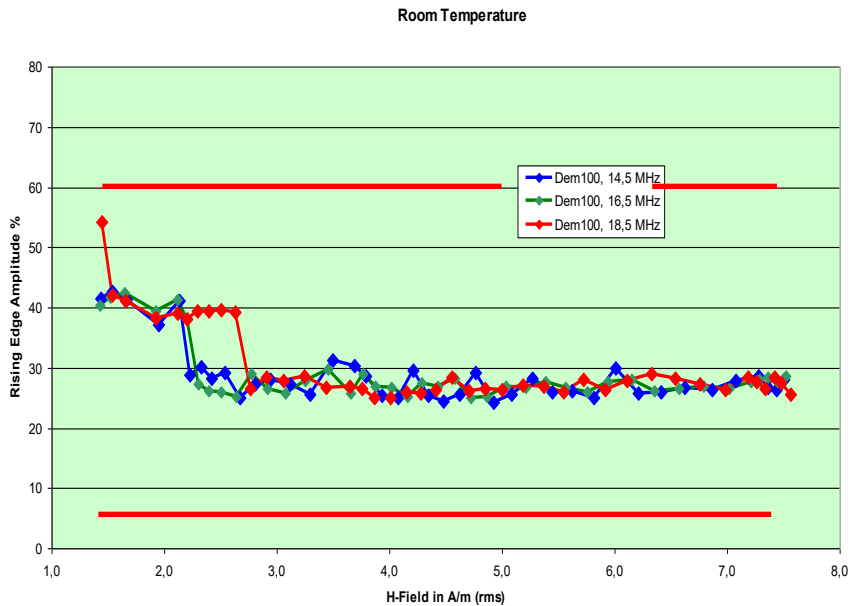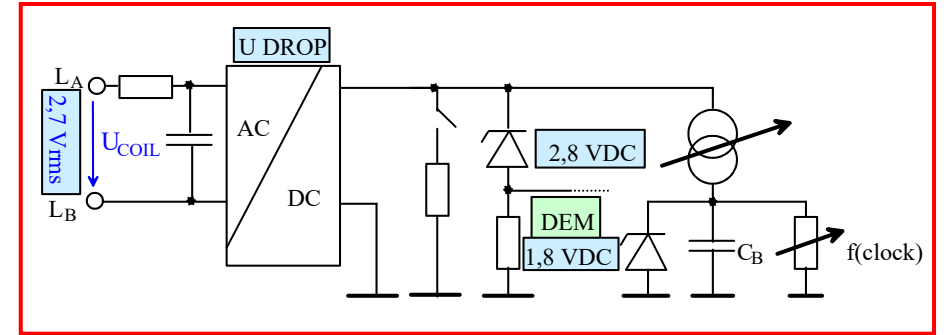
Start up time

- **Explanation**
  - The transponder must get ready for operation after a specified time of sufficient carrier H-field strength
- **Test procedure**
  - A sequence, consisting of *HF pause – non-modulated carrier – Reader command – non-modulated carrier* is repeated iteratively. The H-field strength is varied from minimum to maximum value (1,5 – 7,5 A/m for Class 1 transponder antenna).
- **Criterion**
  - Correct content of the Proximity card response
- **(possible) frame conditions**
  - Resonance frequency
  - Temperature…

Reset time

- **Explanation**
  - The transponder shall be reset (to initial state) after a certain time of H-field off.
- **Test procedure**
  - First, the transponder is set to a specific state (HALT). Then, the 13,56 MHz alternating H-field is switched off for an adjustable duration. Next, the H-field is switched on again (min. for the start-up time) and a REQUEST command is sent. The H-field strength is at least varied from H_{MIN} to H_{MAX}.
- **Criterion**
  - If the transponder does respond to the REQUEST, it was reset.
- **(possible) frame conditions**
  - Resonance frequency
  - Temperature…

Problem Aspect: EMD ("Electro-Magnetic Distortion")

- A switch in chip current consumption (e.g. CPU clock setting change) will cause a non intended load modulation, which could affect a reader reception. The base standard defines a time window for low EMD, with specified maximum level. Measurement is done in ISO/IEC10373-6 antenna arrangement, with Spectrum Analyzer or Scope and processing software.
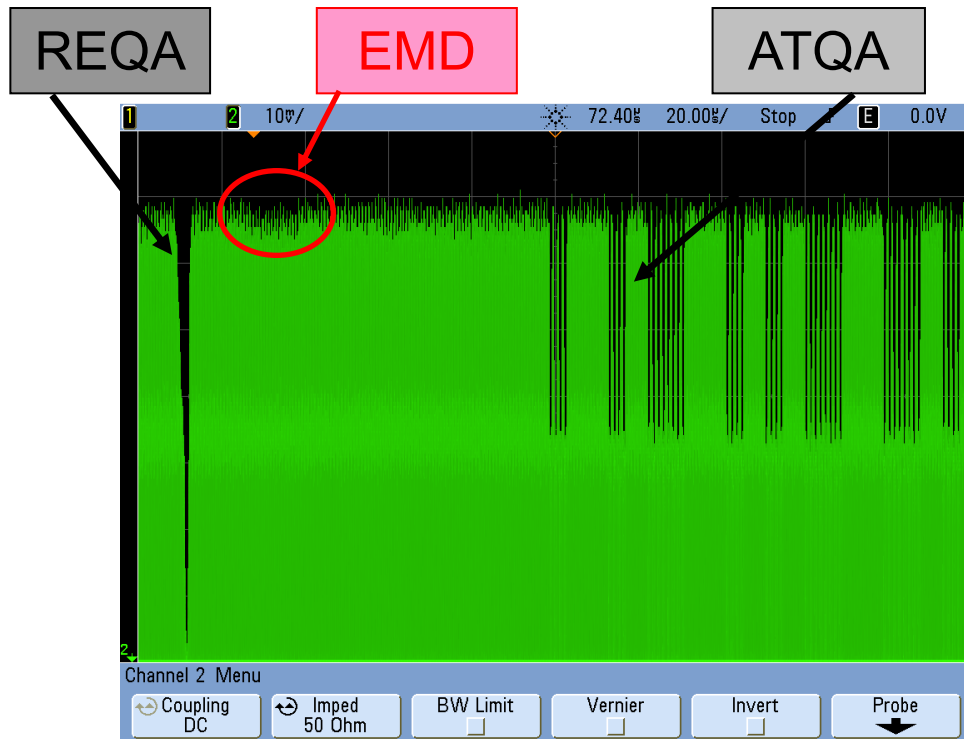
Agilent DSO 7052A screenshot
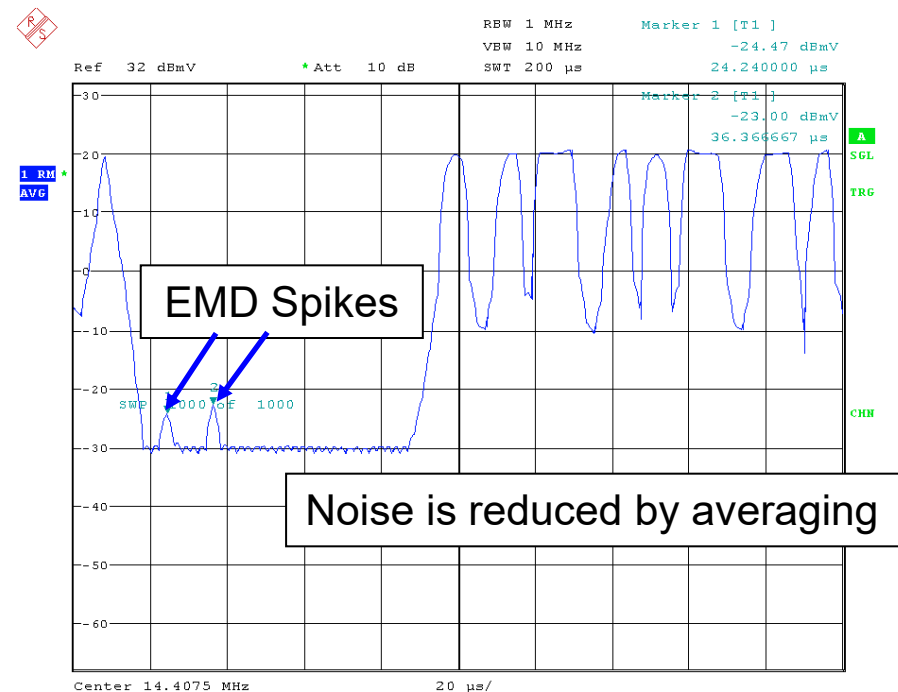
R&S Spectrum Analyzer FSQ

