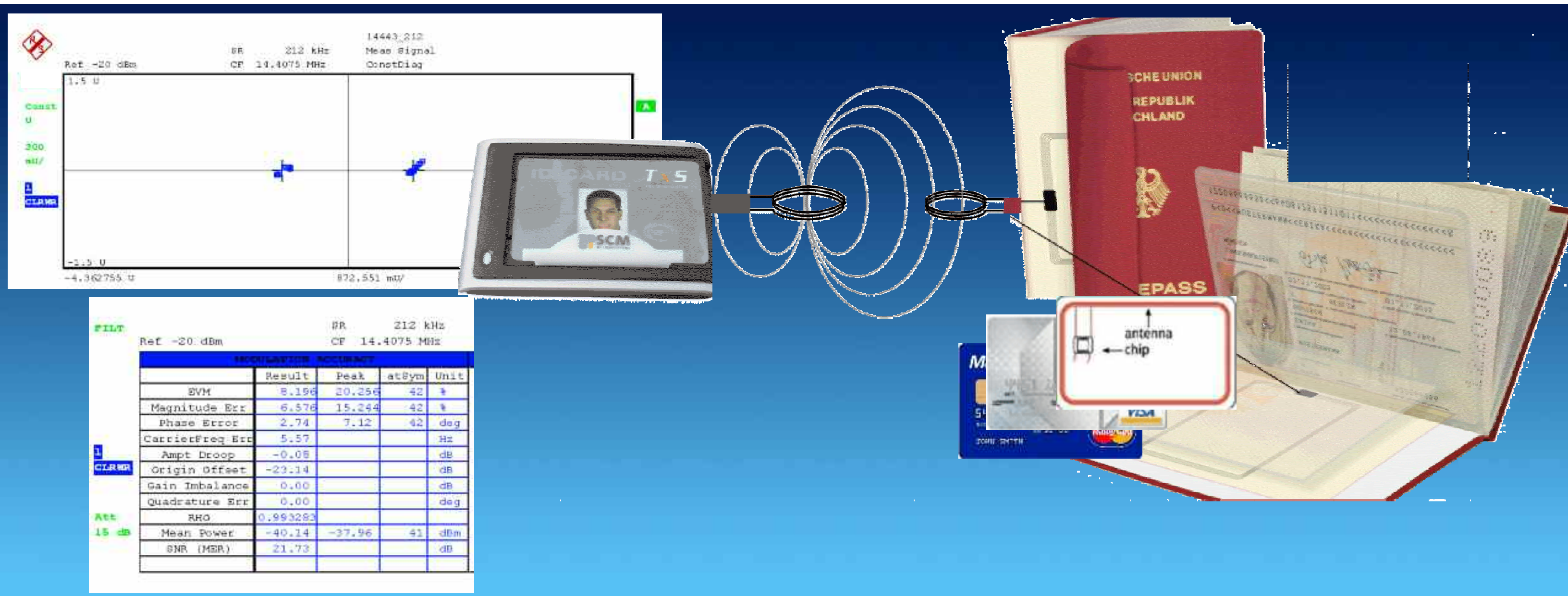

Products: SMJ, SMU, AMU, FSG, FSU, FSQ

Measuring Electro Magnetic Disturbance During ISO/IEC 14443 Chipcard Data Transmission

Application Note

The Electromagnetic Disturbance (EMD) emitted by Proximity-Integrated-Circuit-Cards (PICC) is a unwanted form of load modulation. This Application Note describes a method for measuring EMD during data transmission using vector signal analysis.

Subject to change –Minihold/Erker 10/2007 – 1MA120

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1 Overview

The Electromagnetic Disturbance (EMD) emitted by Proximity-Integrated-Circuit-Cards (PICC) is an unwanted form of load modulation, caused by load change generated by switching within PICC internal digital circuits, especially using fast cryptographic calculations. EMD occurs during normal operation; high disturbance levels will degenerate the communication between the PICC and the Proximity Coupling Device (PCD).

A method for measuring EMD where no communication is taking place from PICC to PCD is already available from R&S, see Application Note 1MA113. The method is based on a selective level measurement using a spectrum analyzer in zero span.
During communication this method will not work, because the load modulation caused by the PICC will cover the EMD. However, the communication PICC to PCD could be severely harmed by EMD during transmission. A new measurement method is described in this AN for measuring EMD during transmission.

Nearly all PCDs in the contactless market are based on an IQ-demodulator. A vector signal analyzer is a measuring instrument also based on an IQ-demodulator which can display the I- and the Q-signals for measurement purposes. The vector signal analyzer can be seen as a reference reader with similar but more precise reception. It shows the signals available to the digital detector after the IQ-demodulator inside a real reader. It can distinguish and quantify unwanted modulation caused, for example, by EMD from wanted modulation. Consequently a vector signal analyzer is the correct instrument to evaluate the influence of EMD during data transmission on a reader.

The following abbreviations are used in this Application Note for Rohde & Schwarz test equipment:

- The Vector Signal Generator R&S®SMJ100A is referred to as the SMJ.
- The Vector Signal Generator R&S®SMU200A is referred to as the SMU.
- The I/Q Modulation Generator R&S®AMU200A is referred to as the AMU.
- The I/Q Modulation Generator R&S®AFQ100A is referred to as the AFQ.

