Test Report
20-1-0127501T01a

D-PL-12047-01-01
D-PL-12047-01-03
D-PL-12047-01-04

Number of pages:	32	**Date of Report:**	2022-May-31
Testing company:	CETECOM GmbH Im Teelbruch 116 45219 Essen Germany Tel. + 49 (0) 20 54 / 95 19-0 Fax: + 49 (0) 20 54 / 95 19-150	**Applicant:**	ElektronikSystem i Umeå AB
Product: **Model:** **Type:**	**LoRa device** **EMS** **-**		
FCC ID:	2ANX3-EMS01	**IC:**	26904-EMS01
Testing has been carried out in accordance with:	**Title 47 CFR, Chapter I** **FCC Regulations, Subchapter A** **Subpart C: §15.247 (DTS)** **RSS-247, Issue2 — Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and License-Exempt Local Area Network (LE-LAN) Devices** Deviations, modifications or clarifications (if any) to above mentioned documents are written in each section under "Test method and limit".		
Tested Technology:	SRD (Short Range Device)		
Test Results:	**☒ The EUT complies with the requirements in respect of all parameters subject to the test.** The test results relate only to devices specified in this document		

Signatures:

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Dipl.-Ing. Ninovic Perez	Dipl.-Ing. Christian Lorenz
Test Lab Manager	Senior Test manager
Authorization of test report	Responsible of test report

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1 General information

1.1 Disclaimer and Notes

The test results of this test report relate exclusively to the test item specified in this test report as specified in chapter 2.7. CETECOM 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.
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Also we refer on special conditions which the applicant should fulfill according §2.927 to §2.948, special focus regarding modification of the equipment and availability of sample equipment for market surveillance tests.

1.1. Summary of Test Results

Test case	Reference Clause FCC ☒	Reference Clause ISED ☒	Page	Remark	Result
Power spectral density	§15.247(e)(f)	RSS-247; Issue 2, §5.2(b); §5.3(a), §5.3(b)	13	--	PASSED
Emission Bandwidth 20 dB (FHSS) Emission Bandwidth 6 dB (DTS)	§15.247(a)(1) §15.247(a)(2)	RSS-247, Issue 2, §5.1(a)(b) (FHSS) §5.2(a) (DTS)	14	--	PASSED
Occupied Channel Bandwidth 99%	2.1049(h)	RSS-Gen, Issue 5, §6.7	18	--	PASSED
Carrier Frequency Separation	§15.247(a)(1)	RSS-247, Issue 2, §5.1(b)	15	--	PASSED
Number of Hopping Channels	§15.247(a)(1)(i)	RSS-247, Issue 2, §5.1(c)	16	--	PASSED
Time of Occupancy	§15.247(a)(1)(i) §15.247(f)	RSS-247, Issue 2, §5.1(c)	17	--	PASSED
Emissions in non-restricted frequency bands	§15.247(d)	RSS-247, §5.5	19	--	PASSED
Conducted Band-Edge emissions	§15.247(d)	RSS-247, §5.5 RSS-Gen: Issue 5: §8.9 Table 5+6+7	19	--	PASSED
Radiated field strength emissions below 30 MHz	§15.209(a) §15.205(a)	RSS-Gen: Issue 5 §8.9 Table 6	21	--	PASSED
Radiated field strength emissions 30 MHz – 1 GHz	§15.209(a) §15.247(d) §15.205(a)	RSS-Gen: Issue 5 §8.9 Table 5+7 RSS-247, Issue2, §5.5	25	--	PASSED
Radiated field strength emissions above 1 GHz	§15.209(a) §15.247(d) §15.205(a)	RSS-Gen: Issue 5: §8.9 Table 5+7 RSS-247,Issue 2, §5.5	27	--	PASSED
AC-Power Lines Conducted Emissions	§15.207	RSS-Gen Issue 5: §8.8, Table 4	--	--	N/A

PASSED	The EUT complies with the essential requirements in the standard.
FAILED	The EUT does not comply with the essential requirements in the standard.
NP	The test was not performed by the CETECOM Laboratory.
NT	Not tested
N/A	Not applicable

*The calculation of the measurement uncertainty shows compliance with the "maximum measurement uncertainties" of the tested standard and therefore for result evaluation the stated uncertainties will not be additionally added to the measured results.

1.2. Summary of Test Methods

Test case	Test method
Maximum Peak conducted output power	ANSI C63.10:2013, §11.9.1.1, §11.9.2.2.3
Emission Bandwidth 6 dB	ANSI C63.10:2013, §11.8
Occupied Channel Bandwidth 99%	ANSI C63.10:2013, §6.9.3
Power spectral density	ANSI C63.10:2013, §11.10.2, §11.10.4
Time of occupancy (dwell time)	ANSI C63.10:2013, §7.8.4,
Number of hopping frequencies	ANSI C63.10:2013, §7.8.3
Number of hopping frequencies	ANSI C63.10:2013, §7.8.2
Emissions in non-restricted frequency bands	ANSI C63.10:2013, §11.11, §6.10.5
Radiated Band-Edge emissions	ANSI C63.10-2013; "Marker-Delta method" §11.13, §6.10.6, „Integration method" §11.13
Transmitter Peak output power radiated	Result calculated with measured conducted RF-power value and stated/measured antenna gain for band of interest
Radiated field strength emissions below 30 MHz	ANSI C63.10-2013 §6.3, §6.4
Radiated field strength emissions 30 MHz- 1 GHz	ANSI C63.4-2014 §8.2.3, ANSI C63.10-2013 §6.3, § 6.5
Radiated field strength emissions above 1 GHz	ANSI C63.4-2014 §8.3, ANSI C63.10-2013 §6.3, § 6.6
AC-Power Lines Conducted Emissions	ANSI C63.4-2014 §7, ANSI C63.10-2013 § 6.2