Excessive *H*-field, H_{EXC}

- **Explanation**
  - To assure the transponder is not damaged if there is higher *H*-field for a limited time
- **Test procedure**
  - After a 1st complete characterization test run, the transponder chip with class 1 antenna is stressed with 10 A/m for 30 s (thermal stress). Then the field is switched off and the transponder is stressed with 12 A/m for 5 s (current stress).
- **Criterion**
  - standard compliant behaviour for the 2nd test run after the stress. Pass/FAIL or a gradual degradation can be the result.
- **(possible) frame conditions**
  - Resonance frequency…close to carrier is critical
  - Temperature…high ambient temperature is critical

Problem Aspect: Harmonics Emission

- Due to the nonlinear characteristic of the transponder rectifier, the emission of higher harmonics to the 13,56 MHz carrier frequency is stimulated. Dependency on antenna size, transponder Q-factor (e.g. number of turns), etc. was under investigation. For some FCC regulations (e.g. US) this may be an issue.

Harmonics for 4-turn etched Class 2 Antenna 1,5 A/m SMX C14

Harmonics for 4-turn etched Class 2 Antenna 7,5 A/m SMX C14
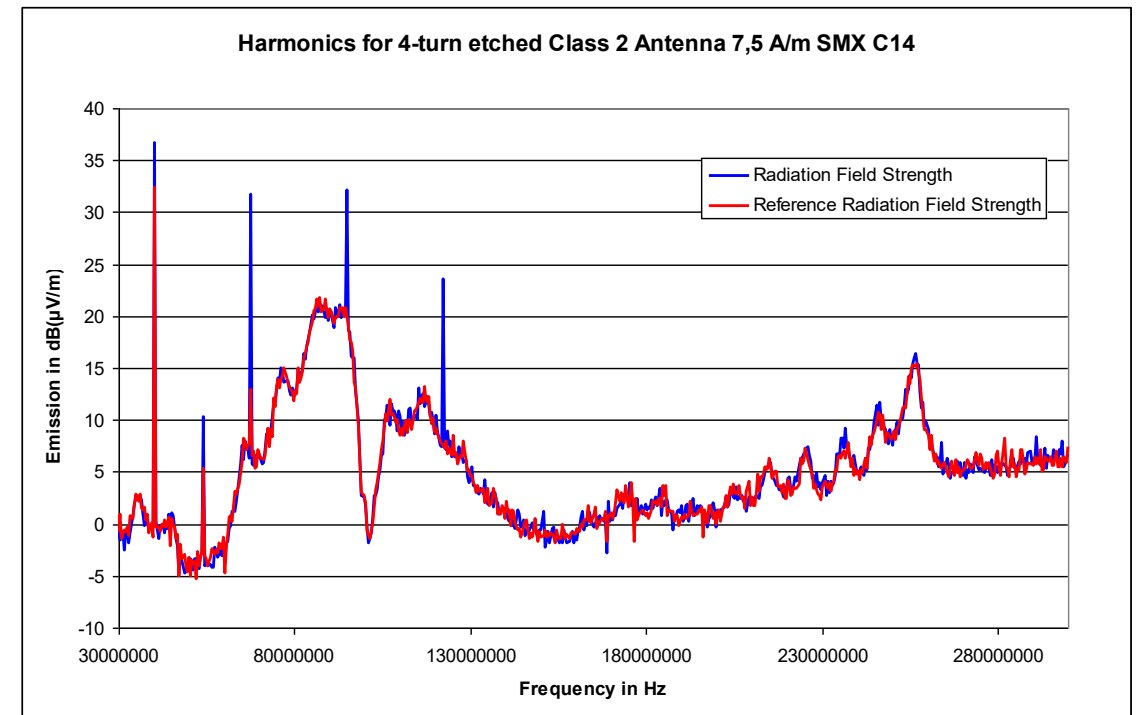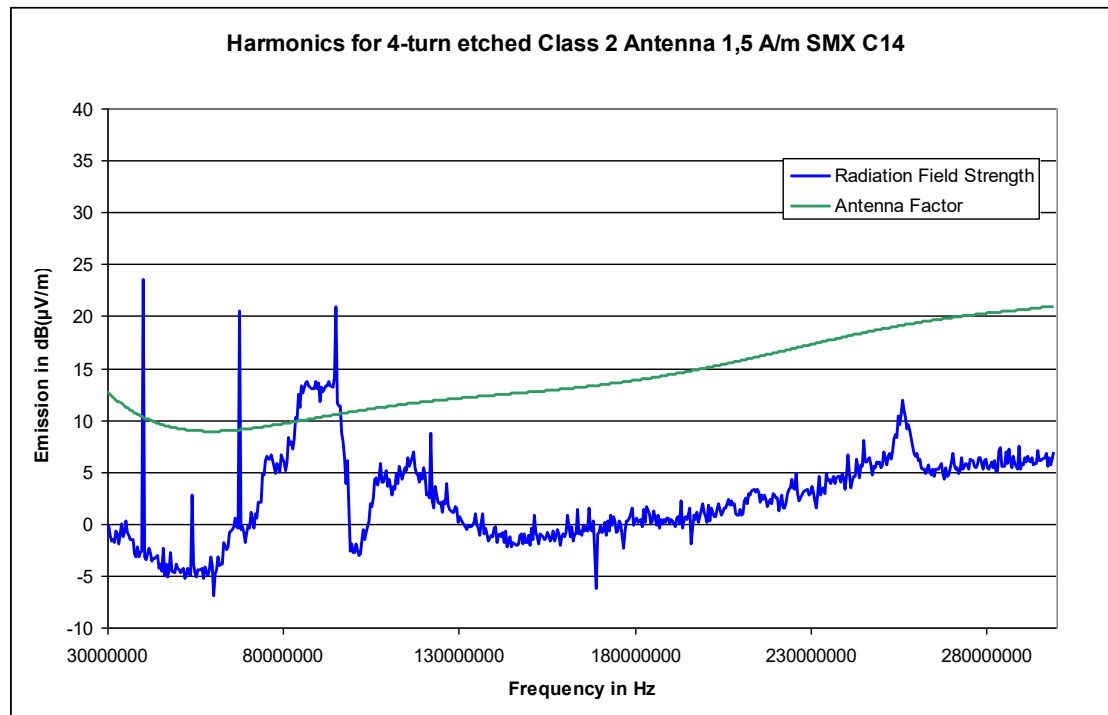
Setup for Reader test