- The Spectrum Analyzer R&S®FSG is referred to as the FSG
- The Spectrum Analyzer R&S®FSU is referred to as the FSU
- The Signal Analyzer R&S®FSQ is referred to as the FSQ
- The Vector Network Analyzer R&S®ZVL is referred to as the ZVL

2 Test Setup

To ensure compatibility with the standard PICC load modulation test, perform this measurement with the test setup as proposed in [8] and similar to as described in chapter 7.1 “PICC load modulation amplitude” of the ISO/IEC 10373-6 standard. The oscilloscope is replaced with the spectrum analyzer and an active high impedance probe, as shown in figure 1. The high impedance probe’s output impedance shall be 50 Ω to guarantee a proper matching with the spectrum analyzer’s input. The spectrum analyzer requires a vector signal analysis option. A signal generator is used to stipulate the PICC under test.

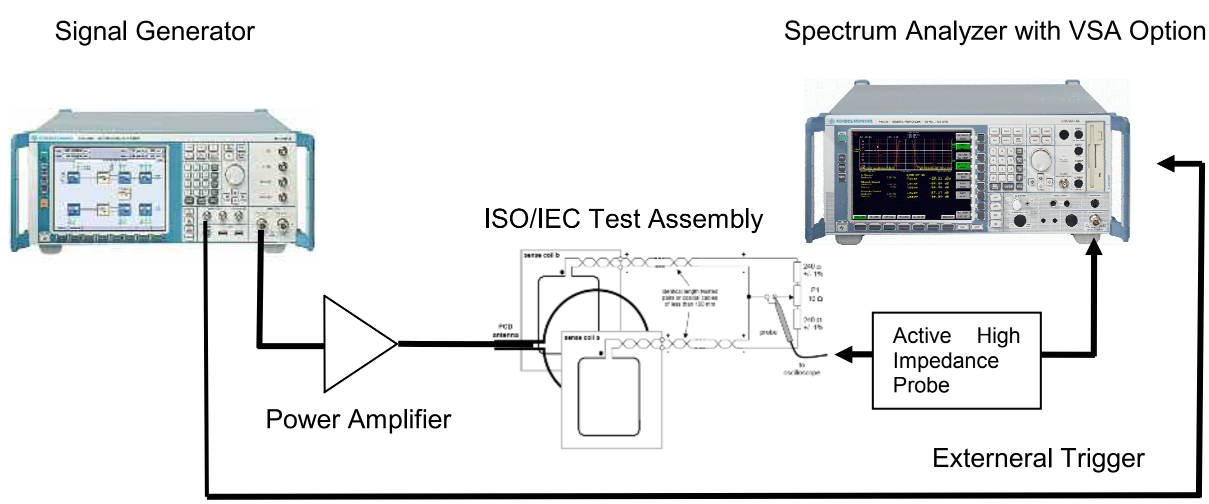


Figure 1: Test Setup

3 Stipulating the PICC

Stipulate the PICC for the measurement either with a Reader or with a signal generator followed by a power amplifier.

The R&S®xxx-K6 pulse sequencer software is ideal for generating simple reader frames to stipulate the PICC under test. The pulse files generated can then be transferred and output to any of the R&S®SMU200A, R&S®SMJ200A, R&S®SMATE200A, R&S®AMU200A, or R&S®AFQ100A signal generators. The signal generator requires the R&S®xxx-K6 pulse sequencer option. Detailed information can be found in [8].

4 Measurement of the PICC's EMD during Data Transmission

Digital modulation is used for PICC data transmission. For PICCs according to ISO/IEC 14443 A, On/Off Keying (OOK) modulation is used for bit rate f_c/128 (~106 kBit/s). For higher bitrates and for all PICCs according to ISO/IEC 14443 B, Binary Phase Shift Keying (BPSK) modulation is used. A measure for the quality is the Error Vector Magnitude (EVM). Significant EMD during data transmission can degrade the quality of the digital modulation by adding spikes and noise. EMD will increase the EVM of the wanted load modulation signal. Ensuring that EVM does not exceed a certain value will ensure that the PICC - PCD communication will not be degraded severely by EMD during data transmission.

For measuring the EMD during transmission, a spectrum analyzer with vector signal analysis option (e.g. FSG with FSQ-K70, FSU with FSU-B73 or FSQ with FSQ-K70) is used. The following example describes all the required steps for EMD measurement using a FSG, FSU or FSQ with the VSA option. Before starting, the digital standard files (14443A106KB.vau, 14443A106KB.vai , 14443A106KB.vas , 14443B106KB.vau, 14443B106KB.vai, 14443B106KB.vas) and the mapping file (2ASK.vam) delivered with this Application Note have to be copied to the *R_S\Instr\VSA\Data\STANDARD* and *R_S\Instr\VSA\Data\MAPPING* directory on the instrument.