And reference also to Test methods in KDB558074

2 Administrative Data

2.1 Identification of the Testing Laboratory

Company name:	CETECOM GmbH
Address:	Im Teelbruch 116 45219 Essen - Kettwig Germany
Responsible for testing laboratory:	Ninovic Perez
Accreditation scope:	DAkkS Webpage
Test location:	CETECOM GmbH; Im Teelbruch 116; 45219 Essen - Kettwig

2.2 General limits for environmental conditions

Temperature:	22±2 °C
Relative. humidity:	45±15% rH

2.3 Test Laboratories sub-contracted

Company name:	--

2.4 Organizational Items

Responsible test manager:	Christian Lorenz
Receipt of EUT:	2020-Nov-04
Date(s) of test:	2020-Nov-18 – 2022-May-05
Version of template:	14.4

2.5 Applicant's details

Applicant's name:	ElektronikSystem i Umeå AB (Elsys)
Address:	Industrivägen 10 90130, Umeå Sweden
Contact Person:	Johan Haake
Contact Person's Email:	johan.haake@elsys.se

2.6 Manufacturer's details

Manufacturer's name:	ElektronikSystem i Umeå AB (Elsys)
Address:	Industrivägen 10 90130, Umeå Schweden

2.7 EUT: Type, S/N etc. and short descriptions used in this test report

Short description*)	PMT Sample No.	Product	Model	Type	S/N	HW status	SW status
EUT 1	20-1-01275S14_C01	LoRa device	EMS	n/a	n/a	9	2
EUT 2	20-1-01275S12_C01	LoRa device	EMS	n/a	n/a	8	2
EUT 3	20-1-01275S09_C01	LoRa device	EMS	n/a	n/a	8	2
EUT 4	20-1-01275S11_C01	LoRa device	EMS	n/a	n/a	8	2

*) EUT short description is used to simplify the identification of the EUT in this test report.

2.8 Auxiliary Equipment (AE): Type, S/N etc. and short descriptions

Short description*)	PMT Sample No.	Auxiliary Equipment	Type	S/N	HW status	SW status
--	--	--	--	--	--	--

*) AE short description is used to simplify the identification of the auxiliary equipment in this test report.

2.9 Connected cables

Short description*)	PMT Sample No.	Cable type	Connectors	Length
--	--	--	--	--

*) CAB short description is used to simplify the identification of the connected cables in this test report.

2.10 Software

Short description*)	PMT Sample No.	Software	Type	S/N	HW status	SW status
--	--	--	--	--	--	--

*) SW short description is used to simplify the identification of the used software in this test report.

2.11 EUT set-ups

set-up no.*)	Combination of EUT and AE	Description
Set. 1	EUT 1	125 kHz FHSS fixed channel EUT used for radiated measurements
Set. 2	EUT 2	125 kHz FHSS fixed channel EUT used for conducted measurements
Set. 3	EUT 3	125 kHz FHSS hopping EUT used for conducted measurements
Set. 4	EUT 4	500 kHz DTS fixed channel EUT used for conducted measurements

*) EUT set-up no. is used to simplify the identification of the EUT set-up in this test report.

2.12 EUT operation modes

EUT operating mode no.*1)	Operating modes	Additional information
Op. 1	TX DTS	Continuous transmission on a low, mid or high channel. LoRa modulated carrier with 500 kHz bandwidth
Op. 2	TX FHSS Fix	Continuous transmission on a low, mid or high channel. LoRa modulated carrier with 125 kHz bandwidth
Op. 3	TX FHSS Hopping	Continuous transmission where the carrier is hopping on all 64 channel. LoRa modulated carrier with 125 kHz bandwidth

*1) EUT operating mode no. is used to simplify the test report.

3 Equipment under test (EUT)

3.1 General Data of Main EUT as Declared by Applicant

Product name	EMS		
Kind of product	LoRa device		
Firmware	☐ for normal use	☒ Special version for test execution	
	☐ AC Mains	-	
	☐ DC Mains	-- V DC via -- Connector	
	☒ Battery	3.6 V DC AA ER14505 Lithium Ion battery	
Operational conditions	T_{nom} =20 °C	T_{min} = 0 °C	T_{max} = 50 °C
EUT sample type	**Pre-Production**		
Weight	10 g excluding batteries / 30 g including batteries		
Size	21.2 x 74.9 x 20.8 mm		
Interfaces/Ports	RF (SRD) interface		
For further details refer Applicants Declaration & following technical documents **EMS_datasheet.pdf (2019-08-21)** **Exhibit_8_Operating Manual EMS.pdf (2020-06-08)** **new_Questionnaire 2020 V11.5.xlsm (2021-02-15)**			