Hardware components and related considerations

ISO/IEC 10373-6 Reference PICC

- The Reference PICC emulates the properties of a card antenna resonance circuit and is used as test hardware for contactless reader tests.

- The antenna part consists of
  - Main antenna for Card loading, *H*-field measurement, Sensitivity to load modulation, Frame delay time measurement, EMD measurement
  - Pick-up antenna (zero-coupling to main antenna) for Modulation envelope shape measurement

- The antenna resonance circuit can be adjusted…
  - Resonance Frequency can be adjusted by trim capacitors
  - Quality factor can be adjusted by trim load resistor / electronically controlled

- An electronic circuit part consists of
  - Rectifier and shunt trim resistor, to generate a DC measurement voltage
  - Transistor current mirror to generate a variable load current, for load modulation
  - RF chokes and SMA connector interface

ISO/IEC 10373-6 Reference PICC circuit
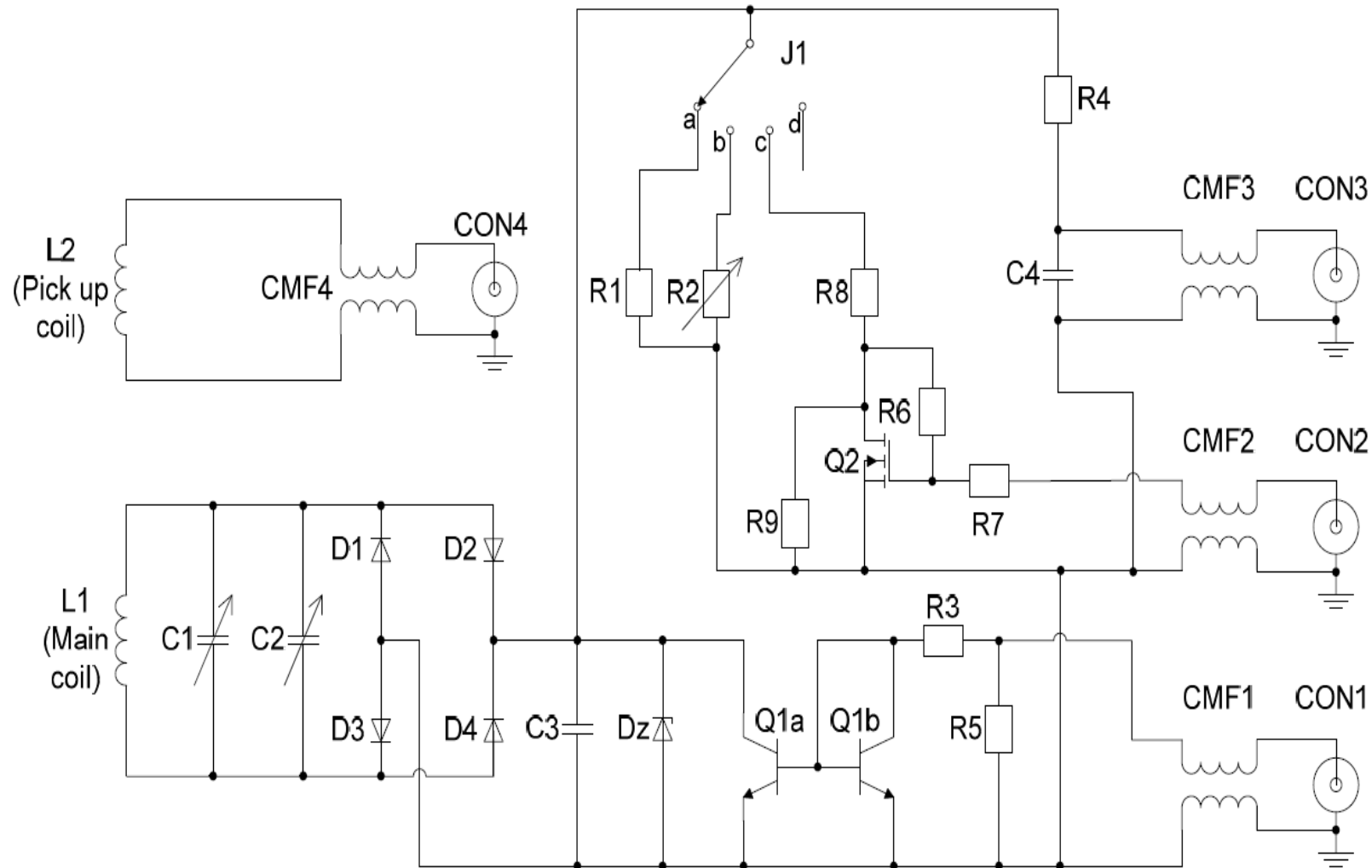
Calibration procedure for analogue part

- **Resonance Frequency:**

  – Jumper 1 is set to position 23 (fixed resistor)

  – Jumper 2 is open.

  – Use Gain-Phase analyzer for Calibration of the resonance frequency:

  – Settings:

  – Impedance R-X, 12 - 20 MHz, Oscillator 0,5V, Compensation (short).

  – Place Coil in 1 cm distance to fixture coil (1 turn). Tune Trim-Cap 1 to achieve maximum R at 19 MHz.

  – Connect Jumper 2. Tune Trim-Cap 2 to achieve R maximum at 13,56 MHz.

  – Set Jumper 1 to position 12 (variable load resistor).