The following settings must be made on the spectrum analyzer (e.g. the FSG, FSU or FSQ) to perform an EVM Measurement on a ISO/IEC 14443 Typ A or B chipcard signal:

PRESET
VSA
FREQ:14,4075 MHz / 12,7125 MHz
TRIG:*Extern*
BW:*ResBWManual:***500 kHz**
HomeVSA:DigitalStandard:(GenericStandard)RFID:14443A / 14443B (either for Type A or Type B Signals)
HomeVSA:ModulationSettings:SymbolRate:(enter required Symbol Rate e.g. 106 kHz for 106 kBit/s)
HomeVSA:MeasResult:CaptureBuffer
MKR:*Marker1(set Marker1on Start of the PICC Answer)*
MKR:*Marker2(set Delta Marker 2 on End of the PICC Answer)*

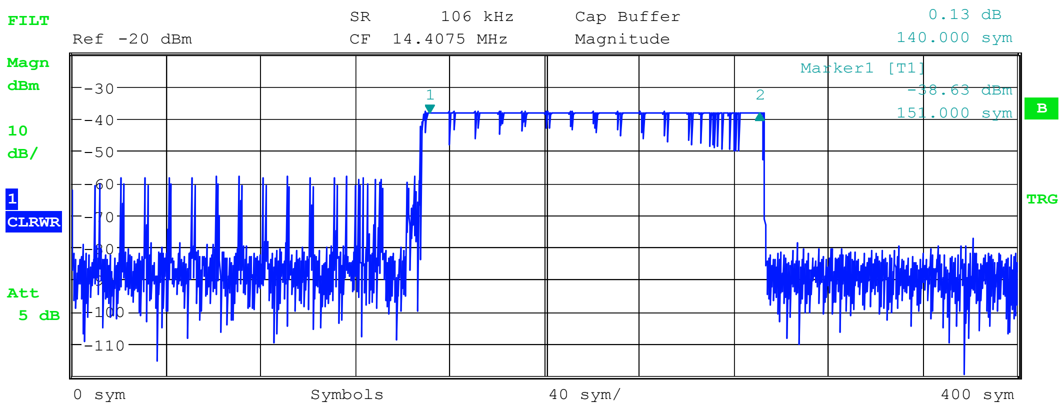


Figure 1: Capture Buffer view:

HomeVSA:Burst&Pattern:ExpertSettings

Userful Length < measured Burst Length
Max Length > measured Burst Length

HomeVSA:Burst&Pattern:Threshold:ThresholdRelative:(enter required Threshold)
HomeVSA:MeasResult :MeasSignal:Magnitude
HomeVSA:DemodSettings:EvaluationLines:EvalLine1(set EvalLine1 on Start of PICC Modulation)
HomeVSA:DemodSettings:EvaluationLines:EvalLine2(set EvalLine2 on End of PICC Modulation)

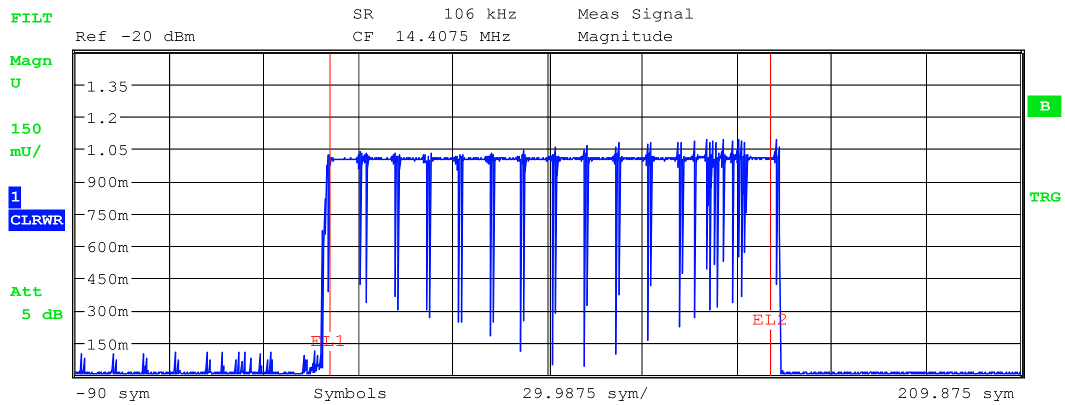
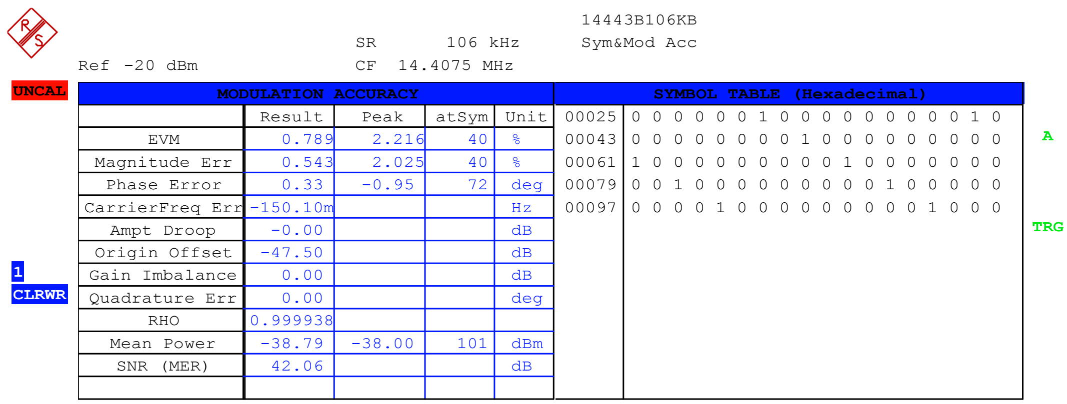