3.2 Detailed Technical data of Main EUT as Declared by Applicant

Frequency Band	902 – 928 MHz
Number of Channels (USA/Canada -bands)	LoRa DTS-mode 8 LoRa FHSS-mode 64
Nominal Channel Bandwidth	LoRa DTS-mode 500 kHz LoRa FHSS-mode 125 kHz
Type of Modulation | Data Rate	☒ LoRa
Other installed options	☐ a/n/ac mode ☐ b/g/n mode ☐ Bluetooth LE (not tested within this report) ☐ Cellular transceiver (2G/3G/4G/5G/GPS, not tested in this report) ☒ None
Rated output power	**14** dBm
EIRP Power (Calculated EIRP)	**14** dBm + **-0.5** dBi = **13.5** dBm
Antenna Type	Integrated PCB antenna
Antenna Gain	-0.5 dBi
FCC label attached	No
Test firmware / software and storage location	EUT 1, EUT 2
For further details refer Applicants Declaration & following technical documents	

Description of Reference Document (supplied by applicant)	Version	Total Pages
EMS_datasheet.pdf (2019-08-21)	**1**	**3**
Exhibit_8_Operating Manual EMS.pdf (2020-06-08)	**1**	**15**
new_Questionnaire 2020 V11.5.xlsm (2021-02-15)	**1**	**-**

3.3 Modifications on Test sample

Additions/deviations or exclusions	

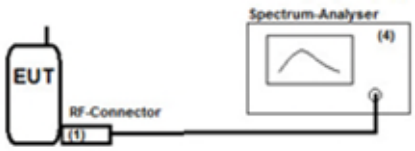
4 Measurements

4.1 Maximum conducted output power, §15.247(b)(2) and §15.247(b)(3)

4.1.1 Description of the general test setup and methodology, see below example:

The EUT's RF-signal is coupled out by a suitable antenna coupling connector (1). The signal is directly connected to the spectrum – analyzer (4) for specific RF-measurements.

Schematic:



Testing method:

The measurement is made according to relevant reference clauses:
(See Tables *Summary of Test Results* and *Summary of Test Methods* on page 6)

EUT settings
The EUT was instructed to send at given channel with maximum power (if adjustable) according applicants instructions.

4.1.2 Measurement Location

Test site	120910 - Radio Laboratory 1

4.1.3 Limit

Frequency Range [MHz]	Mode	Limit [W]	Limit [dBm]	Detector	RBW / VBW
902 - 928	DTS	1W: §15.247(b)(3)	30	MaxPeak	1 MHz / 3 MHz
	FHSS	1W: §15.247(b)(2)		RMS	5 kHz / 50 kHz

4.1.4 Result

Diagram No.	Mode	Channel	Frequency [MHz]	Max Power [dBm]	Result
D02_01	Op. 1	Low	902.8	9.87 (PK)	PASSED
D02_02	Op. 1	Mid	908.4	9.88 (PK)	PASSED
D02_03	Op. 1	High	914.2	9.93 (PK)	PASSED
D12_01	Op. 2	Low	902.2	10.61 (RMS)	PASSED
D12_02	Op. 2	Mid	908.5	10.68 (RMS)	PASSED
D12_03	Op. 2	High	914.9	10.68 (RMS)	PASSED

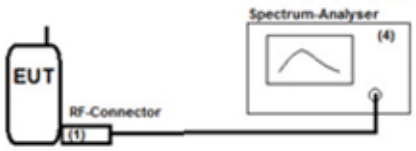
Remark: for more information and graphical plot see annex A1**CETECOM_TR20-1-0127501T01a_A1**

4.2 Maximum power spectral density level, §15.247(e) and §15.247(f)

4.2.1 Description of the general conducted test setup and methodology, see below example:

The EUT's RF-signal is coupled out by a suitable antenna coupling connector (1). The signal is then directly connected to the spectrum – analyzer (4) for specific RF-measurements. The specific attenuation losses for both signal paths/branches are determined prior to the measurement within a set-up calibration. These are then taken into account by correcting the measurement readings on the spectrum-analyzer.

Schematic:



Testing method:

The measurement is made according to relevant reference clauses:
(See Tables *Summary of Test Results* and *Summary of Test Methods* on page 6)

EUT settings
The EUT was instructed to send at fixed channel with maximum power (if adjustable) according applicants instructions.

4.2.2 Measurement Location

Test site	120910 - Radio Laboratory 1

4.2.3 Limit

Limit [dBm] @ 3 kHz	Mode	Detector	RBW [kHz]
≤ 8	DTS	MaxPeak	3
	FHSS	RMS	

4.2.4 Result

Diagram No.	Mode	Channel	Frequency [MHz]	PSD [dBm]	Result
D03_01	Op. 1	Low	902.9	4.77 (PK)	PASSED
D03_02	Op. 1	Mid	908.4	4.76 (PK)	PASSED
D03_03	Op. 1	High	914.1	4.86 (PK)	PASSED
D19_01	Op. 2	Low	902.3	-4.38 (RMS)	PASSED
D19_02	Op. 2	Mid	908.5	-4.52 (RMS)	PASSED
D19_03	Op. 2	High	914.9	-4.52 (RMS)	PASSED

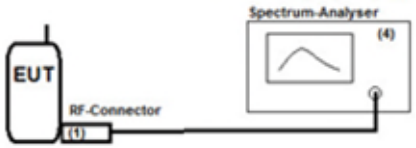
Remark: for more information and graphical plot see annex A1**CETECOM_TR20-1-0127501T01a_A1**

4.3 Emission Bandwidth 6 dB / 20 dB, §15.247(a)(1), §15.247(a)(2)

4.3.1 Description of the general test setup and methodology, see below example:

The EUT's RF-signal is coupled out by a suitable antenna coupling connector (1). The signal is then directly connected to the spectrum – analyzer (4) for specific RF-measurements. The specific attenuation losses for both signal paths/branches are determined prior to the measurement within a set-up calibration. These are then taken into account by correcting the measurement readings on the spectrum-analyzer.

