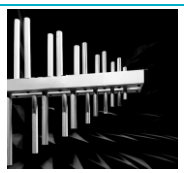
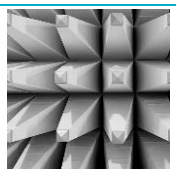

CTC advanced
member of RWTÜV group

TEST REPORT

Test report no.: 1-4079/17-01-04

DAkkS Deutsche Akkreditierungsstelle D-PL-12076-01-01

Testing laboratory

CTC advanced GmbH
Untertuerkheimer Strasse 6 – 10
66117 Saarbruecken / Germany
Phone: + 49 681 5 98 - 0
Fax: + 49 681 5 98 - 9075
Internet: http://www.ctcadvanced.com
e-mail: mail@ctcadvanced.com

Accredited Testing Laboratory:
The testing laboratory (area of testing) is accredited according to DIN EN ISO/IEC 17025 (2005) by the Deutsche Akkreditierungsstelle GmbH (DAkkS)
The accreditation is valid for the scope of testing procedures as stated in the accreditation certificate with the registration number: D-PL-12076-01-03

Applicant

KROHNE Innovation GmbH
Ludwig-Krohne-Straße 5
47058 Duisburg / GERMANY
Phone: +49 0 203 301 0
Fax: +49 0 234 58880 101
Contact: Charalambos Ouzounis
e-mail: c.ouzounis@krohne.com
Phone: +49 0 234 58880 152

Manufacturer

KROHNE Innovation GmbH
Ludwig-Krohne-Straße 5
47058 Duisburg / GERMANY

Test standard/s

47 CFR Part 15	Title 47 of the Code of Federal Regulations; Chapter I; Part 15 – Radio frequency devices
RSS-211	Level Probing Radar Equipment

For further applied test standards please refer to section 3 of this test report.

Test Item

Kind of test item:	**Level Probing Radar**
Model name:	**Optiwave x400 series**
FCC ID:	**Q6BFMCW24GX4L**
IC:	**1991D-FMCW24GX4L**
Frequency:	24.05 GHz – 29.00 GHz
Antenna:	Metallic Horn / Drop Antenna
Power supply:	14.0 – 30.0 V DC, 30 mA
Temperature range:	-40 °C to +85 °C

This test report is electronically signed and valid without handwritten signature. For verification of the electronic signatures, the public keys can be requested at the testing laboratory.

Test report authorized:

B. Gerber

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2018.02.15 10:21:36 +01'00'

Benedikt Gerber
Lab Manager
Radio Communications & EMC

Test performed:

M. Walla

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Meheza Walla
Lab Manager
Radio Communications & EMC

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2 General information

2.1 Notes and disclaimer

The test results of this test report relate exclusively to the test item specified in this test report. CTC advanced GmbH does not assume responsibility for any conclusions and generalizations drawn from the test results with regard to other specimens or samples of the type of the equipment represented by the test item.
The test report may only be reproduced or published in full. Reproduction or publication of extracts from the report requires the prior written approval of CTC advanced GmbH.
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This test report is electronically signed and valid without handwritten signature. For verification of the electronic signatures, the public keys can be requested at the testing laboratory.

2.2 Application details

Date of receipt of order:	2017-07-25
Date of receipt of test item:	2017-07-24
Start of test:	2017-07-24
End of test:	2017-10-25
Person(s) present during the test:	Mr. Charalambos Ouzounis

2.3 Test laboratories sub-contracted

None

3 Test standard/s and references

Test standard	Date	Description
47 CFR Part 15	2017-10	Title 47 of the Code of Federal Regulations; Chapter I; Part 15 – Radio frequency devices
RSS-211	2015-03	Level Probing Radar Equipment
890966 D01 v01r01	2014-09	Measurement Procedure for Level Probing Radars

Reference	Version	Description
ANSI C63.4-2014	-/-	American national standard for methods of measurement of radio-noise emissions from low-voltage electrical and electronic equipment in the range of 9 kHz to 40 GHz
ANSI C63.10-2013	-/-	American national standard of procedures for compliance testing of unlicensed wireless devices
Antennas-for-lpr-applications_v1-3.pdf	Issue 0.1 of 2017-10-04	Antenna pattern provided by manufacturer
Operational description OPTIWAVE x400 series.pdf	Issue 0.5 of 2018-01-29	Technical description of device under test provided by manufacturer

4 Test environment

Temperature :	T_{nom} T_{max} T_{min}	+22 °C during room temperature tests +85 °C during high temperature tests -40 °C during low temperature tests
Relative humidity content :		55 %
Barometric pressure :		1021 hpa
Power supply :	V_{nom} V_{max} V_{min}	24.0 V DC, 30 mA 30.0 V 14.0 V

5 Test item

5.1 General description

Kind of test item	:	Level Probing Radar
Type identification	:	Optiwave x400 series
HMN	:	NA
PMN	:	OPTIWAVE x400 series
HVIN	:	24GHZ-L-C
FVIN	:	NA
S/N serial number	:	Radiated test sample with HART 7 Bus: Prototype Radiated test sample with Profibus PA / Foundation Fieldbus (FF): Prototype Conducted special test sample: Prototype
HW hardware status	:	Display: 4002905801 A Converter Profibus PA / Foundation Fieldbus (FF): Prototype Converter HART 7 Bus: 4002260702 _ Sensor 24GHz: 4002332102 _ RF Module: 4002558501 C Terminal board: 4002522101 _
SW software status	:	Sensor V1.24.02_ Converter V1.24.02_
Frequency band	:	24.05 GHz – 29.00 GHz
Type of modulation	:	FMCW
Number of channels	:	1
Antenna	:	Metallic Horn / Drop Antenna
Power supply	:	14.0 V to 30.0 V DC, 30 mA
Temperature range	:	-40 °C to +85 °C

Note:
Following antennas can be used as LPR application:

Antennas	Gain [dBi]	3dB width E- / H-plane [°]	Side lobe gain relative to main beam [dB]
316L / DN80 (3”) Metallic Horn	24.3	9.2 / 11.8	< -27
316L / DN100 (4”) Metallic Horn	25.7	7.7 / 9.6	< -27
316L / DN150 (6”) Metallic Horn	27.7	5.6 / 6.6	< -27
316L / DN200 (8”) Metallic Horn	28.1	5.1 / 5.8	< -27
PTFE / DN80 (3”) Drop	25.5	7.6 / 7.5	< -27
PP / DN80 (3”) Drop	25.8	7.8 / 7.8	< -27
PEEK / DN80 (3”) Drop	24.0	9.1 / 9.6	< -27
PTFE / DN100 (4”) Drop	27.0	6.1 / 6.2	< -27
PP / DN100 (4”) Drop	27.5	6.3 / 6.4	< -27
PEEK / DN100 (4”) Drop	25.6	7.1 / 7.5	< -27
PTFE / DN150 (6”) Drop	29.5	4.2 / 4.2	< -27
PP / DN150 (6”) Drop	30.4	4.3 / 4.3	< -27
PEEK / DN150 (6”) Drop	28.3	4.7 / 5.0	< -27

5.2 Additional information

Optiwave x400 series is available as LPR and TLPR configuration. The radar system is identical except the antenna which has to be selected depending on the application.
Two different interfaces are available: HART 7 Bus and Profibus PA / Foundation Fieldbus (FF).

The customer provided three test samples for the measurements:

- Two test samples with integrated antenna for radiated spurious: HART 7 Bus and Profibus PA / Foundation Fieldbus (FF);
- Another test sample especially prepared with a waveguide to coax adapter for performing conducted measurements and and high measurement rate / high duty cycle: approx. 10 measurements/second.

Three different cycle times are available T_{Cycle1} = 500 ms, T_{Cycle2} = 200 ms and T_{Cycle3} = 100 ms.

The content of the following annexes is defined in the QA. It may be that not all of the listed annexes are necessary for this report, thus some values in between may be missing.

Test setup- and EUT-photos are included in test report: 1-4079/17-01-01_AnnexA
1-4079/17-01-01_AnnexB
1-4079/17-01-01_AnnexC

6 Sequence of testing

6.1 Sequence of testing radiated spurious 9 kHz to 30 MHz

Setup

- The equipment is set up to simulate normal operation mode as described in the user manual or defined by the manufacturer.
- If the EUT is a tabletop system, it is placed on a table with 0.8 m height.
- If the EUT is a floor standing device, it is placed directly on the turn table.
- Auxiliary equipment and cables are positioned to simulate normal operation conditions as described in ANSI C 63.4.
- The AC power port of the EUT (if available) is connected to a power outlet below the turntable.
- Measurement distance is 3 m (see ANSI C 63.4) – see test details.
- EUT is set into operation.

Premeasurement*

- The turntable rotates from 0° to 315° using 45° steps.
- The antenna height is 1 m.
- At each turntable position the analyzer sweeps with positive-peak detector to find the maximum of all emissions.

Final measurement

- Identified emissions during the pre-measurement are maximized by the software by rotating the turntable from 0° to 360°.
- Loop antenna is rotated about its vertical axis for maximum response at each azimuth about the EUT. (For certain applications, the loop antenna plane may also need to be positioned horizontally at the specified distance from the EUT)
- The final measurement is done in the position (turntable and elevation) causing the highest emissions with quasi-peak (as described in ANSI C 63.4).
- Final levels, frequency, measuring time, bandwidth, turntable position, correction factor, margin to the limit and limit will be recorded. A plot with the graph of the premeasurement and the limit is stored.

*)Note: The sequence will be repeated three times with different EUT orientations.

6.2 Sequence of testing radiated spurious 30 MHz to 1 GHz

Setup

- The equipment is set up to simulate normal operation mode as described in the user manual or defined by the manufacturer.
- If the EUT is a tabletop system, a table with 0.8 m height is used, which is placed on the ground plane.
- If the EUT is a floor standing device, it is placed on the ground plane with insulation between both.
- Auxiliary equipment and cables are positioned to simulate normal operation conditions as described in ANSI C 63.4.
- The AC power port of the EUT (if available) is connected to a power outlet below the turntable.
- Measurement distance is 10 m or 3 m (see ANSI C 63.4) – see test details.
- EUT is set into operation.

Premeasurement

- The turntable rotates from 0° to 315° using 45° steps.
- The antenna is polarized vertical and horizontal.
- The antenna height changes from 1 m to 3 m.
- At each turntable position, antenna polarization and height the analyzer sweeps three times in peak to find the maximum of all emissions.

Final measurement

- The final measurement is performed for at least six highest peaks according to the requirements of the ANSI C63.4.
- Based on antenna and turntable positions at which the peak values are measured the software maximize the peaks by changing turntable position ± 45° and antenna height between 1 and 4 m.
- The final measurement is done with quasi-peak detector (as described in ANSI C 63.4).
- Final levels, frequency, measuring time, bandwidth, antenna height, antenna polarization, turntable angle, correction factor, margin to the limit and limit are recorded. A plot with the graph of the premeasurement with marked maximum final results and the limit is stored.

6.3 Sequence of testing radiated spurious 1 GHz to 18 GHz

Setup

- The equipment is set up to simulate normal operation mode as described in the user manual or defined by the manufacturer.
- If the EUT is a tabletop system, a 2-axis positioner with 1.5 m height is used.
- If the EUT is a floor standing device, it is placed directly on the turn table.
- Auxiliary equipment and cables are positioned to simulate normal operation conditions as described in ANSI C 63.4.
- The AC power port of the EUT (if available) is connected to a power outlet below the turntable.
- Measurement distance is 3 m (see ANSI C 63.4) – see test details.
- EUT is set into operation.

Premeasurement

- The turntable rotates from 0° to 315° using 45° steps.
- The antenna is polarized vertical and horizontal.
- The antenna height is 1.5 m.
- At each turntable position and antenna polarization the analyzer sweeps with positive peak detector to find the maximum of all emissions.

Final measurement

- The final measurement is performed for at least six highest peaks according to the requirements of the ANSI C63.4.
- Based on antenna and turntable positions at which the peak values are measured the software maximizes the peaks by rotating the turntable from 0° to 360°. This measurement is repeated for different EUT-table positions (0° to 150° in 30°-steps) and for both antenna polarizations.
- The final measurement is done in the position (turntable, EUT-table and antenna polarization) causing the highest emissions with Peak and RMS detector (as described in ANSI C 63.4).
- Final levels, frequency, measuring time, bandwidth, turntable position, EUT-table position, antenna polarization, correction factor, margin to the limit and limit are recorded. A plot with the graph of the premeasurement with marked maximum final results and the limit is stored.