Figure 2: Meas Signal Magnitude (magnitude of measured signal) view



MODULATION ACCURACY	Result	Peak	atSym	Unit
EVM	0.789	2.216	40	%
Magnitude Err	0.543	2.025	40	%
Phase Error	0.33	-0.95	72	deg
CarrierFreq Err	-150.10m			Hz
Ampt Droop	-0.00			dB
Origin Offset	-47.50			dB
Gain Imbalance	0.00			dB
Quadrature Err	0.00			deg
RHO	0.999938			
Mean Power	-38.79	-38.00	101	dBm
SNR (MER)	42.06			dB

SYMBOL TABLE (Hexadecimal)																		
00025	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
00043	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
00061	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
00079	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
00097	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0

Figure 3: EVM Result on the Symbol Table & Modulation Accuracy view

Note:

The UNCAL message in figures 3, 4 and 6 is caused by the manual setting of the Resolution Bandwidth (RBW) which could in general worsen the EVM indication if set to low, see also [7], chapter 3, "Analog RBW Filters". However, in this application the RBW setting (500kHz) is necessary to suppress the Reader carrier which otherwise would severely distort the demodulation process of the PICC's signal. The influence to the EVM indication can be discounted in this application.

Measurement Examples

PICC ISO/IEC 14443 A with 106kBit/s, OOK Modulation

The measurement documented below shows a pretty small EVM_{rms} value of about 1%, the measured constellation points are situated near to the ideal OOK constellation points.

14443A106KB
SR 106 kHz Sym&Mod Acc
Ref -20 dBm CF 14.4075 MHz

UNCAL A TRG 1 CLRWR

MODULATION ACCURACY	Result	Peak	atSym	Unit
EVM	1.026	1.792	18	%
Magnitude Err	0.683	1.444	18	%
Phase Error	30.33	111.40	17	deg
CarrierFreq Err	-2.59			Hz
Ampt Droop	-0.13			dB
Origin Offset	-30.87			dB
Gain Imbalance	0.00			dB
Quadrature Err	0.00			deg
RHO	0.999910			
Mean Power	-43.23	-39.52	34	dBm
SNR (MER)	39.78			dB

SYMBOL TABLE (Hexadecimal)	
00001	0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 1 0
00019	0 0 0 0 1 0 1 1 0 1 1 1 1 0 0 0 1