Cap 1

Cap 2

Jumper 2 connected (13,56 MHz)

Jumper 1 to *12* (variable resistor)
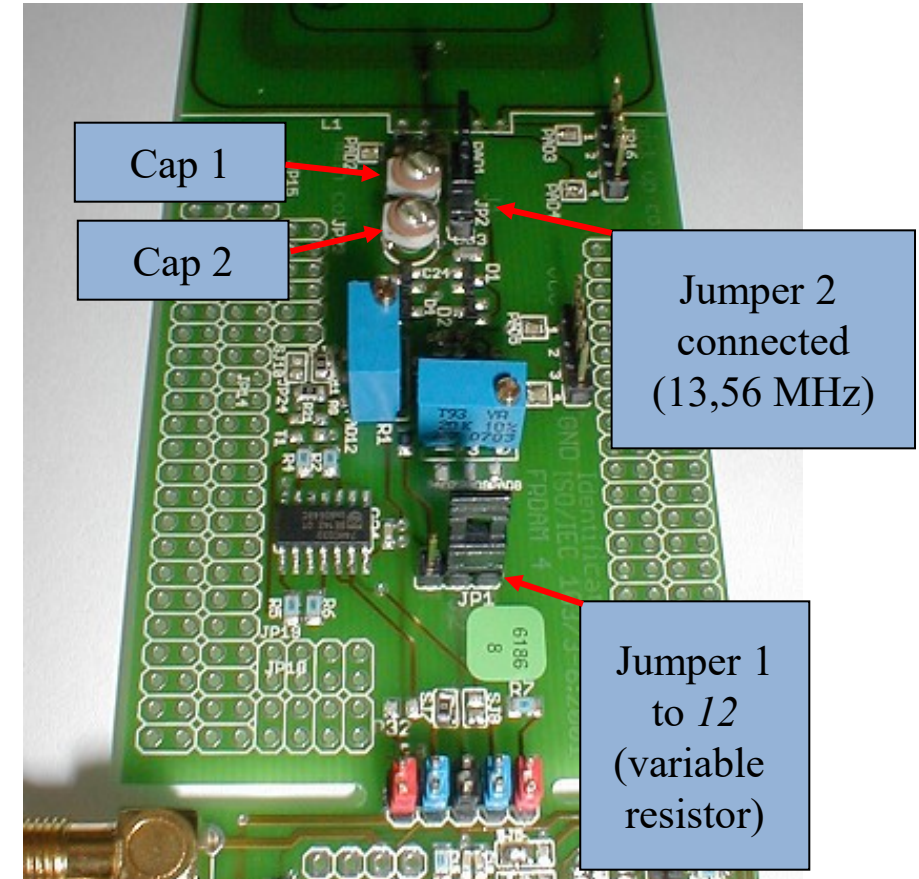
Calibration procedure for analogue part

- **Quality Factor**
  - Place Ref. PICC as DUT in ISO-Setup. Apply CW 13,56 MHz, observe *H*-field with Calibration coil. Connect a Voltmeter to DC output.

- **Adjustment for H_{MIN} measurement**
  - Set Ref. PICC to 13,56 MHz (J2 closed) and to variable load resistor (J1 to position 12).
  - Adjust a DC voltage of 3 V for an *H*-field of 1,5 A/m (= 1,36 Vpp at Calibration coil).

- **Adjustment for H_{MAX} measurement**
  - Set Ref. PICC to 19 MHz (J2 open) and to variable load resistor (J1 to position 12).
  - Adjust a DC voltage of 3 V for an *H*-field of 7,5 A/m (= 6,82 Vpp at Calibration Coil).
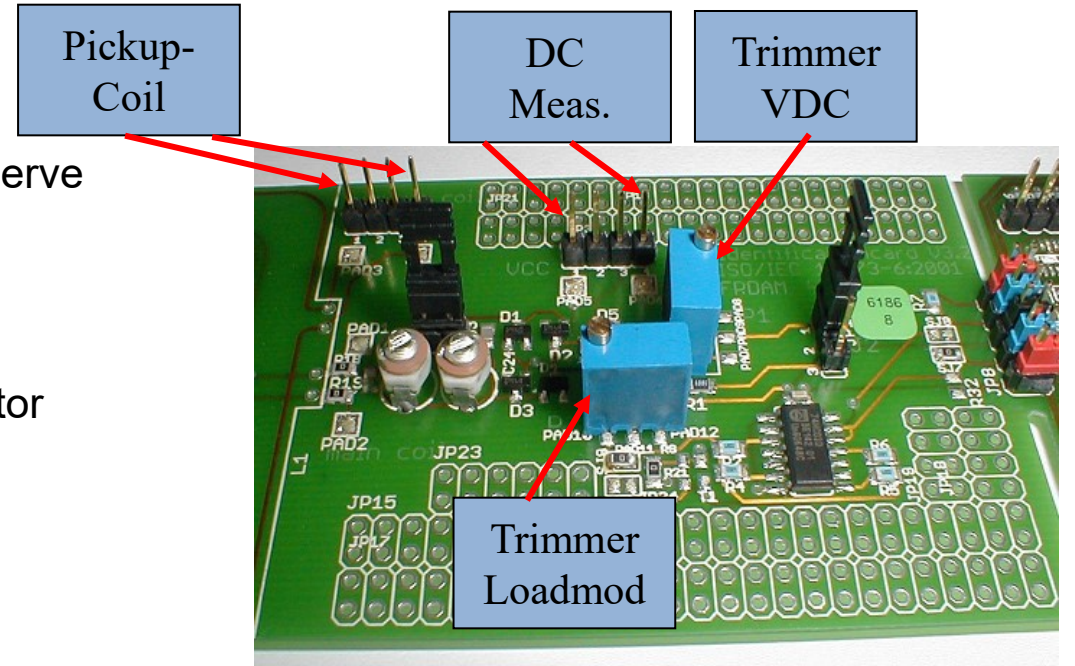
Main Contactless Reader Test Cases

- **Emitted *H*-field strength**
  - Reference PICC emulates card properties (card loading)
  - ISO/IEC14443: *H*-field range 1,5 A/m – 7,5 A/m
  - H_{MIN}: Maximum loading (fres = 13,56 MHz, calibration to 6 VDC at 1,5 A/m in ISO-Setup)
  - ➔ find distance for *H* > 1,5 A/m (and verify down to zero distance)
  - H_{MAX}: Minimum loading (fres = 19,0 MHz, calibration to 3 VDC at 7,5 A/m in ISO-Setup)
  - ➔ verify reader *H*-field < 7,5 A/m in every position!
- **Reader Modulation Envelope Shapes**
  - Measure on Pickup coil of Reference PICC
  - Reference PICC tuned to 16,5 MHz resonance frequency and 3 VDC at 1,5 A/m
  - Measure at all positions in *H*-field range (1,5 A/m - H_{MAX} of reader)
  - ➔ Practice: Find distance for 1,5 A/m and measure there and in zero distance
  - Software for automated pulse parameter analysis

Main Contactless Reader Test Cases

● **Sensitivity to load modulation**

– Calibrate Reference PICC loading, set Load modulation levels to the Standard requirements for one *H*-field strength, place

Ref. PICC over reader and find distance for equal *H*-field, apply card response and check if the reader is able to receive it.

– Characterization: Adjust PICC to minimum LMA limit for reader and measure value in ISO-Setup

– Evaluation: Adjust LMA minimum limit in ISO-Setup and verify on reader.