6.4 Sequence of testing radiated spurious above 18 GHz

Setup

- The equipment is set up to simulate normal operation mode as described in the user manual or defined by the manufacturer.
- Auxiliary equipment and cables are positioned to simulate normal operation conditions as described in ANSI C 63.4.
- The AC power port of the EUT (if available) is connected to a power outlet.
- The measurement distance is as appropriate (e.g. 0.5 m).
- The EUT is set into operation.

Premeasurement

- The test antenna is handheld and moved carefully over the EUT to cover the EUT's whole sphere and different polarizations of the antenna.

Final measurement

- The final measurement is performed at the position and antenna orientation causing the highest emissions with Peak and RMS detector (as described in ANSI C 63.4).
- Final levels, frequency, measuring time, bandwidth, correction factor, margin to the limit and limit are recorded. A plot with the graph of the premeasurement and the limit is stored.

6.5 Sequence of testing radiated spurious above 50 GHz with external mixers

Setup

- The equipment is set up to simulate normal operation mode as described in the user manual or defined by the manufacturer.
- Auxiliary equipment and cables are positioned to simulate normal operation conditions as described in ANSI C 63.4.
- The AC power port of the EUT (if available) is connected to a power outlet.
- The measurement distance is as appropriate for far field (e.g. 0.25 m).
- The EUT is set into operation.

Premeasurement

- The test antenna with external mixer is handheld and moved carefully over the EUT to cover the EUT's whole sphere and different polarizations of the antenna.
- Caution is taken to reduce the possible overloading of the external mixer.

Final measurement

- The final measurement is performed at the position and antenna orientation causing the highest emissions with Peak and RMS detector (as described in ANSI C 63.4).
- As external mixers may generate false images care is taken to ensure that any emission measured by the spectrum analyzer does indeed originate in the EUT. Signal identification feature of spectrum analyzer is used to eliminate false mixer images (i.e., it is not the fundamental emission or a harmonic falling precisely at the measured frequency).
- Final levels, frequency, measuring time, bandwidth, correction factor, margin to the limit and limit are recorded. A plot with the graph of the premeasurement and the limit is stored.

7 Description of the test setup

Typically, the calibrations of the test apparatus are commissioned to and performed by an accredited calibration laboratory. The calibration intervals are determined in accordance with the DIN EN ISO/IEC 17025. In addition to the external calibrations, the laboratory executes comparison measurements with other calibrated test systems or effective verifications. Weekly chamber inspections and range calibrations are performed. Where possible, RF generating and signaling equipment as well as measuring receivers and analyzers are connected to an external high-precision 10 MHz reference (GPS-based or rubidium frequency standard).

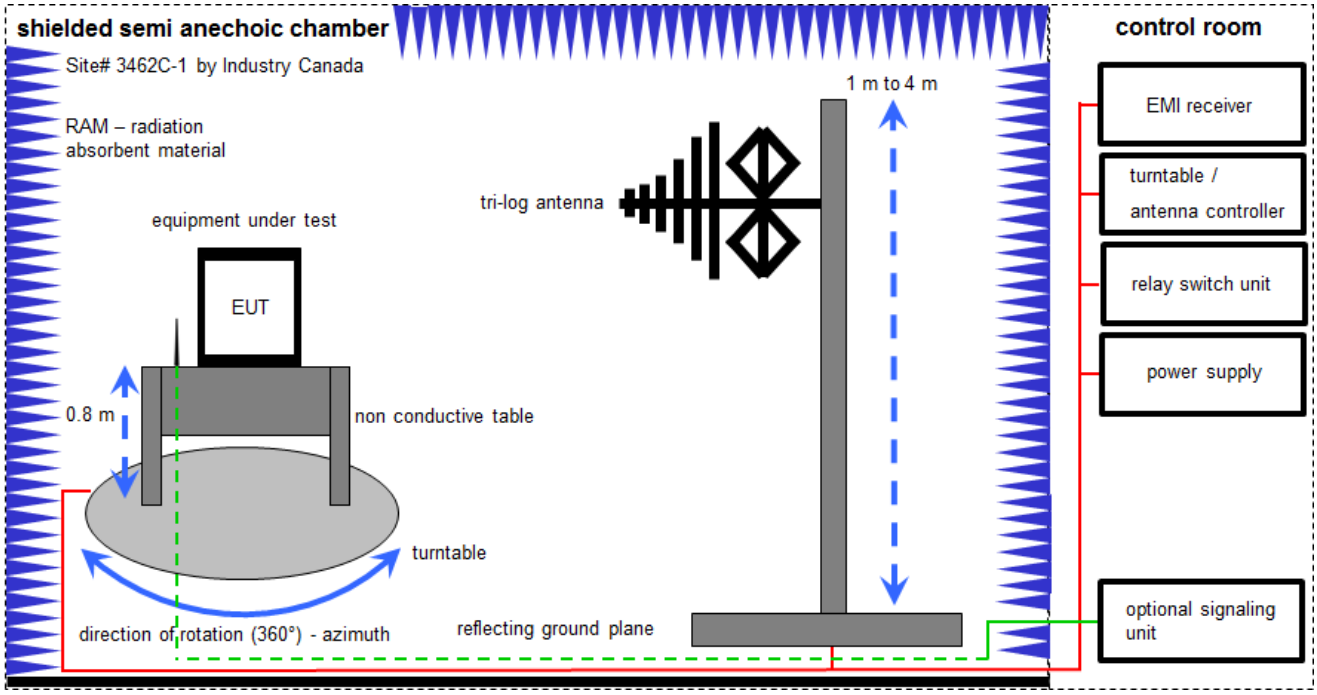
In order to simplify the identification of the equipment used at some special tests, some items of test equipment and ancillaries can be provided with an identifier or number in the equipment list below (Lab/Item).

Agenda: Kind of Calibration

k	calibration / calibrated	EK	limited calibration
ne	not required (k, ev, izw, zw not required)	zw	cyclical maintenance (external cyclical maintenance)
ev	periodic self verification	izw	internal cyclical maintenance
Ve	long-term stability recognized	g	blocked for accredited testing
vlkl!	Attention: extended calibration interval		
NK!	Attention: not calibrated	*)	next calibration ordered / currently in progress

7.1 Shielded semi anechoic chamber

The radiated measurements are performed in vertical and horizontal plane in the frequency range from 9 kHz to 1 GHz in semi-anechoic chambers. The EUT is positioned on a non-conductive support with a height of 0.80 m above a conductive ground plane that covers the whole chamber. The receiving antennas are confirmed with specifications ANSI C63. These antennas can be moved over the height range between 1.0 m and 4.0 m in order to search for maximum field strength emitted from EUT. The measurement distances between EUT and receiving antennas are indicated in the test setups for the various frequency ranges. For each measurement, the EUT is rotated in all three axes until the maximum field strength is received. The wanted and unwanted emissions are received by spectrum analyzers where the detector modes and resolution bandwidths over various frequency ranges are set according to requirement ANSI C63.



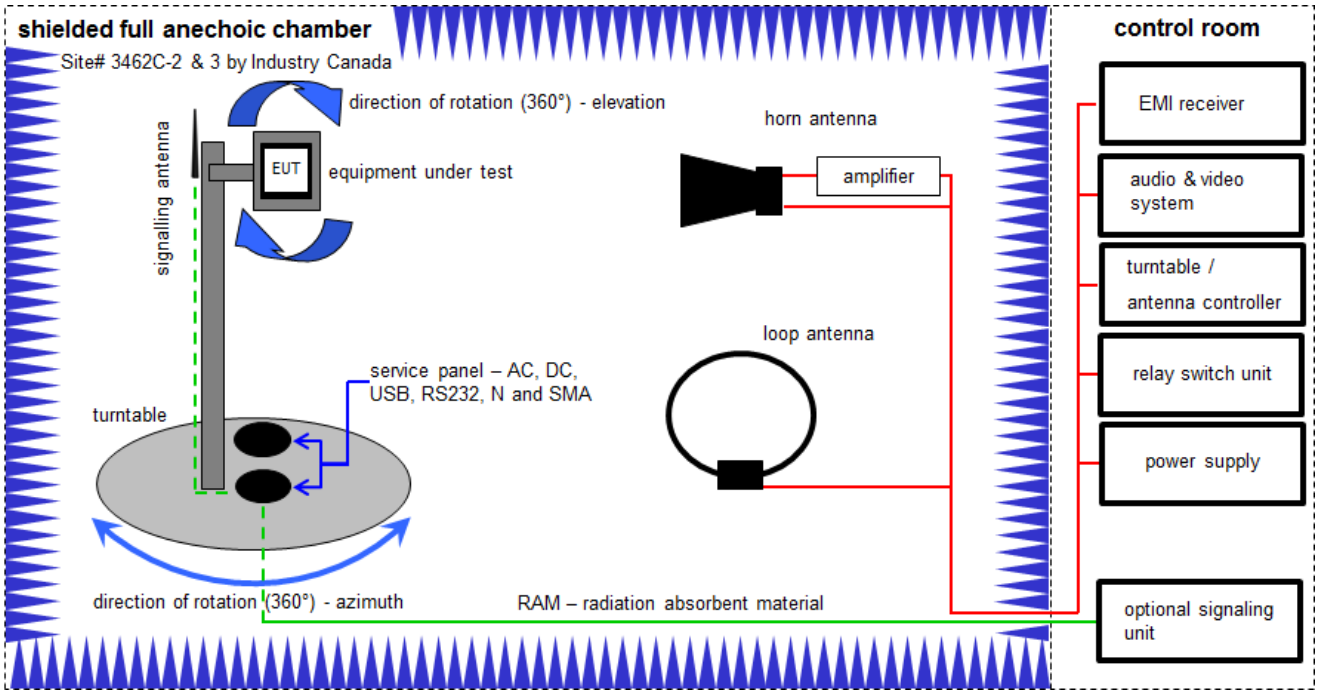
FS = UR + CL + AF
(FS-field strength; UR-voltage at the receiver; CL-loss of the cable; AF-antenna factor)

Example calculation:
FS [dBµV/m] = 12.35 [dBµV/m] + 1.90 [dB] + 16.80 [dB/m] = 31.05 [dBµV/m] (35.69 µV/m)

Equipment table:

No.	Lab / Item	Equipment	Type	Manufacturer	Serial No.	INV. No	Kind of Calibration	Last Calibration	Next Calibration
1	n. a.	Switch-Unit	3488A	HP	2719A14505	300000368	ev	-/-	-/-
2	n. a.	DC power supply, 60Vdc, 50A, 1200 W	6032A	HP	2920A04466	300000580	ne	-/-	-/-
3	n. a.	Meßkabine 1	HF-Absorberhalle	MWB AG 300023		300000551	ne	-/-	-/-
4	n. a.	EMI Test Receiver	ESCI 3	R&S	100083	300003312	k	01.02.2017	31.01.2018
5	n. a.	Analyzer-Reference-System (Harmonics and Flicker)	ARS 16/1	SPS	A3509 07/0 0205	300003314	vIKI!	02.02.2016	01.02.2018
6	n. a.	Antenna Tower	Model 2175	ETS-Lindgren	64762	300003745	izw	-/-	-/-
7	n. a.	Positioning Controller	Model 2090	ETS-Lindgren	64672	300003746	izw	-/-	-/-
8	n. a.	Turntable Interface-Box	Model 105637	ETS-Lindgren	44583	300003747	izw	-/-	-/-
9	n. a.	TRILOG Broadband Test-Antenna 30 MHz - 3 GHz	VULB9163	Schwarzbeck	295	300003787	k	25.04.2016	25.04.2018
10	n. a.	Spectrum-Analyzer	FSU26	R&S	200809	300003874	k	31.01.2017	30.01.2018