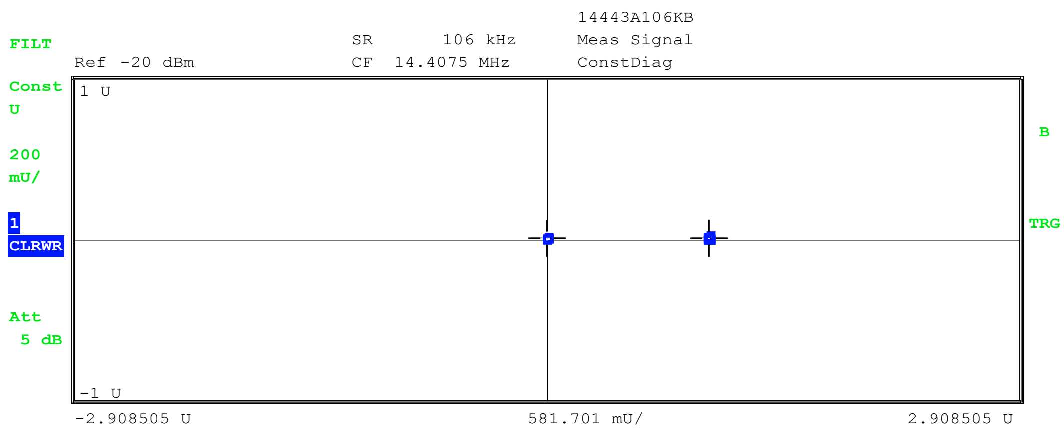


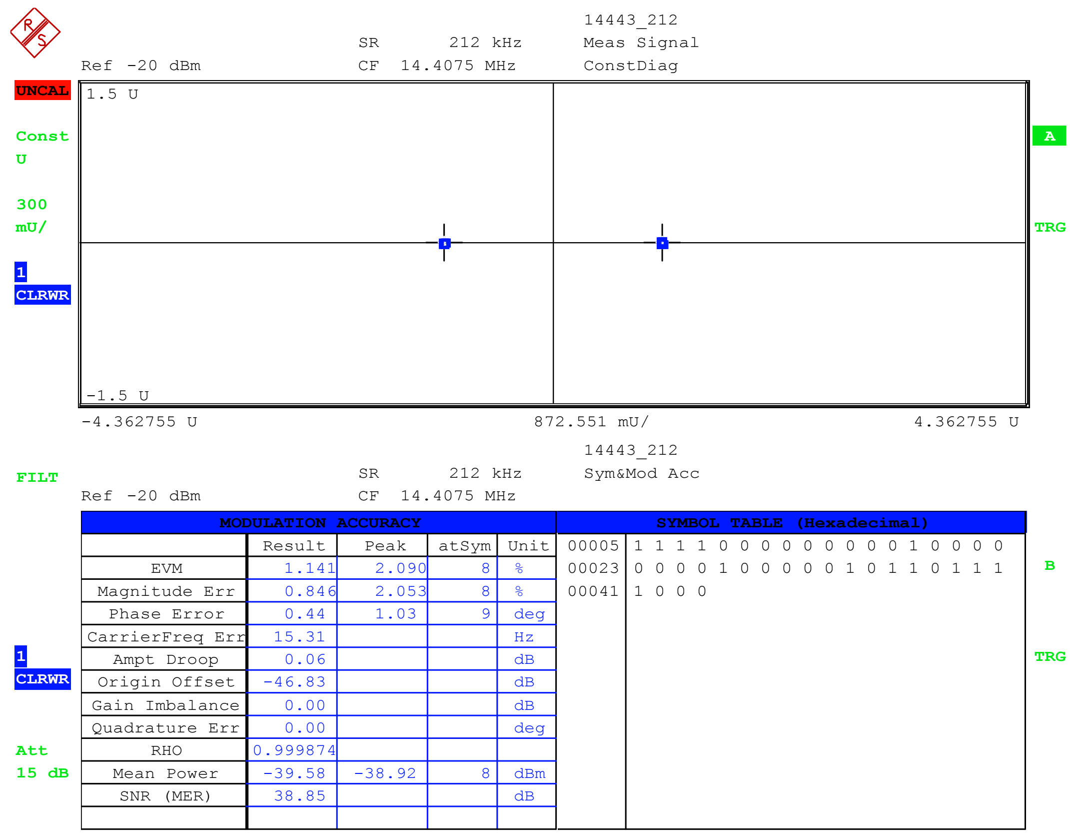
Figure 4: Symbol Table & Modulation Accuracy and Constellation Diagram of OOK-Modulation Measurement

Note:

The peak phase error of 30.33 degrees in Figure 4 stems from a measurement point near the origin where even small EVM values can produce high peak phase errors.

PICC ISO/IEC 14443 A with 212 kbit/s, BPSK Modulation

The measurement documented below shows again a pretty small EVM_{rms} of about 1%. The measured constellation points are situated near the ideal BPSK constellation points.



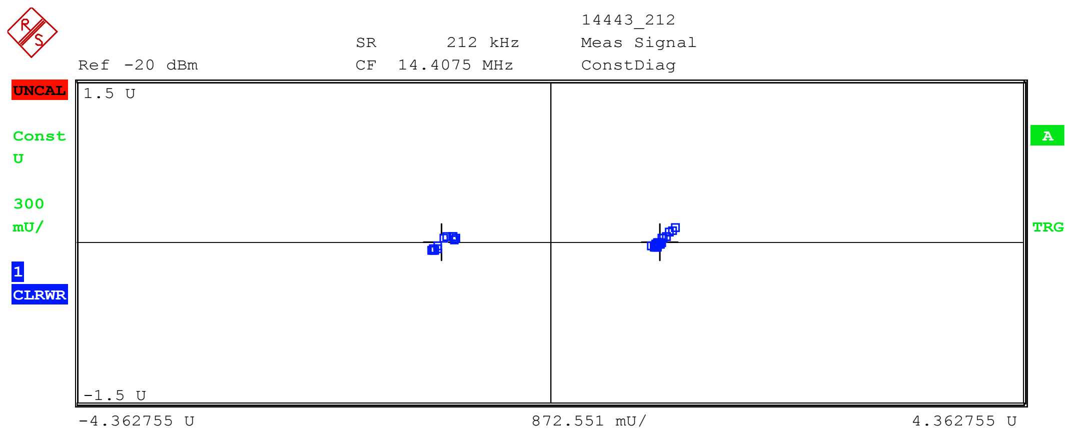
MODULATION ACCURACY	Result	Peak	atSym	Unit
EVM	1.141	2.090	8	%
Magnitude Err	0.846	2.053	8	%
Phase Error	0.44	1.03	9	deg
CarrierFreq Err	15.31			Hz
Ampt Droop	0.06			dB
Origin Offset	-46.83			dB
Gain Imbalance	0.00			dB
Quadrature Err	0.00			deg
RHO	0.999874			
Mean Power	-39.58	-38.92	8	dBm
SNR (MER)	38.85			dB

SYMBOL TABLE (Hexadecimal)	
00005	1 1 1 1 0 0 0 0 0 0 0 0 0 1 0 0 0 0
00023	0 0 0 0 1 0 0 0 0 0 1 0 1 1 0 1 1 1
00041	1 0 0 0

Figure 5: Constellation Diagram and Symbol Table & Modulation Accuracy (BPSK 212 kbit/s)

PICC ISO/IEC 14443 A with 212 kbit/s, BPSK Modulation and High EMD During Transmission

The measurement documented below is on a special PICC according to ISO/IEC 14443 A with 212 kbit/s. The PICC produces high EMD during data transmission leading to a measured EVM_{rms} of about 8 % and a peak EVM of about 20%. The measured constellation points are not close to the ideal BPSK constellation points.