● Additional Tests

Setup for Reader test

Measurement methods for Proximity reader tests

H-field (amplitude at CW carrier)

- **Explanation**
  - To assure, a reader will emit 13,56 MHz alternating *H*-field strength according to Product Standard specification, within the „Operating Volume" (or distance) specified by manufacturer, for coaxially positioned cards.
- **Test procedure for H_{MAX}**
  - Reference PICC adjusted to minimum loading (19 MHz, 3 VDC for 7,5 A/m)
  - **Criterion:** Measurement in all the Operating Volume shows DC voltages below 3 V.
- **Test procedure for H_{MIN}**
  - Reference PICC adjusted to max. loading (13,56 MHz, 6 VDC for 1,5 A/m)
  - **Criterion:** Measurement in all the Operating Volume shows DC voltages above 6 V.
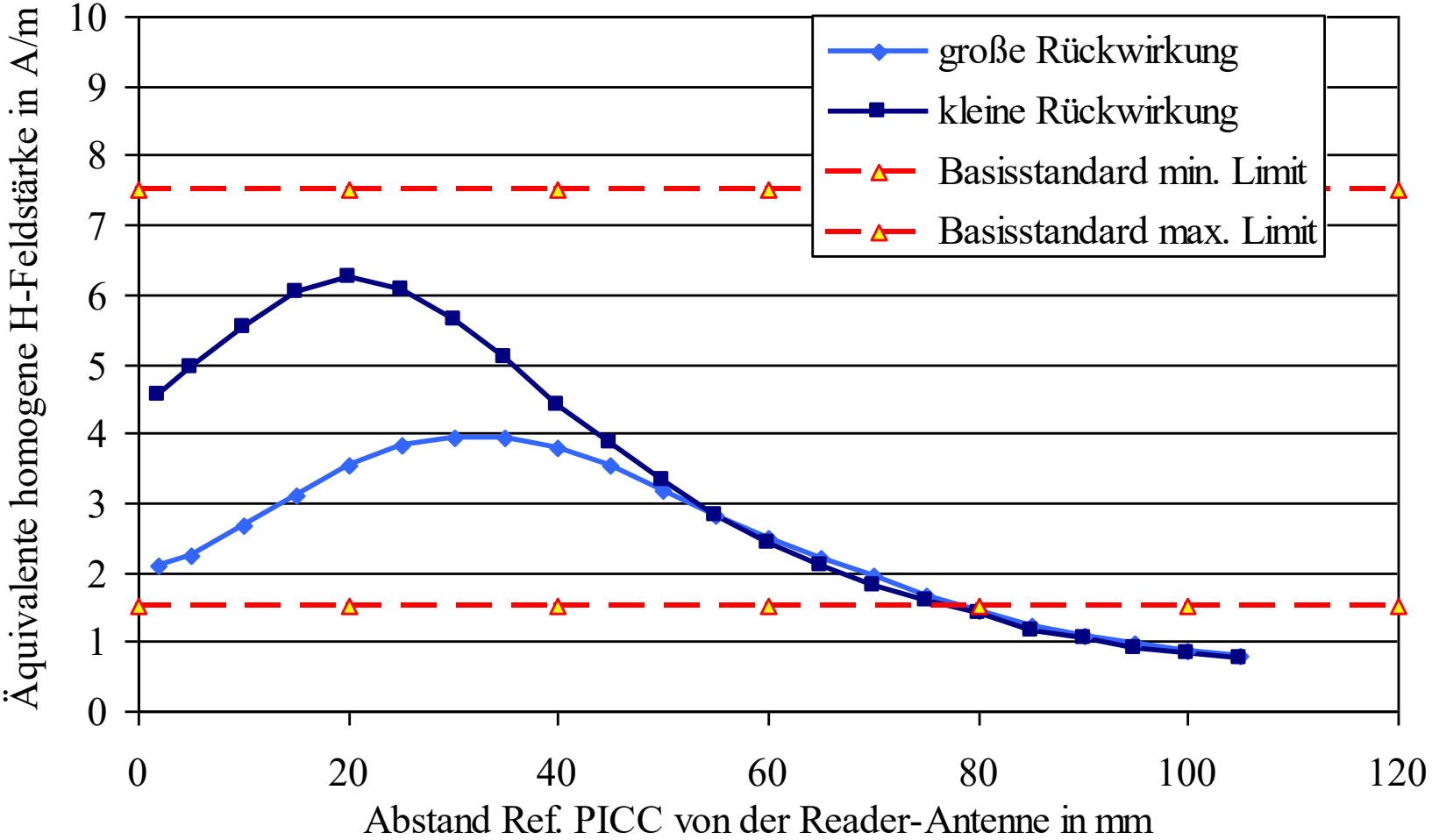- **(possible) frame conditions**
  - Position or distance to the reader (though always coaxial orientation)
  - Antenna size of Ref. PICC (most relevant is class 1, but also other classes…)

Measurement – Reader *H*-field over distance

Modulation envelope parameters

- **Explanation**
  - To assure, a reader will fulfill the Modulation properties according to Product Standard specification, within the „Operating Volume" (or distance) specified by manufacturer, for coaxially positioned cards.
- **Test procedure**
  - Reference PICC is adjusted to average resonance (16,5 MHz). In the setup for card test the Ref PICC is adjusted to 3 VDC at an H-field of 1,5 A/m. Then, the Ref PICC is positioned coaxially to a reader in such distance, that 3 VDC can be measured. The reader modulation is captured with Oscilloscope using the Pickup-coil of the Ref PICC.
- **Criterion**
  - Modulation parameters, evaluated by offline processing, should be in the specified value range.
- **(possible) frame conditions**
  - Loading of the Ref PICC (resonance, or adjusted voltage at H-field)
  - Antenna size of Ref. PICC (most relevant is class 1, but also other classes…)

Example: Reader Modulation envelope

- Reader modulations, measured under different loading conditions. Especially interesting for 14443A are time parameters and decay, for 14443B are modulation index and overshoots.