7.2 Shielded fully anechoic chamber



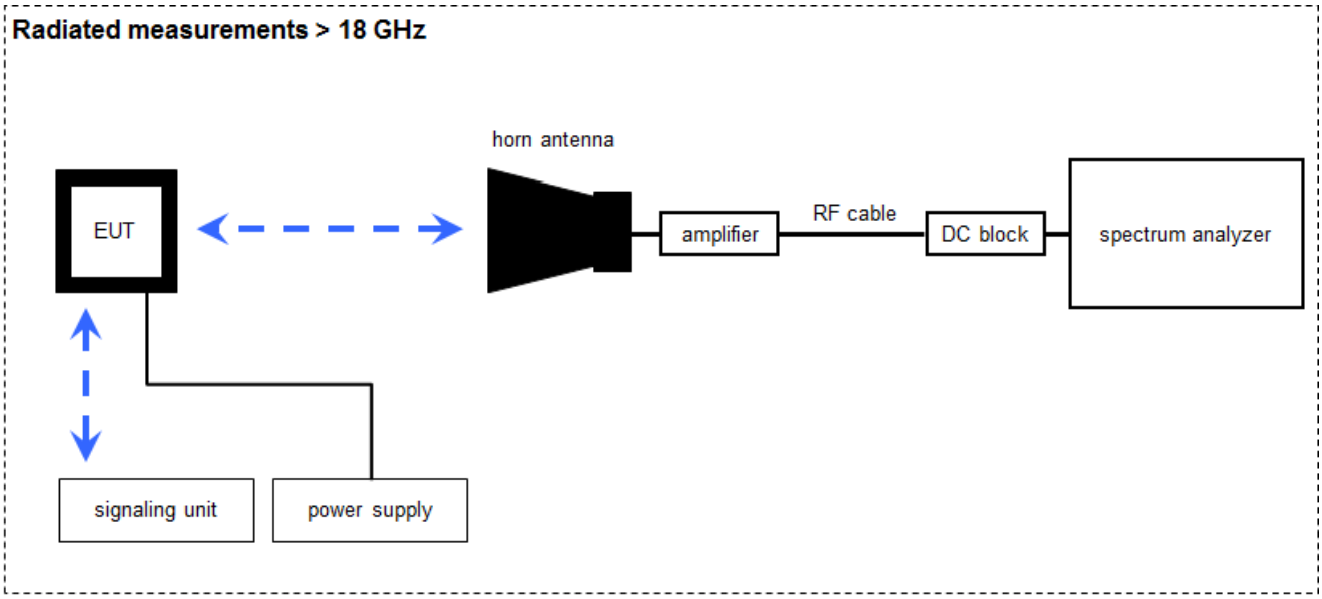
FS = UR + CA + AF
(FS-field strength; UR-voltage at the receiver; CA-loss of the signal path; AF-antenna factor)

Example calculation:
FS [dBµV/m] = 40.0 [dBµV/m] + (-35.8) [dB] + 32.9 [dB/m] = 37.1 [dBµV/m] (71.61 µV/m)

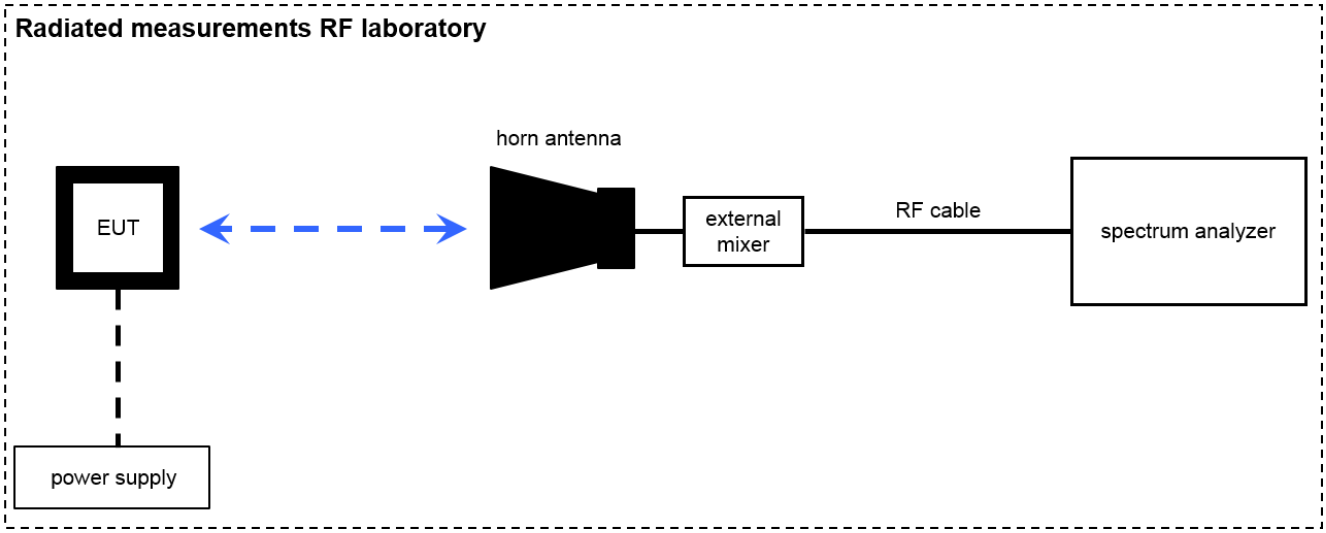
Equipment table:

No.	Lab / Item	Equipment	Type	Manufact.	Serial No.	CTC no.	Kind of Calibration	Last Calibration	Next Calibration
1	n. a.	DC power supply, 60Vdc, 50A, 1200 W	6032A	HP	2818A03450	300001040	vIKI!	20.01.2015	19.01.2018
2	n. a.	Anechoic chamber	FAC 3/5m	MWB / TDK	87400/02	300000996	ev	-/-	-/-
3	19	Double-Ridged Waveguide Horn Antenna 1-18.0GHz	3115	EMCO	9107-3697	300001605	vIKI!	14.02.2017	13.02.2019
4	n. a.	Switch / Control Unit	3488A	HP	*	300000199	ne	-/-	-/-
5	n. a.	EMI Test Receiver 20Hz- 26,5GHz	ESU26	R&S	100037	300003555	k	31.01.2017	30.01.2018
6	n. a.	Highpass Filter	WHKX7.0/18G-8SS	Wainwright	19	300003790	ne	-/-	-/-
7	n. a.	TRILOG Broadband Test-Antenna 30 MHz - 3 GHz	VULB9163	Schwarzbeck	371	300003854	vIKI!	29.10.2014	29.10.2017
8	n. a.	Broadband Amplifier 0.5-18 GHz	CBLU5184540	CERNEX	22049	300004481	ev	-/-	-/-
9	n. a.	Broadband Amplifier 5-13 GHz	CBLU5135235	CERNEX	22010	300004491	ev	-/-	-/-
10	n. a.	4U RF Switch Platform	L4491A	Agilent Technologies	MY50000037	300004509	ne	-/-	-/-
11	n. a.	NEXIO EMV-Software	BAT EMC V3.16.0.49	EMCO		300004682	ne	-/-	-/-
12	n. a.	PC	ExOne	F+W		300004703	ne	-/-	-/-
13	n. a.	RF-Amplifier	AMF-6F06001800-30-10P-R	NARDA-MITEQ Inc	2011572	300005241	ev	-/-	-/-

7.3 Radiated measurements > 18 GHz



7.4 Radiated measurements > 50 GHz

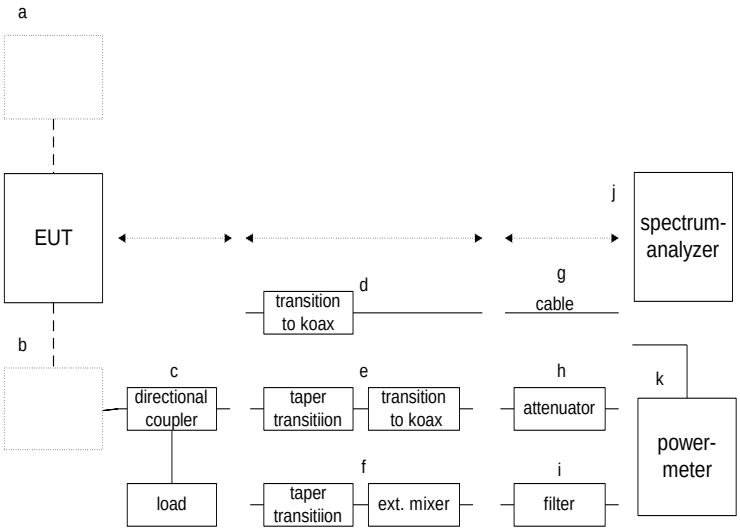


OP = AV + D - G
(OP-rad. output power; AV-analyzer value; D-free field attenuation of measurement distance; G-antenna gain)

Example calculation:
OP [dBm] = -54.0 [dBm] + 64.0 [dB] - 20.0 [dBi] = -10 [dBm] (100 µW)

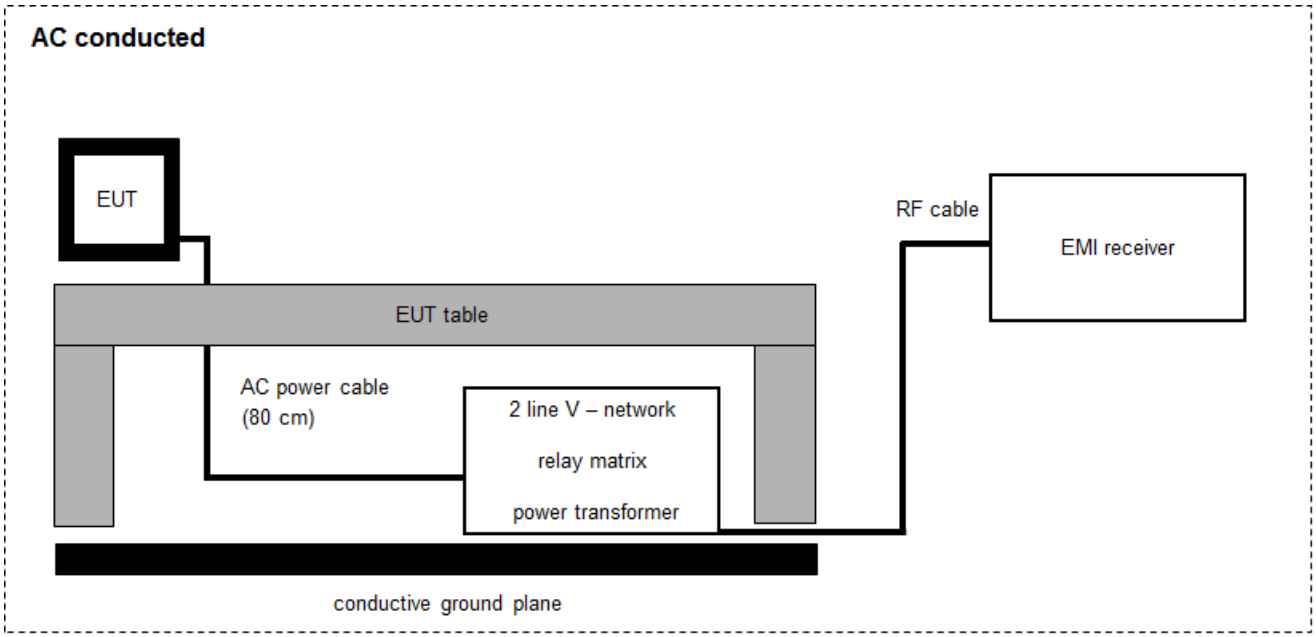
Note: conversion loss of mixer is already included in analyzer value.