Schematic:



Testing method:

The measurement is made according to relevant reference clauses:
(See Tables *Summary of Test Results* and *Summary of Test Methods* on page 6)

EUT settings
The EUT was instructed to send at given channel with maximum power (if adjustable) according applicants instructions.

4.3.2 Measurement Location

Test site	120910 - Radio Laboratory 1

4.3.3 Limit

Limit [kHz]	Detector [MaxHold]	RBW / VBW [kHz]
6 dB BW ≥ 500 kHz: DTS	MaxPeak	100 / 300
20 dB BW ≤ 500 kHz: FHSS	MaxPeak	3 / 10

4.3.4 Result

Diagram No.	Mode	Channel	Frequency [MHz]	6 dB bandwidth [kHz]	Result
D01_01	Op. 1	Low	903.1	769.23	PASSED
D01_02	Op. 1	Mid	908.1	778.85	PASSED
D01_03	Op. 1	High	914.0	774.04	PASSED
Diagram No.	**Mode**	**Channel**	**Frequency [MHz]**	**20 dB bandwidth [kHz]**	**Result**
D08_01	Op. 2	Low	902.2	140.26	PASSED
D08_02	Op. 2	Mid	908.4	139.42	PASSED
D08_03	Op. 2	High	914.8	142.63	PASSED

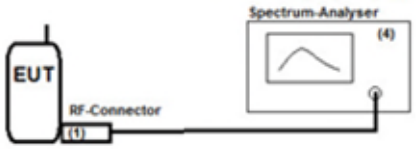
Remark: for more information and graphical plot see annex A1**CETECOM_TR20-1-0127501T01a_A1**

4.4 Carrier frequency separation, §15.247(a)(1)

4.4.1 Description of the general test setup and methodology, see below example:

The EUT's RF-signal is coupled out by a suitable antenna coupling connector (1). The signal is then directly connected to the spectrum – analyzer (4) for specific RF-measurements. The specific attenuation losses for both signal paths/branches are determined prior to the measurement within a set-up calibration. These are then taken into account by correcting the measurement readings on the spectrum-analyzer.

Schematic:



Testing method:

The measurement is made according to relevant reference clauses:
(See Tables *Summary of Test Results* and *Summary of Test Methods* on page 6)

EUT settings
The EUT was instructed to send with maximum power (if adjustable) according applicants instructions.

4.4.2 Measurement Location

Test site	120910 - Radio Laboratory 1

4.4.3 Limit

Limit	Detector [MaxHold]	RBW / VBW [kHz]
25 kHz or ≥ 20 dB bandwidth	MaxPeak	10 / 30

4.4.4 Result

Diagram No.	Mode	Channel separation [kHz]	Limit: 20 dB bandwidth [kHz]	Result
D09_01	Op. 3	200	142.63 [1)]	PASSED

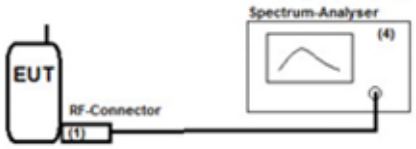
Remark: for more information and graphical plot see annex A1**CETECOM_TR20-1-0127501T01a_A1**
Remark 1): maximum value from Low, Mid and High channel of the 20 dB emission bandwidth chosen

4.5 Number of Hopping Channels, §15.247(a)(1)(i)

4.5.1 Description of the general test setup and methodology, see below example:

The EUT's RF-signal is coupled out by a suitable antenna coupling connector (1). The signal is then directly connected to the spectrum – analyzer (4) for specific RF-measurements. The specific attenuation losses for both signal paths/branches are determined prior to the measurement within a set-up calibration. These are then taken into account by correcting the measurement readings on the spectrum-analyzer.

Schematic:



Testing method:

The measurement is made according to relevant reference clauses:
(See Tables *Summary of Test Results* and *Summary of Test Methods* on page 6)

EUT settings
The EUT was instructed to send with maximum power (if adjustable) according applicants instructions.

4.5.2 Measurement Location

Test site	120910 - Radio Laboratory 1

4.5.3 Limit

Limit	Channels	Detector [MaxHold]	RBW / VBW [kHz]
20 dB bandwidth ≤ 250 kHz	≥ 50	MaxPeak	10 / 30
20 dB bandwidth ≥ 250 kHz	≥ 25		

4.5.4 Result

Diagram No.	Mode	Number of Channels [kHz]	Limit: 20 dB bandwidth ≤ 250 kHz	Result
D10_01 – D10_02	Op. 3	64	≥ 50	PASSED

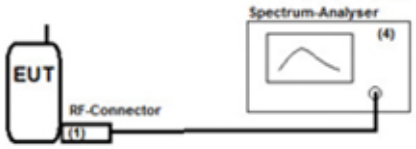
Remark: for more information and graphical plot see annex A1**CETECOM_TR20-1-0127501T01a_A1**

4.6 Time of occupancy, $15.247(a)(1)(i)

4.6.1 Description of the general test setup and methodology, see below example:

The EUT's RF-signal is coupled out by a suitable antenna coupling connector (1). The signal is then directly connected to the spectrum – analyzer (4) for specific RF-measurements. The specific attenuation losses for both signal paths/branches are determined prior to the measurement within a set-up calibration. These are then taken into account by correcting the measurement readings on the spectrum-analyzer.