106 kbit/s Type A Reader Pulse Shape

848 kbit/s Type A Reader Pulse Shape
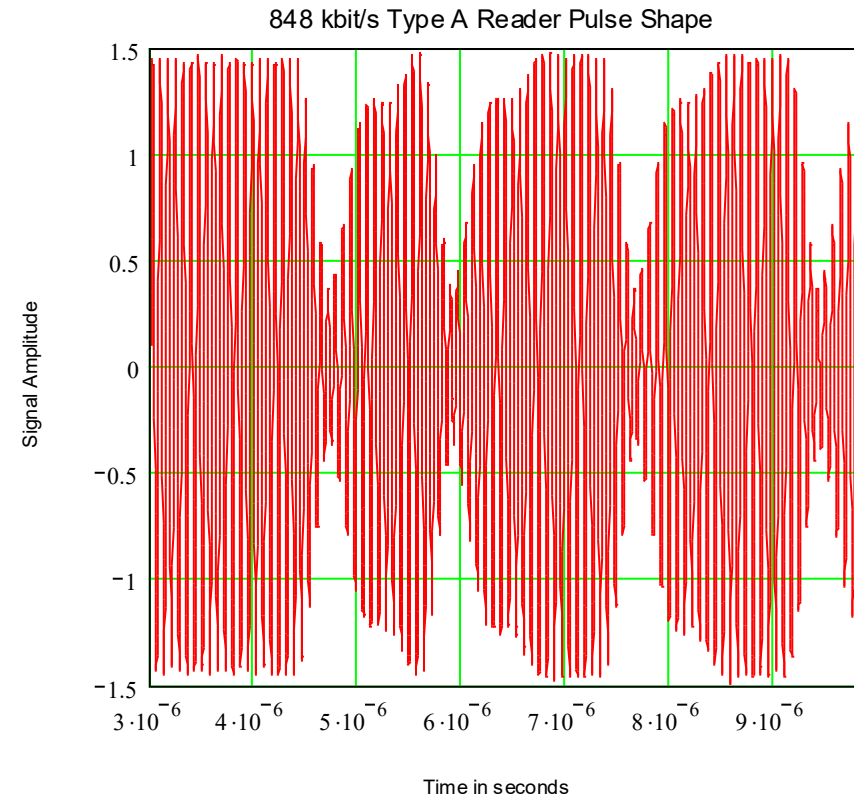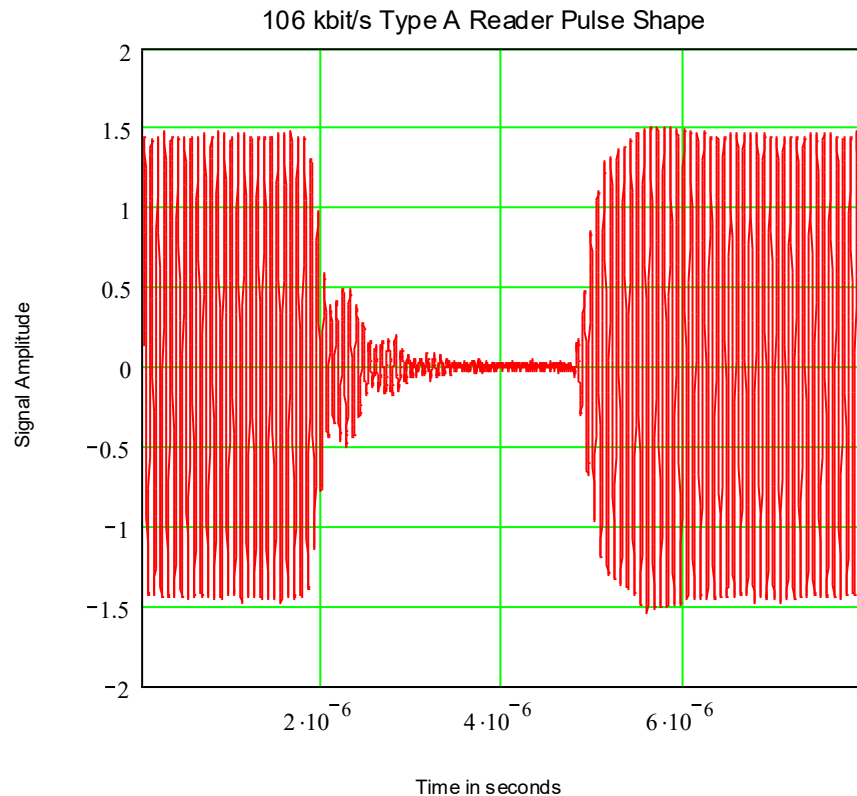
Reader sensitivity to Load modulation

- **Explanation**
  - To assure, a reader will be able to receive card Load modulation according to Product Standard specification, within the „Operating Volume" (or distance) specified by manufacturer, for coaxially positioned cards.
- **Test procedure**
  - Reference PICC is adjusted to average resonance (16,5 MHz). In the setup for Card test the Ref PICC is adjusted to 3 VDC at an H-field of 1,5 A/m. Then, the Ref PICC is positioned coaxially to a reader in such distance, that 3 VDC can be measured. At this position a correct card backmodulation is emitted at the lowest amplitude, for which the reader decodes a correct response. Then, in the setup for Card test the Ref PICC Load modulation amplitude value is measured for equal H-field strength (3 VDC).
- **Criterion**
  - Modulation parameters, evaluated by offline processing, should be in the specified value range..
- **(possible) frame conditions**
 - Different distances / H-field strengths
  - Antenna size of Ref. PICC (most relevant is class 1, but also other classes…)