7.5 Conducted measurements in test lab



No.	Lab / Item	Equipment	Type	Manufacturer	Serial No.	INV. No.	Kind of Calibration	Last Calibration	Next Calibration
1	n. a.	Broadband LNA 18-50 GHz	CBL18503070PN	CERNEX	25240	300004948	ev	-/-	-/-
2	n. a.	Harmonic Mixer 2-Port, 50-75 GHz	FS-Z75	R&S	100099	300003949	k	30.06.2017	29.06.2018
3	n. a.	Harmonic Mixer 3-Port, 60-90 GHz	FS-Z90	R&S	101555	300004691	k	30.06.2017	29.06.2018
4	n. a.	Harmonic Mixer 3-Port, 75-110 GHz	FS-Z110	R&S	101411	300004959	k	03.07.2017	02.07.2018
5	n. a.	Spectrum Analyzer 20 Hz - 50 GHz	FSU50	R&S	200012	300003443	Ve	28.10.2016	27.10.2018
6	n. a.	Std. Gain Horn Antenna 12.4-18.0 GHz	639	Narda	8402	300000787	ne	-/-	-/-
7	n. a.	Std. Gain Horn Antenna 18.0-26.5 GHz	638	Narda		300000486	ne	-/-	-/-
8	n. a.	Std. Gain Horn Antenna 26.5-40.0 GHz	V637	Narda	82-16	300000510	ne	-/-	-/-
9	n. a.	Std. Gain Horn Antenna 33.0-50.1 GHz	2324-20	Flann	57	400000683	ne	-/-	-/-
10	n. a.	Std. Gain Horn Antenna 49.9-75.8 GHz	2524-20	Flann	*	300001983	ne	-/-	-/-
11	n. a.	Std. Gain Horn Antenna 60-90 GHz	COR 60_90	Thomson CSF		300000814	ne	-/-	-/-
12	n. a.	Std. Gain Horn Antenna 75-110 GHz	2724-20	Flann	*	300001988	ne	-/-	-/-

7.6 AC conducted



FS = UR + CF + VC
(FS-field strength; UR-voltage at the receiver; CR-loss of the cable and filter; VC-correction factor of the ISN)

Example calculation:
FS [dBµV/m] = 37.62 [dBµV/m] + 9.90 [dB] + 0.23 [dB] = 47.75 [dBµV/m] (244.06 µV/m)

Equipment table:

No.	Lab / Item	Equipment	Type	Manufacturer	Serial No.	INV. No.	Kind of Calibration	Last Calibration	Next Calibration
1		Two-line V-Network (LISN) 9 kHz to 30 MHz	ESH3-Z5	R&S	893045/004	300000584	k	31.01.2017	30.01.2018
2		RF-Filter-section	85420E	HP	3427A00162	300002214	k	27.11.2006	-/-
3		Hochpass 150 kHz	EZ-25	R&S	100010	300003798	ev	08.04.2008	-/-
4		Power Supply	NGSM 32/10	R&S	3939	400000192	vIKI!	31.01.2017	30.01.2020
5		MXE EMI Receiver 20 Hz to 26,5 GHz	N9038A	Agilent Technologies	MY51210197	300004405	k	16.08.2016	16.08.2018
6		Wideband Radio Communication Tester	CMW500	R&S	102375	300004187	k	14.12.2015	13.12.2017

8 Measurement uncertainty

Measurement uncertainty	
Test case	**Uncertainty**
Spectrum bandwidth	span/1000
Conducted output power	± 3 dB
Spurious emissions radiated below 30 MHz	± 3 dB
Spurious emissions radiated 30 MHz to 1 GHz	± 3 dB
Spurious emissions radiated 1 GHz to 12.75 GHz	± 3.7 dB
Spurious emissions radiated above 12.75 GHz	± 4.5 dB
Spurious emissions conducted below 30 MHz (AC conducted)	± 2.6 dB

9 Summary of measurement results

☒	**No deviations from the technical specifications were ascertained**
☐	There were deviations from the technical specifications ascertained
☐	This test report is only a partial test report. The content and verdict of the performed test cases are listed below.

TC identifier	Description	verdict	date	Remark
RF-Testing	47 CFR Part 15 / RSS-211	see below	2018-02-08	-/-

Test Specification Clause	Test Case	Temperature Conditions	Power Source Voltages	C	NC	NA	NP	Results
§15.215(c)	Frequency stability	Nominal Extreme	Nominal Extreme	☒	☐	☐	☐	Complies
§15.256(f) RSS-211, 2.4	Fundamental bandwidth	Nominal	Nominal	☒	☐	☐	☐	Complies
§15.256(g) RSS-211,5.2b	Fundamental emissions limits	Nominal	Nominal	☒	☐	☐	☐	Complies
§15.256(h) RSS-211,5.1d	Unwanted emissions limit	Nominal	Nominal	☒	☐	☐	☐	Complies
§15.256(i) RSS-211,5.2a	Antenna beamwidth	Nominal	Nominal	☒	☐	☐	☐	Complies
§15.256(j) RSS-211,5.2c	Antenna side lobe gain	Nominal	Nominal	☒	☐	☐	☐	Complies
§15.256(k) RSS-Gen, 7.1	Emissions from digital circuitry	Nominal	Nominal	☒	☐	☐	☐	Complies
§15.107/207 RSS-Gen, 8.8	Conducted limits	Nominal	Nominal	☒	☐	☐	☐	Complies

Note: C = Compliant; NC = Not compliant; NA = Not applicable; NP = Not performed

10 Test results

10.1 Frequency stability and fundamental bandwidth

Description:

§15.215(c) Intentional radiators operating under the alternative provisions to the general emission limits, as contained in §§15.217 through 15.257 and in subpart E of this part, must be designed to ensure that the 20 dB bandwidth of the emission, or whatever bandwidth may otherwise be specified in the specific rule section under which the equipment operates, is contained within the frequency band designated in the rule section under which the equipment is operated. In the case of intentional radiators operating under the provisions of subpart E, the emission bandwidth may span across multiple contiguous frequency bands identified in that subpart. The requirement to contain the designated bandwidth of the emission within the specified frequency band includes the effects from frequency sweeping, frequency hopping and other modulation techniques that may be employed as well as the frequency stability of the transmitter over expected variations in temperature and supply voltage. If a frequency stability is not specified in the regulations, it is recommended that the fundamental emission be kept within at least the central 80% of the permitted band in order to minimize the possibility of out-of-band operation.

§15.256(f) The fundamental bandwidth of an LPR emission is defined as the width of the signal between two points, one below and one above the center frequency, outside of which all emissions are attenuated by at least 10 dB relative to the maximum transmitter output power when measured in an equivalent resolution bandwidth.

Measurement:

f_C is the point in the radiation where the power is at maximum. The frequency points where the power falls 10 dB below the f_C level and above f_C level are designated as f_L and f_H respectively.
The operating frequency range (i.e. the frequency band of operation) is defined as f_H - f_L.

Measurement parameters:

Resolution bandwidth:	1 MHz
Video bandwidth:	≥1 MHz
Detector:	Pos-Peak
Trace:	Max hold

Limits:

As specified in Section 15.215(c), the bandwidth of the fundamental emission must be contained within the frequency band over the temperature range -20 to +50 degrees Celsius with an input voltage variation of 85% to 115% of rated input voltage. Frequency stability is to be measured according to Section 2.1055 at the highest and lowest frequency of operation and with the modulation that produces the widest emission bandwidth.

§15.256(f)(1) The minimum fundamental emission bandwidth shall be 50 MHz for LPR operation under the provisions of this section.
§15.256(f)(2) LPR devices operating under this section must confine their fundamental emission bandwidth within the 5.925-7.250 GHz, 24.05-29.00 GHz, and 75-85 GHz bands under all conditions of operation.

Same requirements for fundamental emission bandwidth are given in RSS-211, 2.4 and 5.1.a)

Results:

Test Conditions	Transmitter Frequency Range (GHz)		10 dB bandwidth (GHz)
	f_L	f_H	
-40 °C / V_{nom}	24.076	26.080	2.004
-30 °C / V_{nom}	24.076	26.080	2.004
-20 °C / V_{nom}	24.076	26.086	2.010
-10 °C / V_{nom}	24.076	26.080	2.004
0 °C / V_{nom}	24.076	26.086	2.010
10 °C / V_{nom}	24.076	26.086	2.010
20 °C / V_{min} - V_{max}	24.076	26.086	2.010
30 °C / V_{nom}	24.076	26.080	2.004
40 °C / V_{nom}	24.076	26.080	2.004
50 °C / V_{nom}	24.076	26.080	2.004
60 °C / V_{nom}	24.076	26.086	2.010
70 °C / V_{nom}	24.076	26.080	2.004
80 °C / V_{nom}	24.076	26.080	2.004
85 °C / V_{nom}	24.076	26.086	2.010
deviation based on 20 °C	±1.0 kHz (±0.04 ppm)	-6.0 MHz (-230 ppm)	

10.2 Fundamental emissions

Description:

§15.256(g) Fundamental emissions limits.
(1) All emission limits provided in this section are expressed in terms of Equivalent Isotropic Radiated Power (EIRP).

(2) The EIRP level is to be determined from the maximum measured power within a specified bandwidth.

(i) The EIRP in 1 MHz is computed from the maximum power level measured within any 1-MHz bandwidth using a power averaging detector;

(ii) The EIRP in 50 MHz is computed from the maximum power level measured with a peak detector in a 50-MHz bandwidth centered on the frequency at which the maximum average power level is realized and this 50 MHz bandwidth must be contained within the authorized operating bandwidth. For a RBW less than 50 MHz, the peak EIRP limit (in dBm) is reduced by 20 log(RBW/50) dB where RBW is the resolution bandwidth in megahertz. The RBW shall not be lower than 1 MHz or greater than 50 MHz. The video bandwidth of the measurement instrument shall not be less than the RBW. If the RBW is greater than 3 MHz, the application for certification filed shall contain a detailed description of the test procedure, calibration of the test setup, and the instrumentation employed in the testing.

(3) The EIRP limits for LPR operations in the bands authorized by this rule section are provided in Table below. The emission limits in Table below are based on boresight measurements (i.e., measurements performed within the main beam of an LPR antenna).

Limits:

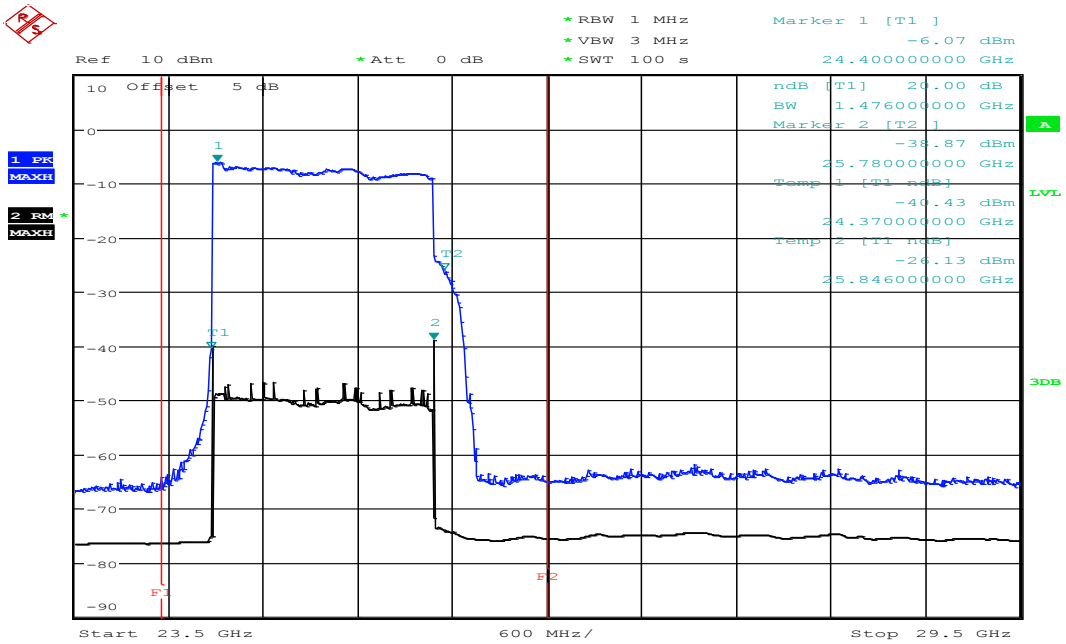
Frequency range (GHz)	Average emission limit (EIRP in dBm / 1 MHz)	Peak emission limit (EIRP in dBm / 50 MHz)
5.925 to 7.250	-33	+7 dBm
24.05 to 29.00	-14	+26 dBm
75.00 to 85.00	-3	+34 dBm

Same requirements are given in RSS-211, 5.2.b)