Schematic:



Testing method:

The measurement is made according to relevant reference clauses:
(See Tables *Summary of Test Results* and *Summary of Test Methods* on page 6)

EUT settings
The EUT was instructed to send with maximum power (if adjustable) according applicants instructions.

4.6.2 Measurement Location

Test site	120910 - Radio Laboratory 1

4.6.3 Limit

Limit	Time of occupancy	Detector [MaxHold]	RBW / VBW [kHz]
20 dB bandwidth ≤ 250 kHz	0.4 s within 20 s	MaxPeak	30 / 100
20 dB bandwidth ≥ 250 kHz	0.4 s within 10 s		

4.6.4 Result

Diagram No.	Mode	Time of occupancy [s]	Result
D11_01 – D11_02	Op. 3	0.0926 [1)]	PASSED

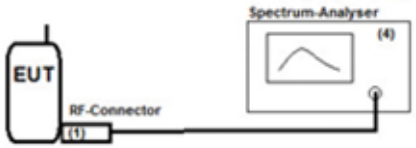
Remark: for more information and graphical plot see annex A1**CETECOM_TR20-1-0127501T01a_A1**
Remark 1): value with a smaller sweep time to get a better resolution. No other peaks within 20 s occurred

4.7 Occupied Channel Bandwidth 99%, §2.1049(h)

4.7.1 Description of the general test setup and methodology, see below example:

The EUT's RF-signal is coupled out by a suitable antenna coupling connector (1). The signal is then directly connected to the spectrum – analyzer (4) for specific RF-measurements. The specific attenuation losses for both signal paths/branches are determined prior to the measurement within a set-up calibration. These are then taken into account by correcting the measurement readings on the spectrum-analyzer.

Schematic:



Testing method:

The measurement is made according to relevant reference clauses:
(See Tables *Summary of Test Results* and *Summary of Test Methods* on page 6)

EUT settings
The EUT was instructed to send at given channel with maximum power (if adjustable) according applicants instructions.

4.7.2 Measurement Location

Test site	120910 - Radio Laboratory 1

4.7.3 Limit

When the occupied bandwidth limit is not stated in the applicable reference measurement method, the transmitted signal bandwidth shall be reported as the 99% emission bandwidth, as calculated or measured.

4.7.4 Result

Diagram No.	Mode	Channel	Frequency [MHz]	99% Occupied bandwidth [kHz]
D01_01	Op. 1	Low	903.1	840
D01_02	Op. 1	Mid	908.1	846
D01_03	Op. 1	High	914.0	867
D08_01	Op. 2	Low	902.2	127
D08_02	Op. 2	Mid	908.4	126
D08_03	Op. 2	High	914.8	128

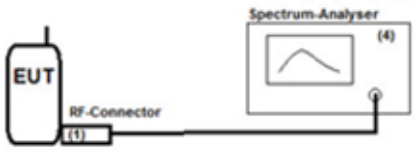
Remark: for more information and graphical plot see annex A1**CETECOM_TR20-1-0127501T01a_A1**

4.8 Emissions in non-restricted frequency bands, §15.247(d)

4.8.1 Description of the general conducted test setup and methodology, see below example:

The EUT's RF-signal is coupled out by a suitable antenna coupling connector (1). The signal is then directly connected to the spectrum – analyzer (4) for specific RF-measurements. The specific attenuation losses for both signal paths/branches are determined prior to the measurement within a set-up calibration. These are then taken into account by correcting the measurement readings on the spectrum-analyzer.

Schematic:



Testing method:

The measurement is made according to relevant reference clauses:
(See Tables *Summary of Test Results* and *Summary of Test Methods* on page 6)

EUT settings
The EUT was instructed to send at fixed channel with maximum power (if adjustable) according applicants instructions.

4.8.2 Measurement Location

Test site	120910 - Radio Laboratory 1

4.8.3 Limit

Frequency Range [MHz]	Mode	Limit [dBc]
0.15 – 9500	DTS	≥ 20 [1)]
	FHSS	≥ 30 [2)]

Remark 1): limit where conducted power measurement complies based on peak detector
Remark 2): limit where conducted power measurement complies based on RMS detector

4.8.4 Result spurious emissions

Diagram No.	Mode	Channel	Frequency [MHz]	Maximum level [dBm]	Limit [dBm]	Result
D04_01 – D04_05	Op.1	Low	1806	-29.51	-10.52	PASSED
D05_01 – D05_05	Op.1	Mid	1818	-30.63	-10.43	PASSED
D06_01 – D06_05	Op.1	High	1828	-29.60	-10.40	PASSED
D13_01 – D13_04	Op.2	Low	1804	-31.13	-19.80	PASSED
D14_01 – D14_04	Op.2	Mid	1818	-31.75	-19.70	PASSED
D15_01 – D15_04	Op.2	High	1830	-31.31	-19.33	PASSED

Remark: for more information and graphical plot see annex A1**CETECOM_TR20-1-0127501T01a_A1**