Reader sensitivity to Load modulation

Measurement (function of distance)
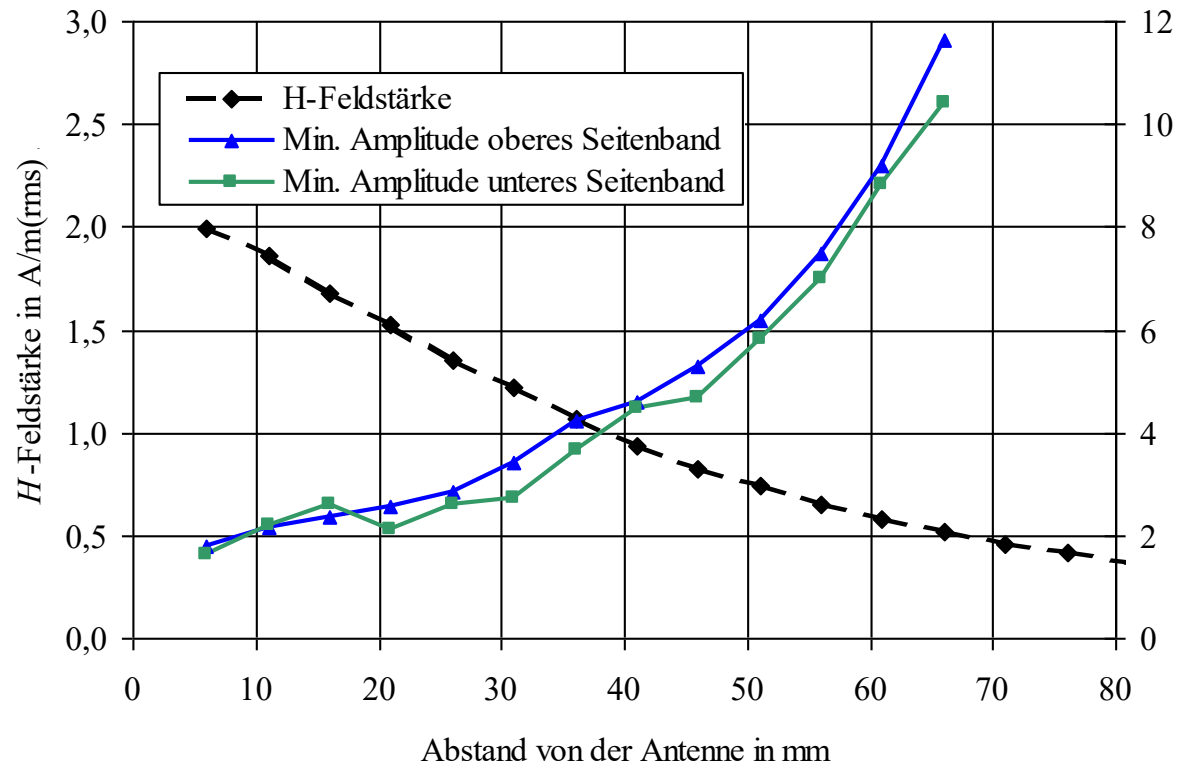
Resulting plot (function of *H*-field)
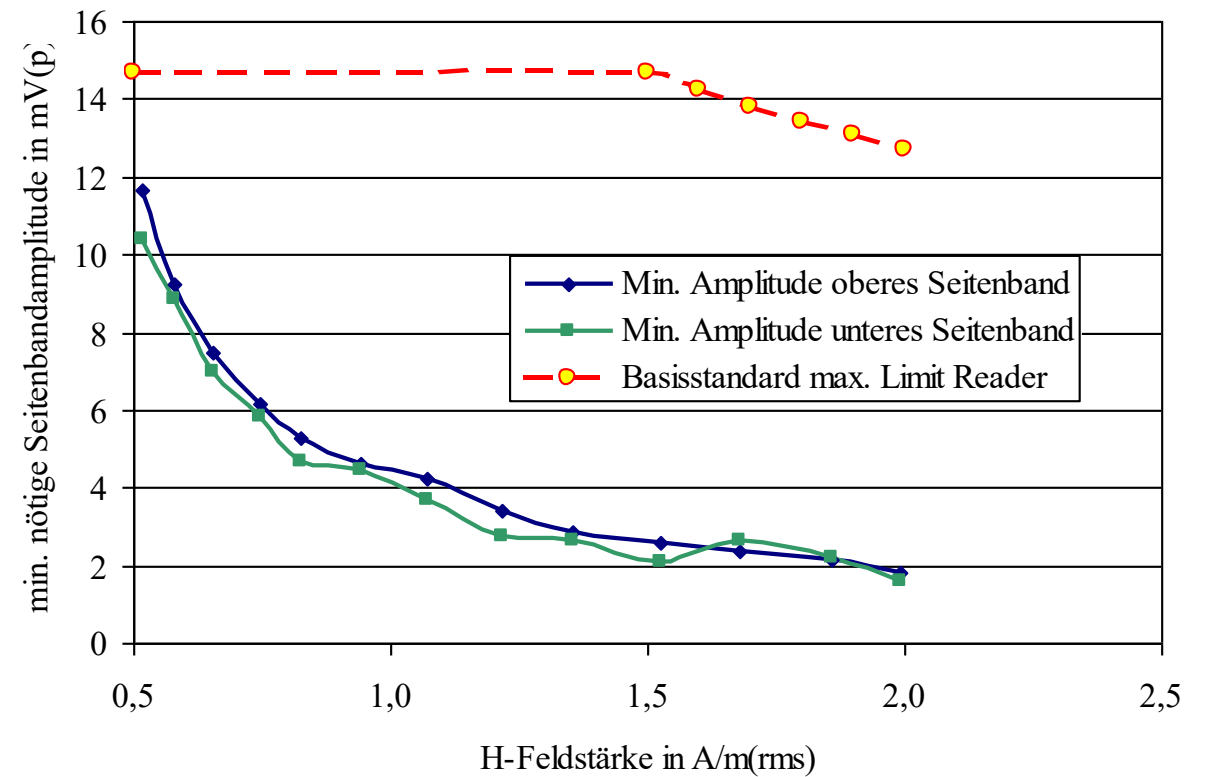
Some Test Plans

Certifications for applications of the ISO/IEC14443 Proximity card standard

Mifare Certification – Motivation

*In the late 1990ies, the **Mifare Certification** was introduced jointly by the governmentally accredited test house Arsenal in Vienna, Austria, and by experts from Philips Semiconductors in Graz. The aim was, to guarantee for customers the interoperability between reader and transponder products. The test house offers lab components for sale and conducts pre-tests and certification measurements according to a test plan, as technical service (today conducted as private company).*

Around the year 2000, Mifare was taken over (with small modifications) to the ISO/IEC14443 Proximity standard, Type A. Consequently, the existing measurement methods and test hardware also became the basis for the ISO/IEC10373-6 Test Standard.

*With the introduction of the Electronic Passport, this had to be taken to a higher, international level. On the existing basis, new test specifications were derived, which are now part of the documents of ICAO (International Civil Aviation Organization), which specifies Passports. These test specifications serve all countries world-wide for the certification of electronic Passports.*

Mifare Certification – Cards, Air Interface

| Test Name	Measured Value	Target Value	Conditions		
Resonance Frequency	f res	14.5 … 18.5 MHz	Temp. = 23 °C		
Maximum field strength	(exposure to 12 A/m)	Remain standard compliant	H = 12 A/m	25 s	+ 50 °C
			H = 0 A/m	5 s	+ 50 °C
			H = 12 A/m	25 s	+ 50 °C
Minimum operating field	H min	H min < 1.25 A/m	SC > 18.44 mVp	0 °C, 23 °C, 50 °C	
Acceptance of Pause [1] (Pulse Envelope Shape variation)	Subcarrier Level	SC > 30 / $H^{1.2}$	H = 1.25 A/m H = 6 A/m	0 °C, 23 °C, 50 °C	T1 max, T1 min, T2 5 %, Hump,
Miller decoder [2] (Channel code timing variation)	Subcarrier Level	SC > 30 / $H^{1.2}$	H = 1.25 A/m H = 6 A/m	0 °C, 23 °C, 50 °C	Miller min, Miller max
Frame delay time PCD => PICC	Delay time / End of Protocol in %	EOP 5 % … 60 %	H = 1.25 A/m H = 6 A/m	0 °C, 23 °C, 50 °C	
Load Modulation	Subcarrier Level	SC > 30 / $H^{1.2}$	H = 1.25 A/m H = 3 A/m H = 4.5 A/m H = 6 A/m	0 °C, 23 °C, 50 °C	

I)
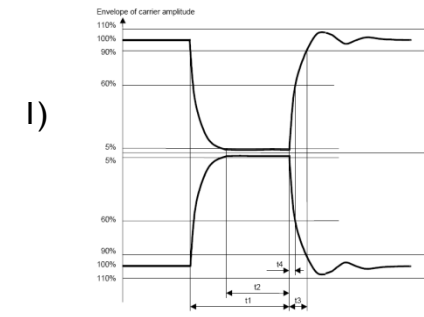
Test pattern	t1 [µs]	t2 [µs]	t3 [µs]	t4 [µs]
T1 MAX	3.0	1.4	1.0	0.4
T1 MIN	2.0	0.7	1.0	0.4
T2 5%	3.0	0.7	1.0	0.4
HUMP *	3.0	1.0	1.0	0.4