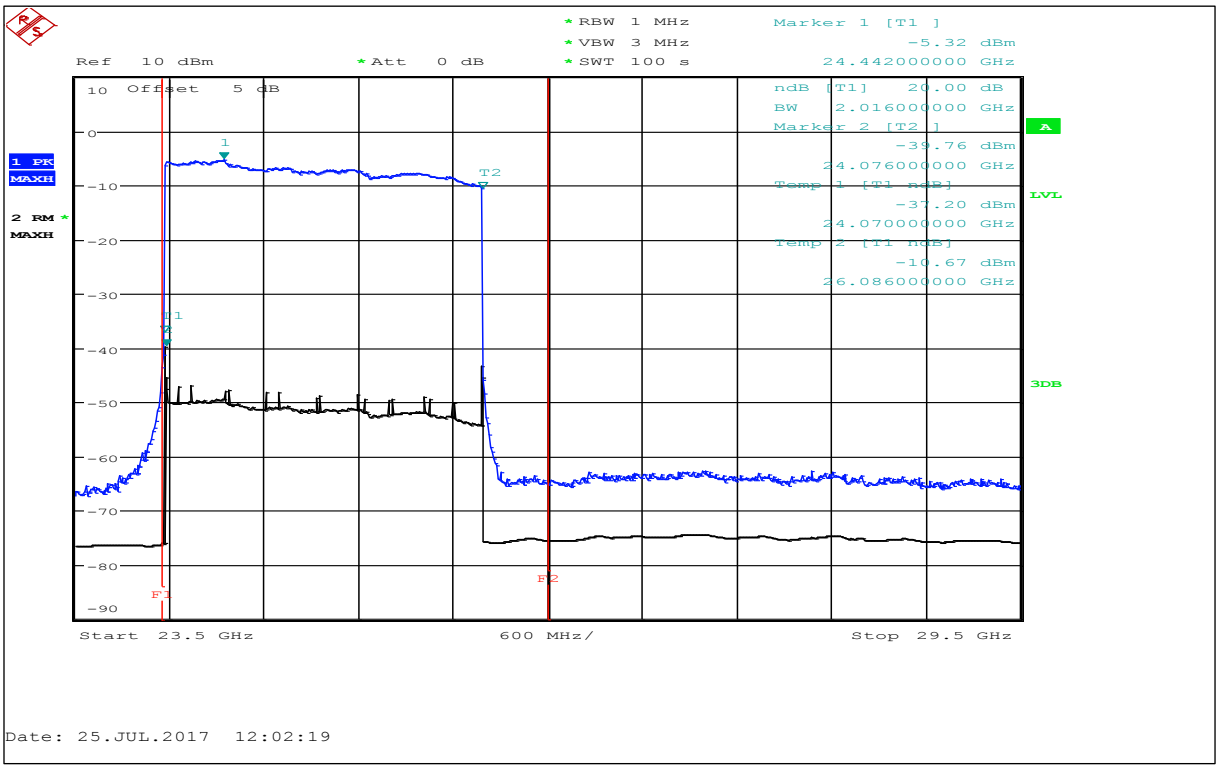
Measurement parameters:

Resolution bandwidth: 1 MHz
Video bandwidth: ≥1 MHz
Span: depends on DUT
Detector: Pos-Peak / RMS
Trace: Max hold

Plot 1: 1.4 GHz Mode, 20 dB bandwidth, Pos-Peak/ RMS measurement



Plot 2: 2 GHz Mode, 20 dB bandwidth, Pos-Peak/ RMS measurement



Results:

There are two different aspects which will affect the peak-to-average ratio resp. RMS value at all:

- Duty cycle of the device
- Frequency domain mitigation / dwell time due to FMCW-modulation

The EUT uses FMCW with a ramp over different bandwidths within T_S = 7 ms.
Three different cycle times are available T_{Cycle1} = 500 ms, T_{Cycle2} = 200 ms and T_{Cycle3} = 100 ms.
This will lead to:

Mode	Bandwidth (ΔF) [GHz]	dwell time (T_D)* [µs/MHz]	averaging factor (AF)** [dB]		
			T_{Cycle} =500ms	T_{Cycle} =200ms	T_{Cycle} =100ms
1.4 GHz	1.476	4.743	-50.2	-46.3	-43.2
2 GHz	2.016	3.472	-51.6	-47.6	-44.6

*dwell time $T_D = T_S / \Delta F$
**averaging factor AF = T_D / cycle time

Antenna type	Gain [dBi]	Maximum conducted power [dBm]	Equivalent isotropically radiated power (e.i.r.p.) [dBm]	
			Peak Power	Max AVG Power
316L / DN80 (3”) Metallic Horn	24.3	-5.3	19.0	-24.2
316L / DN100 (4”) Metallic Horn	25.7		20.4	-22.8
316L / DN150 (6”) Metallic Horn	27.7		22.4	-20.8
316L / DN200 (8”) Metallic Horn	28.1		22.8	-20.4
PTFE / DN80 (3”) Drop	25.5		20.2	-23.0
PP / DN80 (3”) Drop	25.8		20.5	-22.7
PEEK / DN80 (3”) DROP	24.0		18.7	-24.5
PTFE / DN100 (4”) Drop	27.0		21.7	-21.5
PP / DN100 (4”) Drop	27.5		22.2	-21.0
PEEK / DN100 (4”) Drop	25.6		20.3	-22.9
PTFE / DN150 (6”) Drop	29.5		24.2	-19.0
PP / DN150 (6”) Drop	30.4		25.1	-18.1
PEEK / DN150 (6”) Drop	28.4		23.1	-20.1

Peak output power was measured as conducted output power with settings shown in FCC document *890966 D01, Measurement Procedure for Level Probing Radars*. Measurements were performed using a special test adapter supplied by the manufacturer.
Peak EIRP was calculated based on the peak output power and the antenna gain given in above mentioned antenna test report of the manufacturer.
Average EIRP was calculated according to FCC document *890966 D01, Measurement Procedure for Level Probing Radars* with worst case averaging factor of -43.2 dB.

10.3 Unwanted emissions limit

Description:

§15.256(h)
Unwanted emissions from LPR devices shall not exceed the general emission limit in §15.209 of this chapter.

Measurement parameters:

Resolution bandwidth: 100 kHz / 1 MHz
Video bandwidth: ≥ resolution bandwidth
Detector: Quasi Peak / Average (RMS)
Trace: Max hold

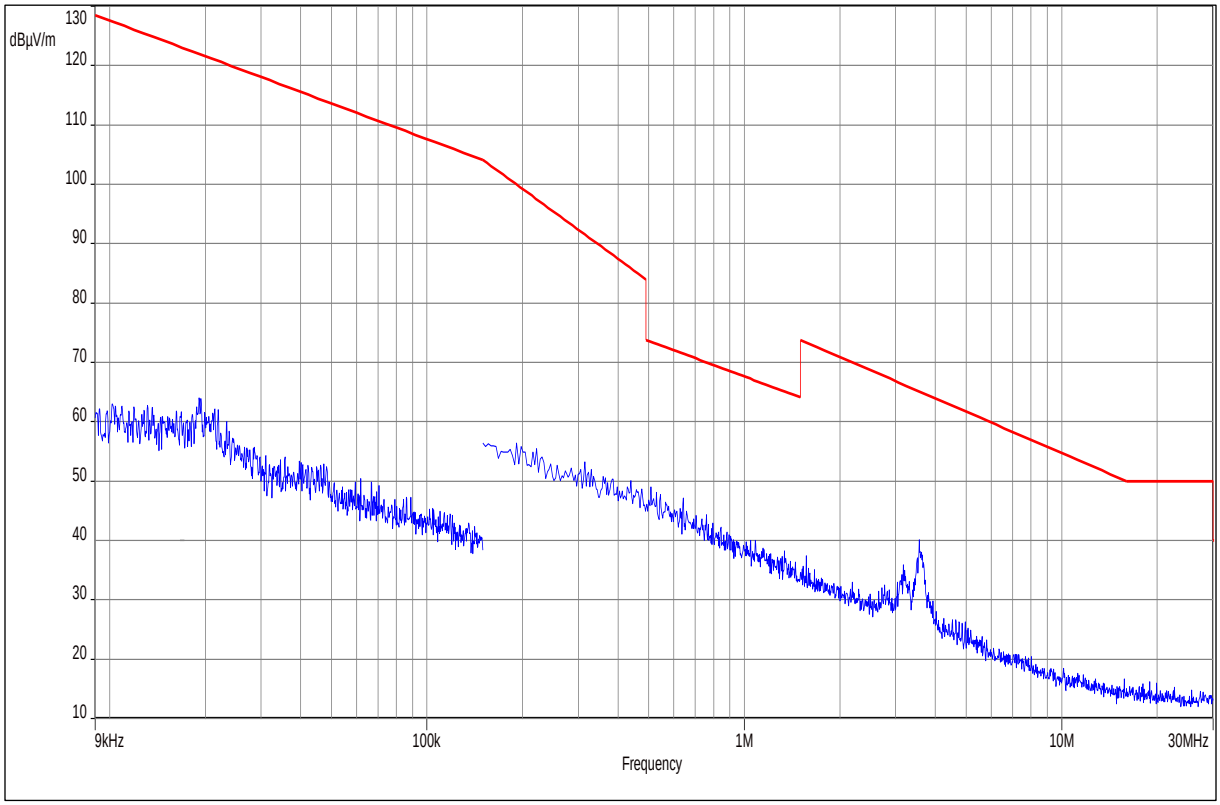
Limits:

FCC §15.209 / RSS-Gen		
Field strength of the harmonics and spurious.		
Frequency (MHz)	**Field strength (µV/m)**	**Measurement distance (m)**
0.009 – 0.490	2400/F(kHz)	300
0.490 – 1.705	24000/F(kHz)	30
1.705 – 30	30 (29.5 dBµV/m)	30
30 – 88	100 (40 dBµV/m)	3
88 – 216	150 (43.5 dBµV/m)	3
216 – 960	200 (46 dBµV/m)	3
>960	500 (54 dBµV/m)	3

Results:

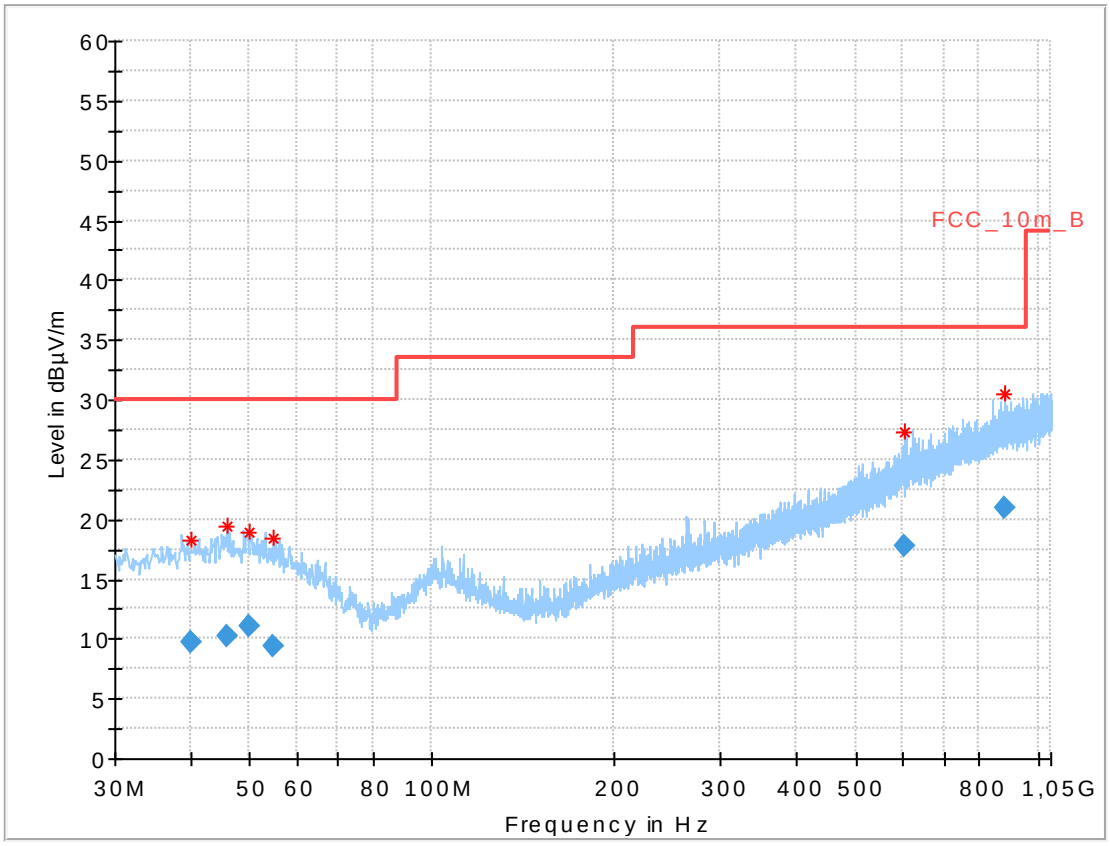
Spurious emission level (dBm)								
-/-			-/-			-/-		
Frequency [GHz]	BW [kHz]	Level [dBm]	Frequency [GHz]	BW [kHz]	Level [dBm]	Frequency [GHz]	BW [kHz]	Level [dBm]
see plots								