4.8.5 Result band-edge emissions

Diagram No.	Mode	Channel	Level at band-edge [dBm]	Result
D07_1	Op. 1	Low	-23.79	PASSED
D07_2	Op. 1	High	1)	PASSED
D16_1 – D16_2	Op. 2	Low	-31.12 3)	PASSED
D17_1	Op. 2	High	-34.96 1) 2)	PASSED
D18_1	Op. 3	Low	-34.84 2)	PASSED
D18_2	Op. 3	High	-35.09 1) 2)	PASSED

Remark: for more information and graphical plot see annex A1**CETECOM_TR20-1-0127501T01a_A1**
Remark 1): due to the large margin of 14 MHz to the upper band edge and the in respect small channel bandwidth of 125-and 500 kHz the result is not critical
Remark 2): noise level
Remark 3): integration method -> integrating the spectrum over 100 kHz right below the band edge to get the power to verify compliance. Measurement were performed in several steps and highest value was chosen

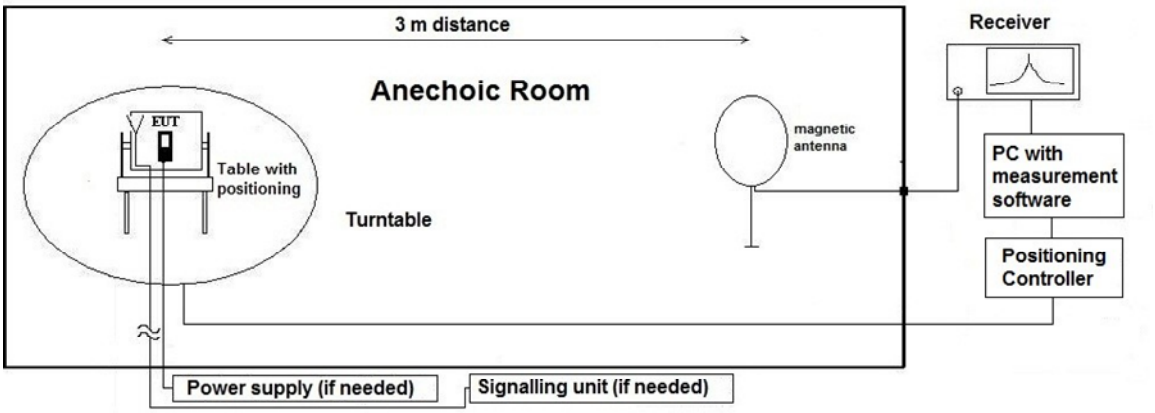
4.9 Radiated field strength emissions below 30 MHz, §15.209

4.9.1 Description of the general test setup and methodology, see below example:

Evaluating the radiated field emissions are done first by an exploratory emission measurement and a final measurement for most critical frequencies determined.

The loop antenna was placed at 1 m height above ground plane and 3 m measurement distance from set-up for investigations. Because of reduced measurement distance, correction data were applied, as stated in chapter "General Limit - Radiated field strength emissions below 30 MHz". The tests are performed in the semi anechoic room recognized by the regulatory commission.

Schematic:



Testing method:

The measurement is made according to relevant reference clauses:
(See Tables *Summary of Test Results* and *Summary of Test Methods* on page 6)

Exploratory, preliminary measurements
The EUT and its associated accessories are placed on a non-conductive position manipulator (tipping device) of 0.8 m height which is placed on the turntable. By rotating the turntable (step 90°, range 0°to 360°) and the EUT itself either on 3-orthogonal axis (portable equipment) or 2-orthogonal axis (defined operational position of EUT), the emission spectrum was recorded.

The loop antenna was moved at least to 2-perpendicular axes (antenna vector in direction of EUT and parallel to EUT) in order to maximize the emissions. The results are documented in a diagram. Critical frequencies (low margin to limit) are saved within a data reduction table for further investigations. If various operating modes are supported, further investigations are made to find the worst-case. Also the interconnection cables and equipment position were varied in order to maximize the emissions.

Final measurement on critical frequencies
Based on the exploratory measurements, the most critical frequencies are re-measured by maintaining the EUT's worst-case operation mode, cable position, etc.

First a frequency zoom around the critical frequency is done to locate the frequency more precisely. After this step, for all identified critical frequencies, the maximum peak was determined.

Following parameters were varied: the turntable angle continuously in the range 0 to 360 degree, the EUT itself either over 3-orthogonal axis (not defined usage position) or 2-orthogonal axis (defined usage position).

On the determined worst-case position, a final measurement with necessary bandwidth and detector according standard has been carried out.

Formula:

$E_C = E_R + AF + C_L + D_F - G_A$

$M = L_T - E_C$

AF = Antenna factor
C_L = Cable loss
D_F = Distance correction factor (if used)
E_C = Electrical field – corrected value
E_R = Receiver reading
G_A = Gain of pre-amplifier (if used)
L_T = Limit
M = Margin

All units are dB-units, positive margin means value is below limit.