FILT

14443_212
SR 212 kHz
Sym&Mod Acc
Ref -20 dBm
CF 14.4075 MHz

1 CLRWR   Att 15 dB   B   TRG

MODULATION ACCURACY

	Result	Peak	atSym	Unit
EVM	8.196	20.256	42	%
Magnitude Err	6.576	15.244	42	%
Phase Error	2.74	7.12	42	deg
CarrierFreq Err	5.57			Hz
Ampt Droop	-0.08			dB
Origin Offset	-23.14			dB
Gain Imbalance	0.00			dB
Quadrature Err	0.00			deg
RHO	0.993283			
Mean Power	-40.14	-37.96	41	dBm
SNR (MER)	21.73			dB

SYMBOL TABLE (Hexadecimal)

00005	1 1 1 1 0 0 0 0 0 0 0 0 0 1 0 0 0 0
00023	0 0 0 0 1 0 0 0 0 0 1 0 1 1 0 1 1 1
00041	1 0 0 0

Figure 6 Constellation Diagram and Symbol Table & Modulation Accuracy (BPSK 212 kbit/s, High EMD PICC)

5 Appendix

Modulation Formats OOK and BPSK

OOK

With OOK modulation, the signal's amplitude changes between zero and full amplitude at the symbol decision points, the phase remains constant with an ideal modulator. With a real modulator, amplitude dependent phase changes may occur.

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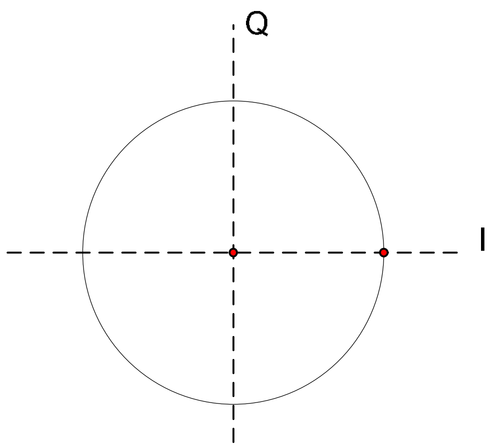

Figure 7: Constellation Diagram of OOK Modulation

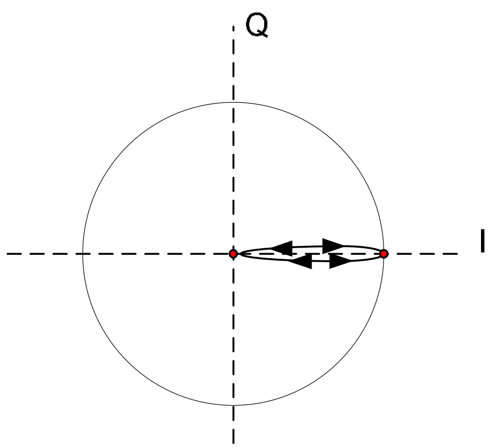

Figure 8: Vector Diagram of OOK Modulation (Non Ideal State Transitions)

BPSK

With BPSK modulation, the signal's phase changes between 0° and 180°: The signal's amplitude is identical at the symbol decision points (full amplitude). Between the symbol decision points, the amplitude is dependent on the modulator characteristic. With an ideal modulator, the amplitude passes zero at the I-axis. With a real modulator it may be desirable that the amplitude is not totally switched off to limit the transmitted spectrum.

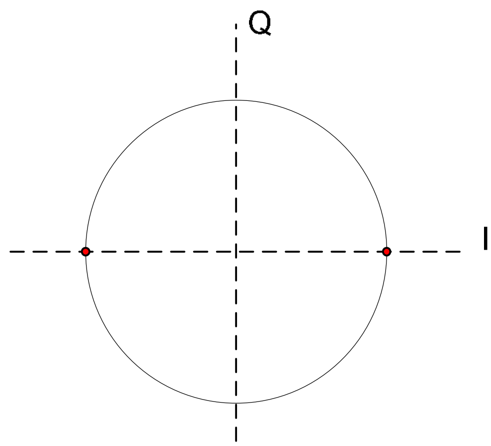

Figure 9: State Diagram of BPSK Modulation

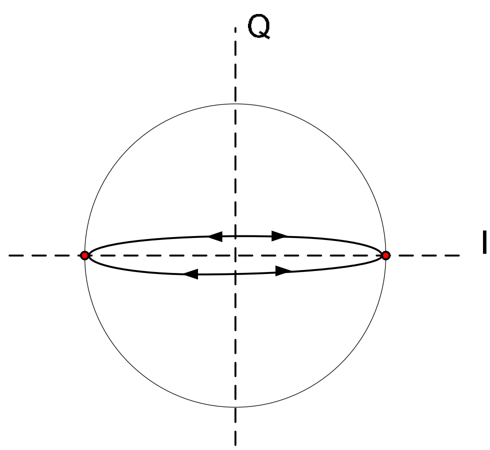

Figure 10: Vector Diagram of BPSK Modulation (Non Ideal State Transitions)

EVM – Error Vector Magnitude

A Vector Signal Analyzer (VSA) generates out of the measured signal a reference signal with ideal modulation. By comparing the measured signal with the internal generated reference signal the VSA can distinguish unwanted modulation caused, for example, by EMD from wanted modulation. Illustrated at a symbol decision point, the EVM is the length of the error vector from the ideal symbol point to the real measured symbol point.