Plot 3: 9 kHz – 30 MHz



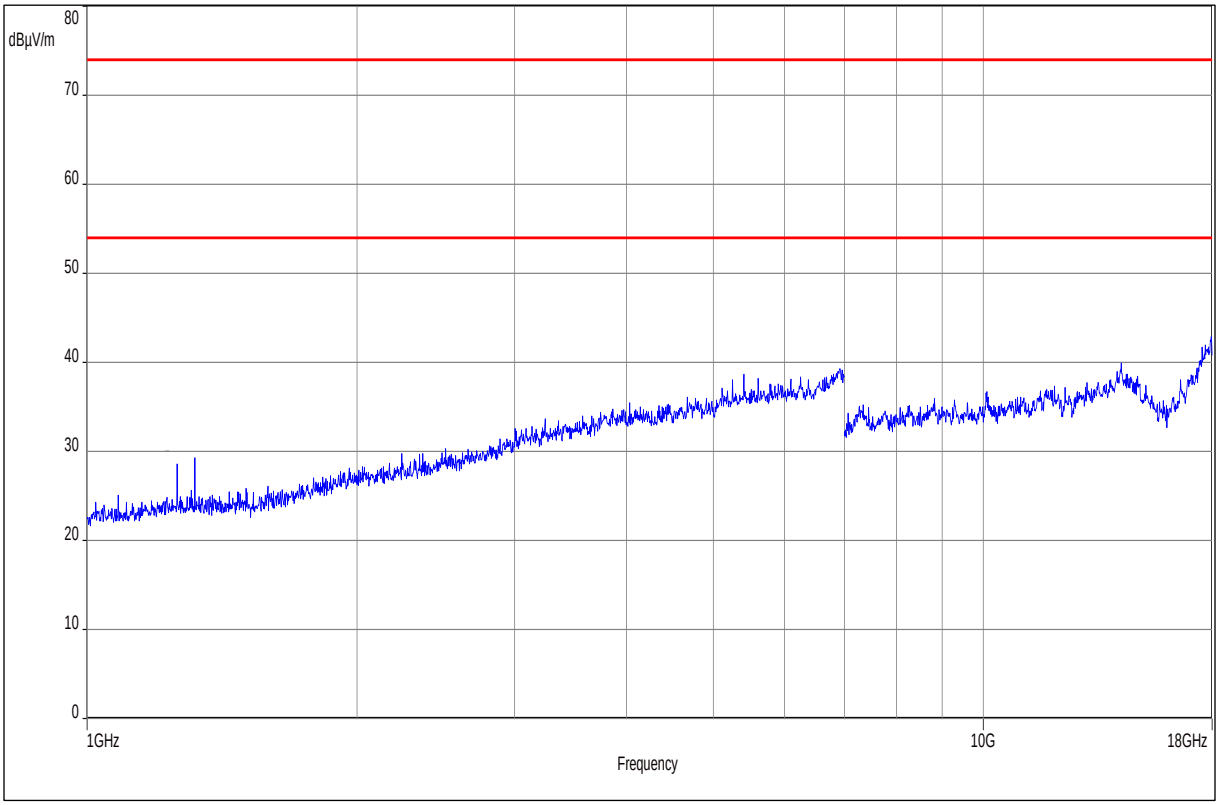
Plot 4: 30 MHz – 1000 MHz

EUT:	OPTIWAVE 7400 C (HART)
Serial number:	F17XXXXXXXXXXX
Test description:	FCC part 15 class B @ 10 m
Operating condition:	normal mode
Operator name:	Hennemann
Comment:	DC 24 V

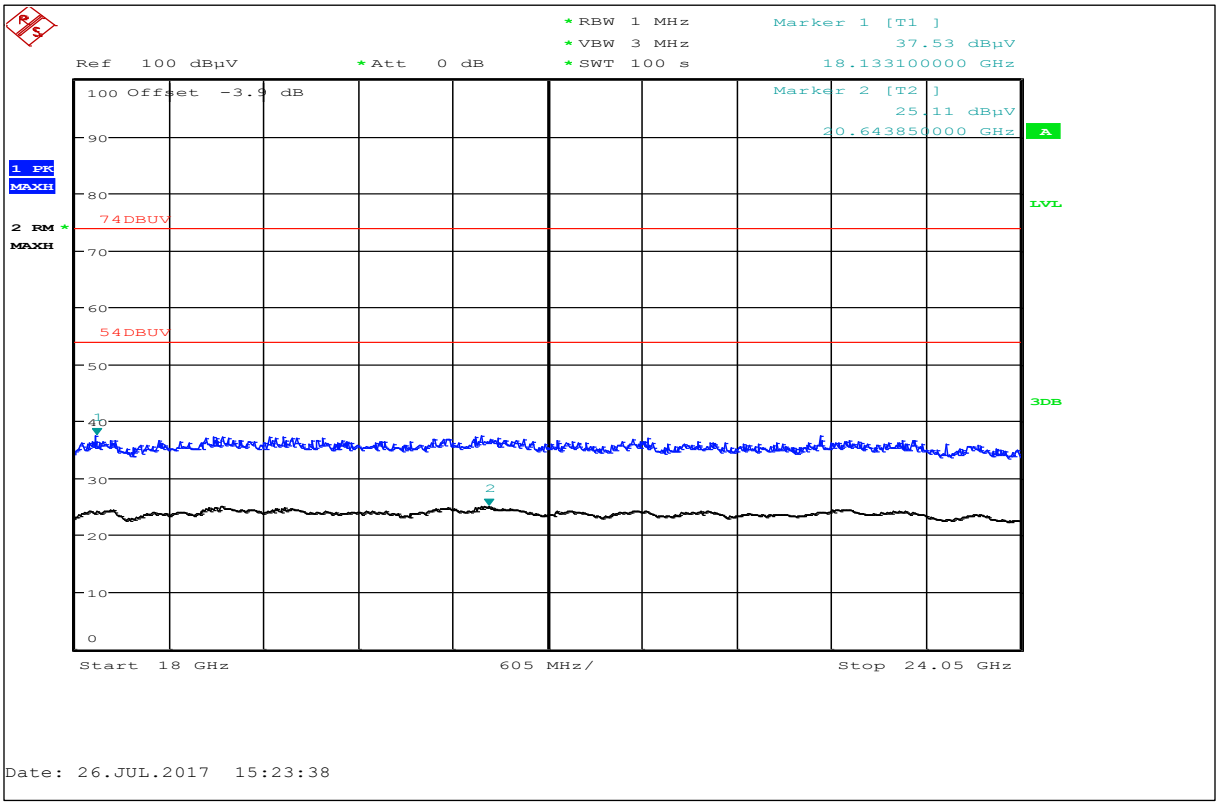


Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
39.977550	9.72	30.00	20.28	1000.0	120.000	348.0	H	165.0	13.2
45.964500	10.24	30.00	19.76	1000.0	120.000	100.0	V	32.0	13.6
49.977150	11.02	30.00	18.98	1000.0	120.000	280.0	V	50.0	13.7
54.865200	9.36	30.00	20.64	1000.0	120.000	172.0	V	-15.0	13.1
602.368350	17.84	36.00	18.16	1000.0	120.000	103.0	V	78.0	20.7
879.684450	21.01	36.00	14.99	1000.0	120.000	171.0	H	-13.0	23.9