4.9.2 Measurement Location

Test site	120901 - SAC - Radiated Emission <1GHz

Correction factors due to reduced meas. distance (f< 30 MHz):

The used correction factors when the measurement distance is reduced compared to regulatory measurement distance, are calculated according Extrapolation formulas valid for EUT's with maximum dimension of 0.625xLambda. Formula 2+3+4 as presented in ANSI C63.10, Chapter 6.4.4 are used for the calculations of proper extrapolation factors

Frequency -Range	f [kHz/MHz]	Lambda [m]	Far-Field Point [m]	Distance Limit accord. 15.209 [m]		1st Condition (dmeas< Dnear-field)	2'te Condition (Limit distance bigger dnear-field)	Distance Correction accord. Formula
kHz	9.00E+03	33333.33	5305.17	300		fullfilled	not fullfilled	-80.00
	1.00E+04	30000.00	4774.65			fullfilled	not fullfilled	-80.00
	2.00E+04	15000.00	2387.33			fullfilled	not fullfilled	-80.00
	3.00E+04	10000.00	1591.55			fullfilled	not fullfilled	-80.00
	4.00E+04	7500.00	1193.66			fullfilled	not fullfilled	-80.00
	5.00E+04	6000.00	954.93			fullfilled	not fullfilled	-80.00
	6.00E+04	5000.00	795.78			fullfilled	not fullfilled	-80.00
	7.00E+04	4285.71	682.09			fullfilled	not fullfilled	-80.00
	8.00E+04	3750.00	596.83			fullfilled	not fullfilled	-80.00
	9.00E+04	3333.33	530.52			fullfilled	not fullfilled	-80.00
	1.00E+05	3000.00	477.47			fullfilled	not fullfilled	-80.00
	1.25E+05	2400.00	381.97			fullfilled	not fullfilled	-80.00
	2.00E+05	1500.00	238.73			fullfilled	fullfilled	-78.02
	3.00E+05	1000.00	159.16			fullfilled	fullfilled	-74.49
	4.00E+05	750.00	119.37			fullfilled	fullfilled	-72.00
	4.90E+05	612.24	97.44			fullfilled	fullfilled	-70.23
	5.00E+05	600.00	95.49	30		fullfilled	not fullfilled	-40.00
	6.00E+05	500.00	79.58			fullfilled	not fullfilled	-40.00
	7.00E+05	428.57	68.21			fullfilled	not fullfilled	-40.00
	8.00E+05	375.00	59.68			fullfilled	not fullfilled	-40.00
	9.00E+05	333.33	53.05			fullfilled	not fullfilled	-40.00
MHz	1.00	300.00	47.75			fullfilled	not fullfilled	-40.00
	1.59	188.50	**30.00**			fullfilled	not fullfilled	-40.00
	2.00	150.00	23.87			fullfilled	fullfilled	-38.02
	3.00	100.00	15.92			fullfilled	fullfilled	-34.49
	4.00	75.00	11.94			fullfilled	fullfilled	-32.00
	5.00	60.00	9.55			fullfilled	fullfilled	-30.06
	6.00	50.00	7.96			fullfilled	fullfilled	-28.47
	7.00	42.86	6.82			fullfilled	fullfilled	-27.13
	8.00	37.50	5.97			fullfilled	fullfilled	-25.97
	9.00	33.33	5.31			fullfilled	fullfilled	-24.95
	10.00	30.00	4.77			fullfilled	fullfilled	-24.04
	10.60	28.30	4.50			fullfilled	fullfilled	-23.53
	11.00	27.27	4.34			fullfilled	fullfilled	-23.21
	12.00	25.00	3.98			fullfilled	fullfilled	-22.45
	13.56	22.12	3.52			fullfilled	fullfilled	-21.39
	15.00	20.00	3.18			fullfilled	fullfilled	-20.51
	15.92	18.85	**3.00**			fullfilled	fullfilled	-20.00
	17.00	17.65	2.81			not fullfilled	fullfilled	-20.00
	18.00	16.67	2.65			not fullfilled	fullfilled	-20.00
	20.00	15.00	2.39			not fullfilled	fullfilled	-20.00
	21.00	14.29	2.27			not fullfilled	fullfilled	-20.00
	23.00	13.04	2.08			not fullfilled	fullfilled	-20.00
	25.00	12.00	1.91			not fullfilled	fullfilled	-20.00
	27.00	11.11	1.77			not fullfilled	fullfilled	-20.00
	29.00	10.34	1.65			not fullfilled	fullfilled	-20.00
	30.00	10.00	1.59			not fullfilled	fullfilled	-20.00

4.9.3 Limit

Radiated emissions limits, (3 meters)					
Frequency Range [MHz]	Limit [µV/m]	Limit [dBµV/m]	Distance [m]	Detector	RBW [kHz]
0.009 – 0.09	2400 / f [kHz]	67.6 – 20Log(f) (kHz)	300	Pk & Avg	0.2
0.09 – 0.11	2400 / f [kHz]	67.6 – 20Log(f) (kHz)	300	Quasi peak	0.2
0.11 – 0.15	2400 / f [kHz]	67.6 – 20Log(f) (kHz)	300	Pk & Avg	0.2
0.15 – 0.49	2400 / f [kHz]	67.6 – 20Log(f) (kHz)	300	Pk & Avg	9
0.49 – 1.705	24000 / f [kHz]	87.6 – 20Log(f) (kHz)	30	Quasi peak	9
1.705 - 30	30	29.5	30	Quasi peak	9

*Remark: In Canada same limits apply, just unit reference is different

4.9.4 Result

Diagram	Channel	Mode	Maximum Level [dBµV/m] Frequency Range 0.009 – 30 MHz	Result
2.01	Low	Op. 2	19.789 *)	PASSED
2.02	Mid	Op. 2	19.730 *)	PASSED
2.03	High	Op. 2	19.541 *)	PASSED