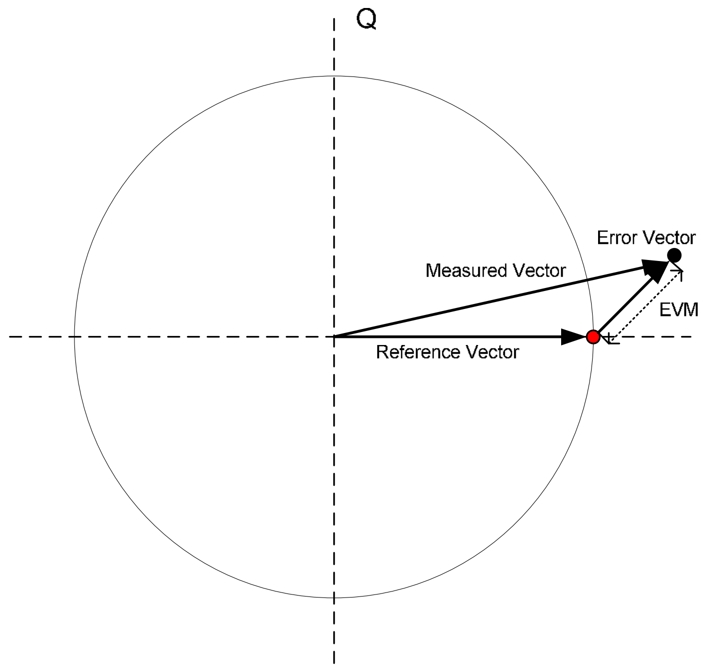

Figure 11: Definition of Error Vector Magnitude (Illustration)

The EVM_{RMS} of a number of symbols is calculated as the quotient of the square root of the sum of the individual error vector lengths and the square root of the sum of the reference vector lengths:

$$EVM_{RMS} = \sqrt{\frac{\sum_{n \in N} |EVM(n)|^2}{\sum_{n \in N} |REF(n)|^2}}$$

Formula 1: Calculation of the RMS Value of EVM over N symbols

Conventions for Instrument Settings for Rohde & Schwarz generators and analyzers

The following conventions of notation are used when referring to settings on Rohde & Schwarz generators and analyzers. Key strokes are in bold italics and softkey strokes in normal italics:

Convention	Description	Example
<***Key***>	Press a key on the front panel	***FREQ***
<*Softkey*>	Press a softkey	*MARKER –>PEAK*
<***Key***>:<*Softkey1*>*:* <*… *>*:…*	In a sequence of key strokes or softkey strokes, a colon is used as a separator	***MARKER:*** *MARKER –>PEAK*
<***nn unit***>	First enter the value using the numerical keypad, then complete the entry with the unit	***12 kHz***
<***nn ENTER***>	First enter the value via the numerical keypad, then complete the entry with the Enter key.	***TDS BS***: *SETTINGS: SCRAMBLING CODE* ***1***: ***ENTER***
(<Comment>)	Comments are enclosed in round brackets.	*(enter required frequency)*

Tabelle 1 Conventions of notation for settings on R&S generators and analyzers

6 Abbreviations

Abbrev.	**Meaning**
AM	Amplitude modulation
ARB	Arbitrary
ASK	Amplitude shift keying
ATQA	Answer to request A
ATQB	Answer to request B
BPSK	Binary phase shift keying
CF	Carrier frequency
CRC	Cyclic redundancy check
CW	Continuous wave
DUT	Device under test
EMD	Electromagnetic disturbance
ETU	Elementary time unit
EVM	Error vector magnitude
FDT	Frame delay time
FFT	Fast Fourier transform
FM	Frequency modulation
FSK	Frequency shift keying
FWT	Frame wait time
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
LSB	Least significant bit
MSB	Most significant bit
NRZ	Non return to zero
OOK	On-off keying
PCD	Proximity coupling device
PICC	Proximity integrated coupling circuit
RBW	Resolution bandwidth
REQA	Request command Type A
REQB	Request command Type B
RF	Radio frequency
RFID	Radio frequency identification
RMS	Root mean square
SWT	Sweep time
WUPA	Wake up command A

WUPB	Wake up command B

7 Literature

[1] ISO/IEC 10373-6 Identification cards - Test methods Part 6: Proximity cards

[2] ISO/IEC 14443-1 Identification cards – Contactless integrated circuit(s) cards – Proximity cards – *Part 1: Physical characteristics*

[3] ISO/IEC 14443-2 Identification cards – Contactless integrated circuit(s) cards – Proximity cards – *Part 2: Radio frequency power and signal interface*