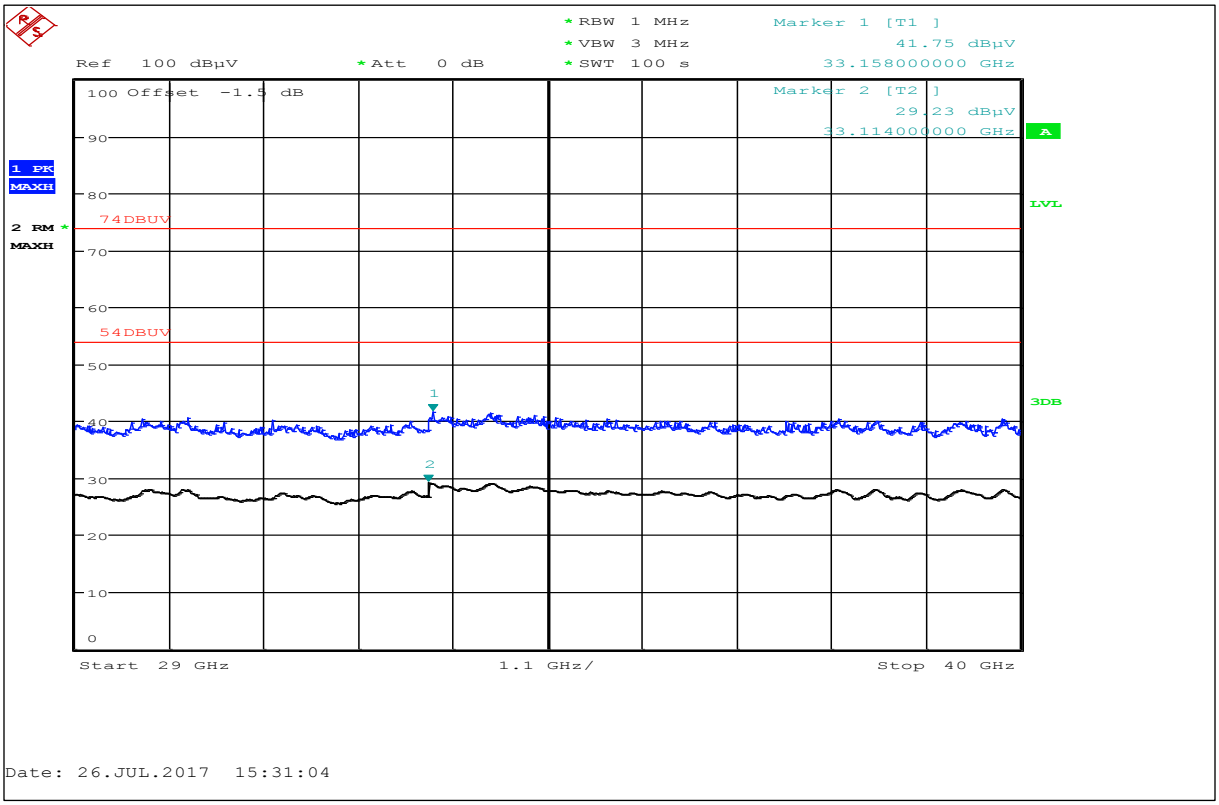
Plot 5: 1 GHz – 18 GHz



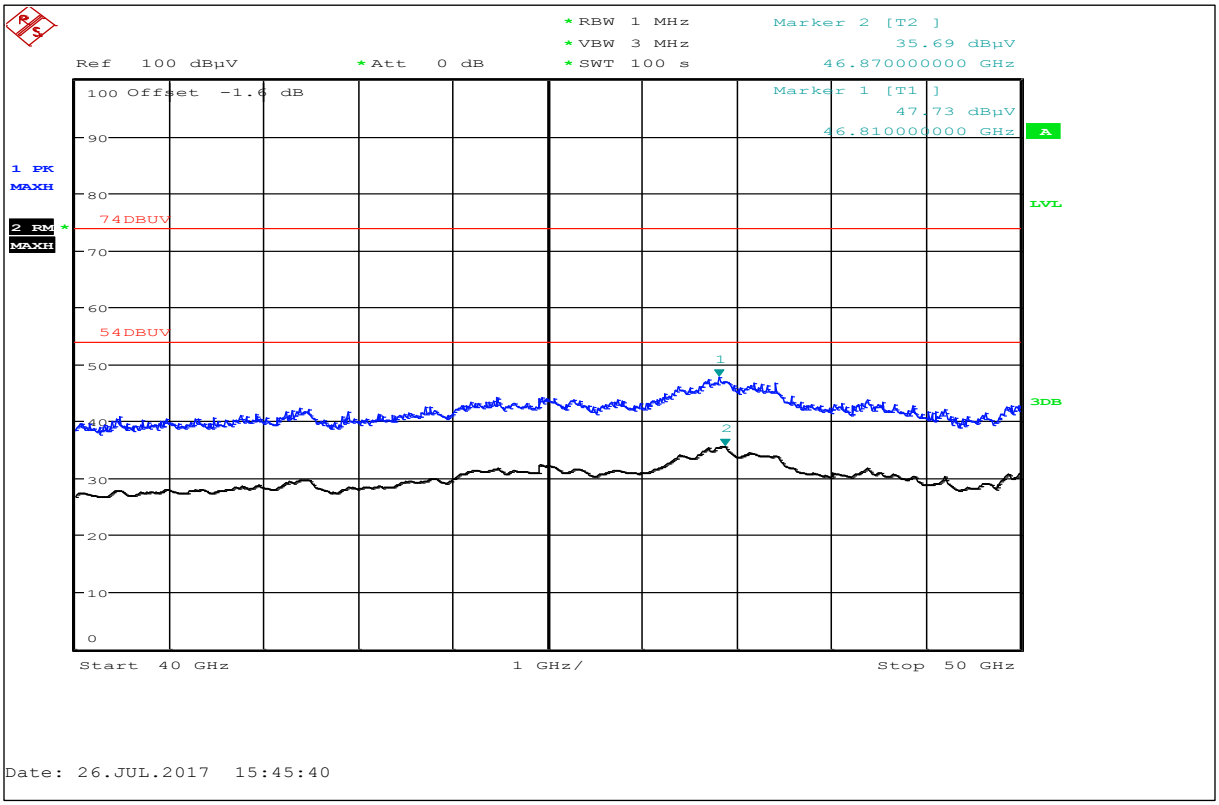
Plot 6: 18 GHz – 24.05 GHz



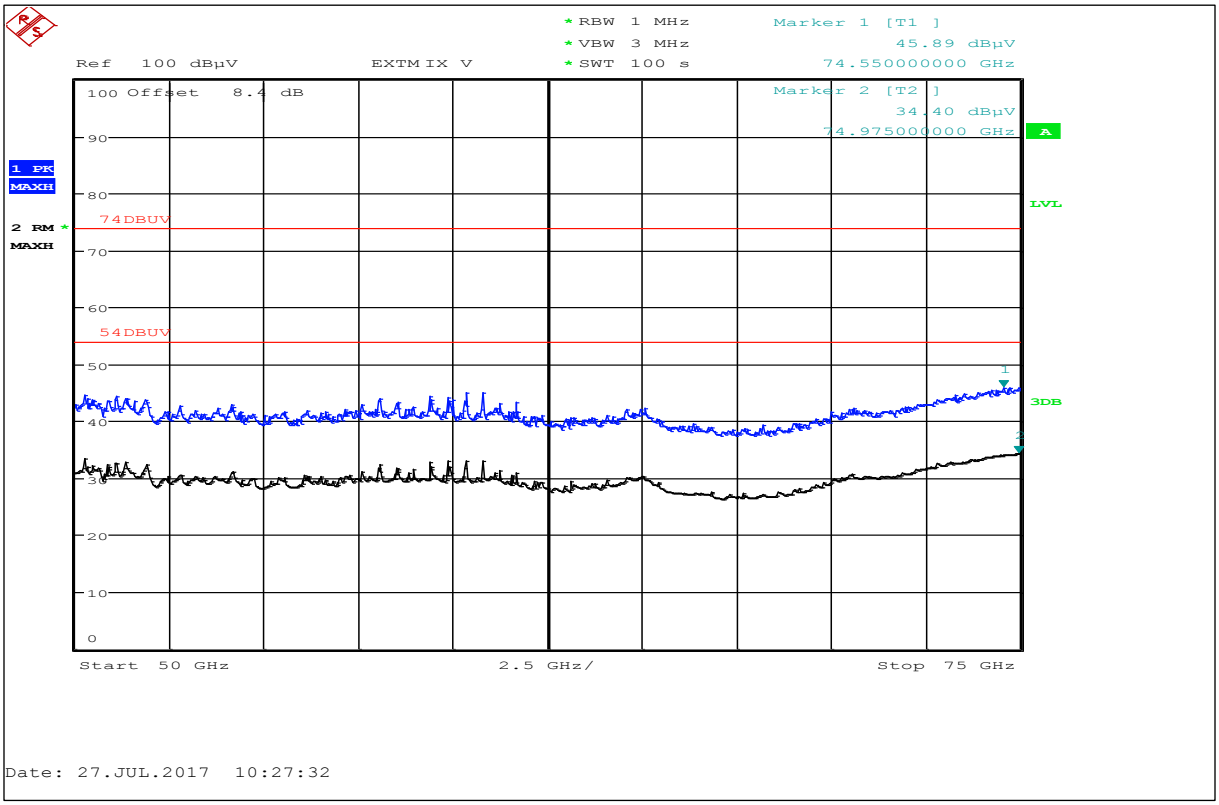
Plot 7: 29 GHz – 40 GHz



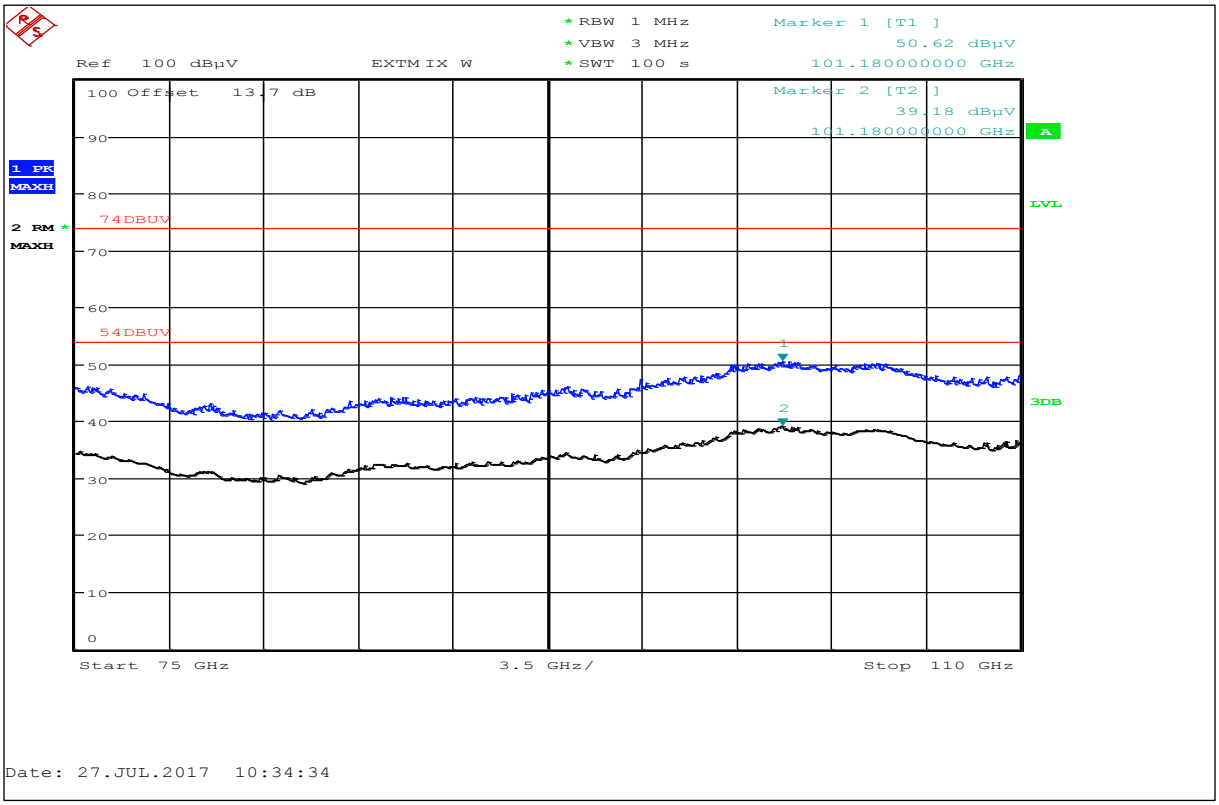
Plot 8: 40 GHz – 50 GHz



Plot 9: 50 GHz – 75 GHz



Plot 10: 75 GHz – 110 GHz



10.4 Antenna beamwidth and antenna side lobe gain

Description:

§15.256(i) Antenna beamwidth
(A) LPR devices operating under the provisions of this section within the 5.925-7.250 GHz and 24.05-29.00 GHz bands must use an antenna with a -3 dB beamwidth no greater than 12 degrees.

(B) LPR devices operating under the provisions of this section within the 75-85 GHz band must use an antenna with a -3 dB beamwidth no greater than 8 degrees.

(j) Antenna side lobe gain. LPR devices operating under the provisions of this section must limit the side lobe antenna gain relative to the main beam gain for off-axis angles from the main beam of greater than 60 degrees to the levels provided in Table below.

Limits:

FCC §15.256 / RSS-211 5.2a) c)		
Frequency range (GHz)	**Antenna beamwidth in degree (°)**	**Antenna side lobe gain limit relative to main beam gain (dB)**
5.925 to 7.250	12	-22
24.05 to 29.00	12	-27
75.00 to 85.00	8	-38

Antenna data:

Antennas	Gain [dBi]	3dB width E- / H-plane [°]	Side lobe gain relative to main beam [dB]
316L / DN80 (3”) Metallic Horn	24.3	9.2 / 11.8	< -27
316L / DN100 (4”) Metallic Horn	25.7	7.7 / 9.6	< -27
316L / DN150 (6”) Metallic Horn	27.7	5.6 / 6.6	< -27
316L / DN200 (8”) Metallic Horn	28.1	5.1 / 5.8	< -27
PTFE / DN80 (3”) Drop	25.5	7.6 / 7.5	< -27
PP / DN80 (3”) Drop	25.8	7.8 / 7.8	< -27
PEEK / DN80 (3”) Drop	24.0	9.1 / 9.6	< -27
PTFE / DN100 (4”) Drop	27.0	6.1 / 6.2	< -27
PP / DN100 (4”) Drop	27.5	6.3 / 6.4	< -27
PEEK / DN100 (4”) Drop	25.6	7.1 / 7.5	< -27
PTFE / DN150 (6”) Drop	29.5	4.2 / 4.2	< -27
PP / DN150 (6”) Drop	30.4	4.3 / 4.3	< -27
PEEK / DN150 (6”) Drop	28.3	4.7 / 5.0	< -27

Note:
See manufacturer’s documentation Antennas-for-lpr-applications_v1-3.pdf, Issue 0.1 of 2017-10-04

10.5 Emissions from digital circuitry

Description:

§15.256(k) Emissions from digital circuitry used to enable the operation of the transmitter may comply with the limits in §15.209 of this chapter provided it can be clearly demonstrated that those emissions are due solely to emissions from digital circuitry contained within the transmitter and the emissions are not intended to be radiated from the transmitter's antenna. Emissions from associated digital devices, as defined in §15.3(k) of this part, e.g., emissions from digital circuitry used to control additional functions or capabilities other than the operation of the transmitter, are subject to the limits contained in subpart B, part 15 of this chapter. Emissions from these digital circuits shall not be employed in determining the -10 dB bandwidth of the fundamental emission or the frequency at which the highest emission level occurs.

Measurement:

Measurement parameter	
Detector:	Quasi Peak / Average (RMS)
Sweep time:	Auto
Resolution bandwidth:	100 kHz / 1 MHz
Video bandwidth:	> resbw
Trace-Mode:	Max-Hold

Limits:

FCC §15.109 / RSS-Gen, 7.1		
Field strength of the harmonics and spurious.		
Frequency (MHz)	**Field strength (µV/m)**	**Measurement distance (m)**
0.009 – 0.490	2400/F(kHz)	300
0.490 – 1.705	24000/F(kHz)	30
1.705 – 30	30 (29.5 dBµV/m)	30
30 – 88	100 (40 dBµV/m)	3
88 – 216	150 (43.5 dBµV/m)	3
216 – 960	200 (46 dBµV/m)	3
>960	500 (54 dBµV/m)	3

Results:

See §15.256(h) / RSS-211, 5.1d Unwanted emissions limit.