2)
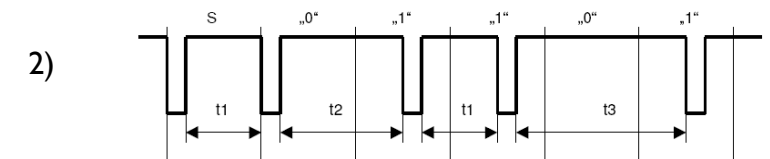
Mifare Certification – Cards, Protocol

Test Name	Tested Command	Target	Conditions	
			H	Temperature
Functional test	ATQ, UID, SAK	Correct response	1.25 A/m	23 °C
State machine test	Specific Command Sequence	Correct response / correct states	1.25 A/m	23 °C

Pattern / Parameter		periods of fc = 13.56 MHz	value in µs
MILLER MIN	t1	100	7.37
	t2	164	12.09
	t3	228	16.81
MILLER MAX	t1	124	9.14
	t2	188	13.86
	t3	252	18.58

Mifare Certification – Terminals, Air Interface

Test Name	Measured Value	Target Value	Conditions	
Carrier Frequency	f carrier	13.56 MHz +/- 7 kHz	VDC min, VDC max	0 °C, 23 °C, 50 °C
PCD exceptional field strength	H carrier max. (around the reader)	< 12 A/m	VDC choosen for max. H carrier	23 °C
PCD operating field strength	H as function of distance	H carrier = 1.25 …. 6 A/m	VDC min, VDC max	0 °C, 23 °C, 50 °C
Power transfer PCD to PICC	Distance (for Power > 5 mW)	Power > 5 mW (Measurement with Ref. PICC according to 10 373-6)	VDC choosen for min. H carrier	Temp. choosen for min. H carrier
Modulation index and wave form (Envelope shape of pause)[1]	Modulation index, Envelope timing (t1, t2, t3, t4), Amplitude Overshoots	90.5 % … 100 % Figure 2, ISO 14 443-2 90 % … 110 %	VDC min, VDC max	0 °C, 23 °C, 50 °C
Miller Coding (Channel code timing)[2]	Channel Code timing (t1, t2, t3)		VDC min, VDC max	0 °C, 23 °C, 50 °C
Load Modulation reception (Sensitivity to Sideband Levels)	Required Subcarrier Level over distance for stable operation	H < 1.5 A/m: SC < 18.44 mVp H > 1.5 A/m: SC < 30 / $H^{1.2}$	VDC min, VDC max	0 °C, 23 °C, 50 °C

1)
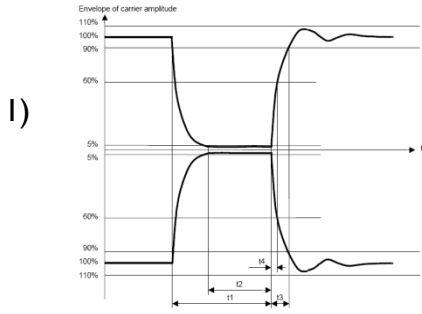
parameter	condition	minimum	maximum
t1		2.0 µs	3.0µs
t2	t1 > 2.5µs	0.5µs	t1
	t1 ≤ 2.5µs	0.7µs	
t3		0	1.5µs
t4		0	0.4µs

2)
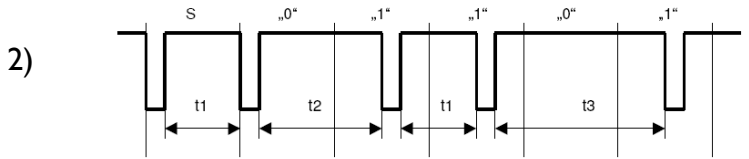
Parameter	periods of fc = 13.56 MHz		values in µs	
	minimum	maximum	minimum	maximum
t1	102	122	7.52	9.00
t2	166	186	12.24	13.72
t3	230	250	16.96	18.44

BSI/ICAO Certification – Cards, Layer 1

- The test plan for ICAO certification is split up into layers, following the ISO/IEC14443 concept.

Test Case	Criterion	Range
Geometrical size of antenna	Class 1	
ESD (electrostatic discharge)	to fulfill criterions of ESD Standard	
Excessive Field (13,56 MHz)	to operate standard compliant after stress	5 minutes at 10 A/m, 5 seconds no field, 30 seconds at 12 A/m

BSI/ICAO Certification – Cards, Layer 2

● **Test Case**   **Criterion**   **Range**

– Load Modulation Amplitude   > 30/H1,2

         H-field: 1,5 – 4,5 – 7,5 A/m

         Temp: - 10 °C, Room Temp., + 50°C*)

         Envelope shape: Standard (only 106 kbit/s)

         Command: REQA

– Operating Field Strength   correct response

         H-field: 1,5 ... 7,5 A/m (1 A/m steps)

         Temp.:   - 10 °C, RT, + 50°C*)

         Envelope shape: Standard (all spec. bit rates)

         Command: REQA - Anticoll - Select - RATS - PPS - TestCommandSequence

– Communication Stability   correct response

         H-field: 1,5 – 4,5 – 7,5 A/m

         Temp.:   - 10 °C, RT, + 50 °C*)

         Env. shape: limit cases (all spec. bit rates)

         Command: REQA - Anticoll - Select - RATS - PPS - Select_Application

– Treshold Resonance Freq.   > 14,8 MHz   Impedance Analyzer, H_{MIN}, RT

– Maximum Loading Effect $\Delta H_{DUT} < \Delta H_{REF}$ PICC (max. loading)   1,5 A/m, RT

– Low Field Recover Capability   no Hang-up H-field: 0,1 ... 1,5 A/m (0,1 A/m steps)

         Temp.:   RT

         Envelope shape: Standard

         Command: REQA - Anticoll - Select - RATS - TestCommand_Sequence

BSI/ICAO Certification – Cards, Layer 3

- **Test Case**   **Criterion**   **Range**

  – Start-up Time   correct response (5 ms)   RT, arbitrary *H*-field, 10 test runs

  – Frame Delay Time   nom. time (400 ns tolerance)   RT, arbitrary *H*-field, arbitrary command,

Thank you for your Audience!

Please feel free to ask questions...

Hinweise – Notizen

Questions for self-evaluation

- Explain the difference between evaluation and characterization! Provide examples, how the measurements are done, which samples are used, requirements for the test bench, etc.

- Describe 3 mainly important measurements, which are done for Proximity Readers in the Lab and are foreseen in the ISO/IEC10373-6 test standard (using Reference PICCs). Which instruments are used, which are typical results?

- Describe 3 mainly important measurements, which are done for Proximity Cards in the Lab and are foreseen in the ISO/IEC10373-6 test standard (using the setup for Card test). Which instruments are used, which are typical results?

- Describe the setup for Proximity Card Test. Which loop antennas and measurement instruments are used? Explain, how the H-field is measured in the ISO/IEC10373-6 Proximity Test Standard.

- In which way is the ISO/IEC measurement setup and concept different to the EMVCo and the NFC Forum measurement setup and concept?