[4] ISO/IEC 14443-3 Identification cards – Contactless integrated circuit(s) cards – Proximity cards – *Part 3: Initialization and anti-collision*

[5] ISO/IEC 14443-4 Identification cards – Contactless integrated circuit(s) cards – Proximity cards – *Part 4: Transmission protocol*

[6] Signal Analyzer R&S®FSQ – Operation Manual

[7] Software Manual Vector Signal Analysis Applications Firmware R&S®FSQ-K70 1161.8038.02 - Rohde&Schwarz

http://www2.rohde-schwarz.com/file_2898/FSQ_K70_e.pdf

[8] Application Note 1MA113 "Measurements on RFID Components According to ISO/IEC 14443 Standard" http://www.rohde-schwarz.com/appnote/1MA113.html

8 Additional Information

This Application Note is likely to be improved and extended. Please visit the website **1MA120** in order to download new versions. Please send any comments or suggestions about this Application Aote to **TM-Applications@rsd.rohde-schwarz.com**.

9 Ordering information

Spectrum analyzer

Designation	Frequency range	Order No.
R&S®FSQ3	20 Hz to 3.6 GHz	1155.5001.03
R&S®FSQ8	20 Hz to 8 GHz	1155.5001.08
R&S®FSQ26	20 Hz to 26.5 GHz	1155.5001.26
R&S®FSQ-K70	Firmware Vector Signal Analyzer	1161.8038.02
R&S®FSU3	20 Hz to 3.6 GHz	1166.1660.03
R&S®FSU8	20 Hz to 8 GHz	1166.1660.08
R&S®FSU26	20 Hz to 26.5 GHz	1166.1660.26
R&S®FSU46	20 Hz to 46 GHz	1166.1660.46
R&S® FSU-U73/-B73	Vector Signal Analyzer for FSUI	1169.5696.0x
R&S®FSG8	9 kHz to 8 GHz	1303.0002.08
R&S®FSG13	9 kHz to 13.6 GHz	1303.0002.13

Signal Generator

R&S®SMJ100A	Vector Signal Generator	1403.4507.02
R&S®SMJ-B103	100 kHz to 3 GHz	1403.8502.02
R&S®SMJ-B106	100 kHz to 6 GHz	1403.8702.02
R&S®SMJ-B9	Baseband Generator with ARB (128 Msamples) and Digital Modulation	1404.1501.02
R&S®SMJ-B10	Baseband Generator with ARB (64 Msamples) and Digital Modulation	1403.8902.02
R&S®SMJ-B11	Baseband Generator with ARB (16 Msamples) and Digital Modulation	1403.9009.02
R&S®SMJ-B13	Baseband Main Module	1403.9109.02
R&S®SMJ-B50	Baseband Generator with ARB (64 Msamples)	1410.5505.02
R&S®SMJ-B51	Baseband Generator with ARB (16 Msamples)	1410.5605.02
R&S®SMJ-K6	Pulse Sequencer	1409.2558.02
R&S®SMU200A	Vector Signal Generator	1141.2005.02
R&S®SMU-B102	RF Path A: 100 kHz to 2.2 GHz	1141.8503.02
R&S®SMU-B103	RF Path A: 100 kHz to 3 GHz	1141.8603.02
R&S®SMU-B104	RF Path A: 100 kHz to 4 GHz	1141.8703.02
R&S®SMU-B106	RF Path A: 100 kHz to 6 GHz	1141.8803.02
R&S®SMU-B203	Baseband Generator with ARB (64 Msamples)	1141.9500.02

R&S®SMU-B9	Baseband Generator with ARB (128 Msamples) and Digital Modulation	1161.0766.02
R&S®SMU-B10	Baseband Generator with ARB (64 Msamples) and Digital Modulation	1141.7007.02
R&S®SMU-B11	Baseband Generator with ARB (16 Msamples) and Digital Modulation	1159.8411.02
R&S®SMU-B13	Baseband Main Module	1141.8003.02
R&S®SMU-K6	Pulse Sequencer	1408.7662.02
R&S®AMU200A	Baseband Signal Generator	1402.4090.02
R&S®AMU-B9	Baseband Generator (128 Msamples)	1402.8809.02
R&S®AMU-B10	Baseband Generator (64 Msamples)	1402.5300.02
R&S®AMU-B11	Baseband Generator (16 Msamples)	1402.5400.02
R&S®AMU-B13	Baseband Main Module	1402.5500.02
R&S®AMU-K6	Pulse Sequencer	1402.9805.02
R&S®AFQ100A	I/Q Modulation Generator	1401.3003.02
R&S® AFQ-B10	Waveform Memory 256 Msample	1401.5106.02
R&S® AFQ-B11	Waveform Memory 1 Gsample	1401.5206.02
R&S® AFQ-K6	Pulse Sequencer	1401.5606.02

ROHDE & SCHWARZ

ROHDE & SCHWARZ GmbH & Co. KG · Mühldorfstraße 15 · D-81671 München · Postfach 80 14 69 · D-81614 München ·
Tel (089) 4129 -0 · Fax (089) 4129 - 13777 · Internet: http://www.rohde-schwarz.com