10.6 Conducted limits

Description:

Measurement of the conducted spurious emissions in transmit mode below 30 MHz. Both power lines, phase and neutral line, are measured. Found peaks are re-measured with average and quasi peak detection to show compliance to the limits.

Measurement:

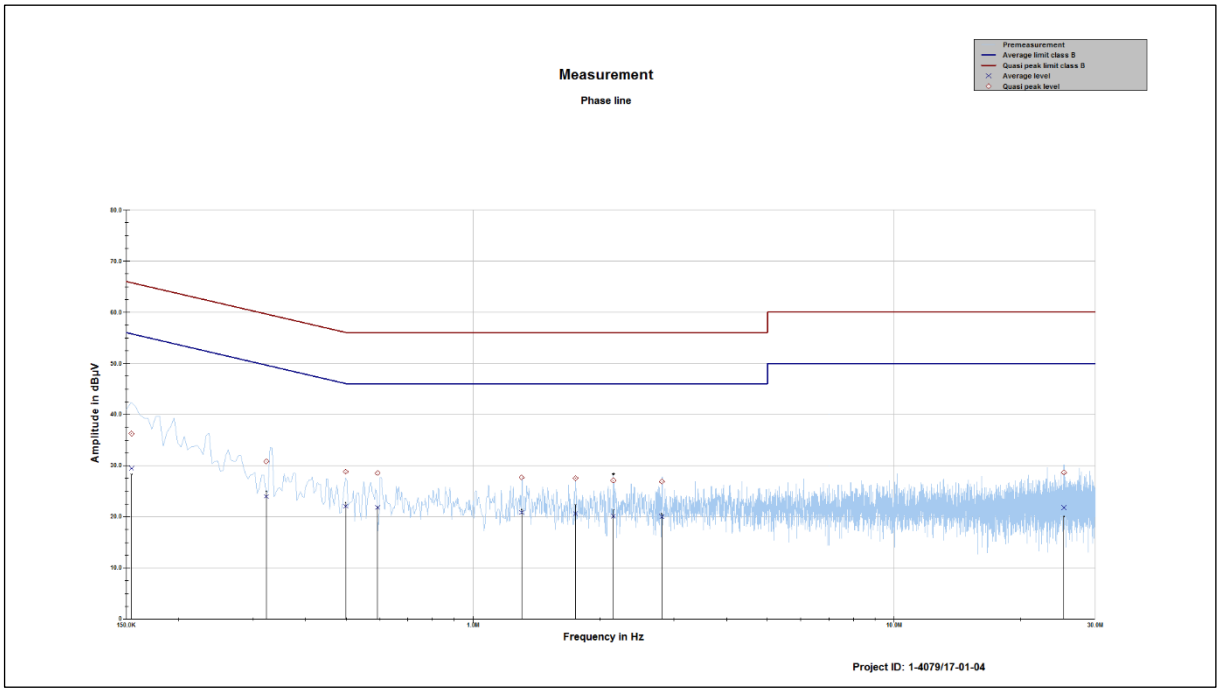
Measurement parameter	
Detector:	Peak - Quasi Peak / Average
Sweep time:	Auto
Resolution bandwidth:	F < 150 kHz: 200 Hz F > 150 kHz: 9 kHz
Video bandwidth:	F < 150 kHz: 1 kHz F > 150 kHz: 100 kHz
Span:	9 kHz to 30 MHz
Trace-Mode:	Max Hold

Limits:

FCC §15.107 / §15.207 / RSS-Gen, 8.8		
Conducted limits		
Frequency of Emission (MHz)	**Conducted Limit (dBµV)**	
	Quasi-peak	Average
0.15 – 0.5	66 to 56 *	56 to 46 *
0.5 – 5	56	46
5 - 30	60	50

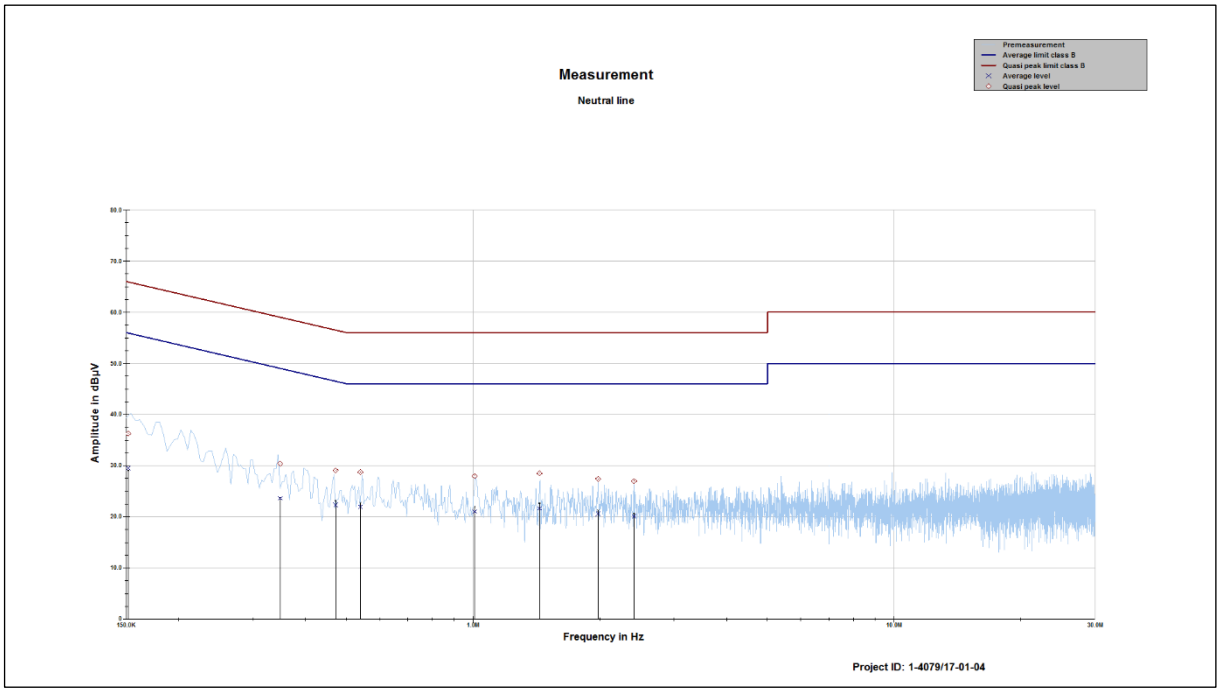
*Decreases with the logarithm of the frequency

Plot 11: Phase line



Frequency	Quasi peak level	Margin quasi peak	Limit QP	Average level	Margin average	Limit AV
MHz	dBµV	dB	dBµV	dBµV	dB	dBµV
0.154359	36.27	29.49	65.762	29.46	26.41	55.875
0.322495	30.82	28.82	59.642	23.98	27.09	51.072
0.497810	28.82	27.21	56.036	22.07	23.99	46.063
0.592864	28.57	27.43	56.000	21.81	24.19	46.000
1.303010	27.71	28.29	56.000	20.87	25.13	46.000
1.749159	27.54	28.46	56.000	20.64	25.36	46.000
2.150868	27.10	28.90	56.000	20.14	25.86	46.000
2.805003	26.88	29.12	56.000	20.00	26.00	46.000
25.304179	28.65	31.35	60.000	21.79	28.21	50.000

Plot 12: Neutral line



Frequency	Quasi peak level	Margin quasi peak	Limit QP	Average level	Margin average	Limit AV
MHz	dBµV	dB	dBµV	dBµV	dB	dBµV
0.151583	36.26	29.66	65.913	29.48	26.47	55.955
0.347884	30.40	28.61	59.013	23.63	26.71	50.346
0.470843	29.08	27.42	56.499	22.29	24.54	46.833
0.539381	28.74	27.26	56.000	21.94	24.06	46.000
1.007782	27.97	28.03	56.000	21.04	24.96	46.000
1.436907	28.49	27.51	56.000	21.64	24.36	46.000
1.979927	27.42	28.58	56.000	20.62	25.38	46.000
2.408782	26.99	29.01	56.000	20.07	25.93	46.000

11 Glossary

EUT	Equipment under test
DUT	Device under test
UUT	Unit under test
GUE	GNSS User Equipment
ETSI	European Telecommunications Standards Institute
EN	European Standard
FCC	Federal Communications Commission
FCC ID	Company Identifier at FCC
IC	Industry Canada
PMN	Product marketing name
HMN	Host marketing name
HVIN	Hardware version identification number
FVIN	Firmware version identification number
EMC	Electromagnetic Compatibility
HW	Hardware
SW	Software
Inv. No.	Inventory number
S/N or SN	Serial number
C	Compliant
NC	Not compliant
NA	Not applicable
NP	Not performed
PP	Positive peak
QP	Quasi peak
AVG	Average
OC	Operating channel
OCW	Operating channel bandwidth
OBW	Occupied bandwidth
OOB	Out of band
DFS	Dynamic frequency selection
CAC	Channel availability check
OP	Occupancy period
NOP	Non occupancy period
DC	Duty cycle
PER	Packet error rate
CW	Clean wave
MC	Modulated carrier
WLAN	Wireless local area network
RLAN	Radio local area network
DSSS	Dynamic sequence spread spectrum
OFDM	Orthogonal frequency division multiplexing
FHSS	Frequency hopping spread spectrum
GNSS	Global Navigation Satellite System
C/N_0	Carrier to noise-density ratio, expressed in dB-Hz

12 Document history

Version	Applied changes	Date of release
-/-	Initial release - DRAFT	2017-11-24
	Editorial changes based on applicants' comments	2018-02-08

13 Accreditation Certificate

first page	last page
DAkkS Deutsche Akkreditierungsstelle Deutsche Akkreditierungsstelle GmbH **Entrusted according to Section 8 subsection 1 AkkStelleG in connection with Section 1 subsection 1 AkkStelleGBV** Signatory to the Multilateral Agreements of EA, ILAC and IAF for Mutual Recognition **Accreditation** The Deutsche Akkreditierungsstelle GmbH attests that the testing laboratory **CTC advanced GmbH** **Untertürkheimer Straße 6-10, 66117 Saarbrücken** is competent under the terms of DIN EN ISO/IEC 17025:2005 to carry out tests in the following fields: **Telecommunication** The accreditation certificate shall only apply in connection with the notice of accreditation of 02.06.2017 with the accreditation number D-PL-12076-01 and is valid until 21.04.2021. It comprises the cover sheet, the reverse side of the cover sheet and the following annex with a total of 43 pages. Registration number of the certificate: **D-PL-12076-01-03** Frankfurt, 02.06.2017 Dipl.-Ing. (FH) Ralf Egner Head of Division See notes overleaf.	Deutsche Akkreditierungsstelle GmbH Office Berlin Spittelmarkt 10 10117 Berlin Office Frankfurt am Main Europa-Allee 52 60327 Frankfurt am Main Office Braunschweig Bundesallee 100 38116 Braunschweig The publication of extracts of the accreditation certificate is subject to the prior written approval by Deutsche Akkreditierungsstelle GmbH (DAkkS). Exempted is the unchanged form of separate disseminations of the cover sheet by the conformity assessment body mentioned overleaf. No impression shall be made that the accreditation also extends to fields beyond the scope of accreditation attested by DAkkS. The accreditation was granted pursuant to the Act on the Accreditation Body (AkkStelleG) of 31 July 2009 (Federal Law Gazette I p. 2625) and the Regulation (EC) No 765/2008 of the European Parliament and of the Council of 9 July 2008 setting out the requirements for accreditation and market surveillance relating to the marketing of products (Official Journal of the European Union L 218 of 9 July 2008, p. 30). DAkkS is a signatory to the Multilateral Agreements for Mutual Recognition of the European co-operation for Accreditation (EA), International Accreditation Forum (IAF) and International Laboratory Accreditation Cooperation (ILAC). The signatories to these agreements recognise each other's accreditations. The up-to-date state of membership can be retrieved from the following websites: EA: www.european-accreditation.org ILAC: www.ilac.org IAF: www.iaf.nu

Note: The current certificate annex is published on the website (link see below) of the Accreditation Body DAkkS or may be received by CTC advanced GmbH on request

http://www.dakks.de/as/ast/d/D-PL-12076-01-03.pdf