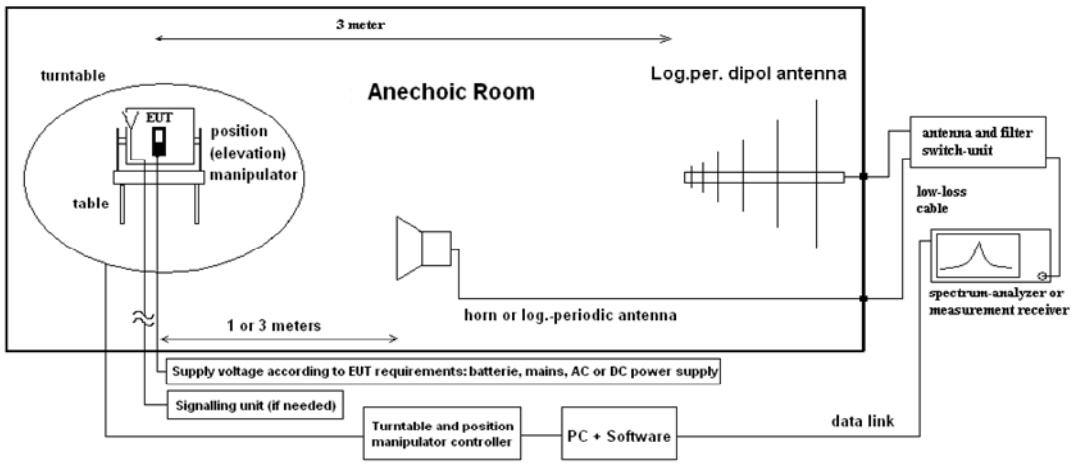
Remark: for more information and graphical plot see annex A1**CETECOM_TR20-1-0127501T01a_A1**
*): noise level

4.10 Radiated field strength emissions 30 MHz – 1 GHz, §15.209

4.10.1 Description of the general test setup and methodology, see below example:

Evaluating the emissions have to be done first by an exploratory emissions measurement and a final measurement for most critical frequencies. The tests are performed in a CISPR 16-1-4:2010 compliant semi anechoic room (SAR) and fully anechoic room (FAR) recognized by the regulatory commission. The measurement distance was set to 3 meter for frequencies up to 18 GHz and 2 meter above 18 GHz. A logarithmic periodic antenna is used for the frequency range 30 MHz to 1 GHz. Horn antennas are used for frequency range 1 GHz to 40 GHz. The EUT is aligned within 3 dB beam width of the measurement antenna with three orthogonal axis measurements on the EUT.

Schematic:



Testing method:

The measurement is made according to relevant reference clauses:
(See Tables *Summary of Test Results* and *Summary of Test Methods* on page 6)

Exploratory, preliminary measurements
The EUT and its associated accessories are placed on a non-conductive position manipulator (tipping device) of 0.8 m height which is placed on the turntable. By rotating the turntable (range 0° to 360°, step 90°) and the EUT itself either on 3-orthogonal axis (portable equipment) or 2-orthogonal axis (defined operational position of EUT) the emission spectrum and its characteristics was recorded with an EMI-receiver, broadband antenna and software.

Measurement antenna: horizontal and vertical, heights: 1,0 m and 1,82 m as worst-case determined by an exploratory emission measurements. The results are documented in a diagram. Critical frequencies (low margin to limit) are saved within a table for further investigations. If various operating modes are supported, further investigations are made to find the worst-case of them. Also the interconnection cables and equipment position were varied in order to maximize the emissions.

Final measurement on critical frequencies
Based on the exploratory measurements, the most critical frequencies are re-measured by maintaining the EUT's worst-case operation mode, cable position, etc. either on 10m OATS or 3m semi-anechoic room.
First a frequency zoom around the critical frequency is done to locate the frequency more precisely. After this step, for all identified critical frequencies, the maximum peak was determined.

Following parameters were varied: the turntable angle continuously in the range 0 to 360 degree, the EUT itself either over 3-orthogonal axis (not defined usage position) or 2-orthogonal axis (defined usage position). The measurement antenna height between 1 m and 4 m.
On the determined worst-case position, a final measurement with necessary bandwidth and detector according standard has been carried out

Formula:

$E_C = E_R + AF + C_L + D_F - G_A$ (1)

$M = L_T - E_C$ (2)

AF = Antenna factor
C_L = Cable loss
D_F = Distance correction factor (if used)
E_C = Electrical field – corrected value
E_R = Receiver reading
G_A = Gain of pre-amplifier (if used)
L_T = Limit
M = Margin

All units are dB-units, positive margin means value is below limit.

4.10.2 Measurement Location

Test site	120901 - SAC - Radiated Emission <1GHz

4.10.3 Limit

Radiated emissions limits, (3 meters)				
Frequency Range [MHz]	Limit [µV/m]	Limit [dBµV/m]	Detector	RBW / VBW [kHz]
30 - 88	100	40.0	Quasi peak	100 / 300
88 - 216	150	43.5	Quasi peak	100 / 300
216 - 960	200	46.0	Quasi peak	100 / 300
960 - 1000	500	54.0	Quasi peak	100 / 300

4.10.4 Result

Diagram	Channel	Mode	Maximum Level [dBµV/m] Frequency Range 30 – 1000 MHz	Result
3.01	Low	Op. 2	No peaks found	PASSED
3.02	Mid	Op. 2	No peaks found	PASSED
3.03	High	Op. 2	No peaks found	PASSED
3.04	High	Op. 2	102.179	2)
3.05	Low	Op. 2	102.609	2)

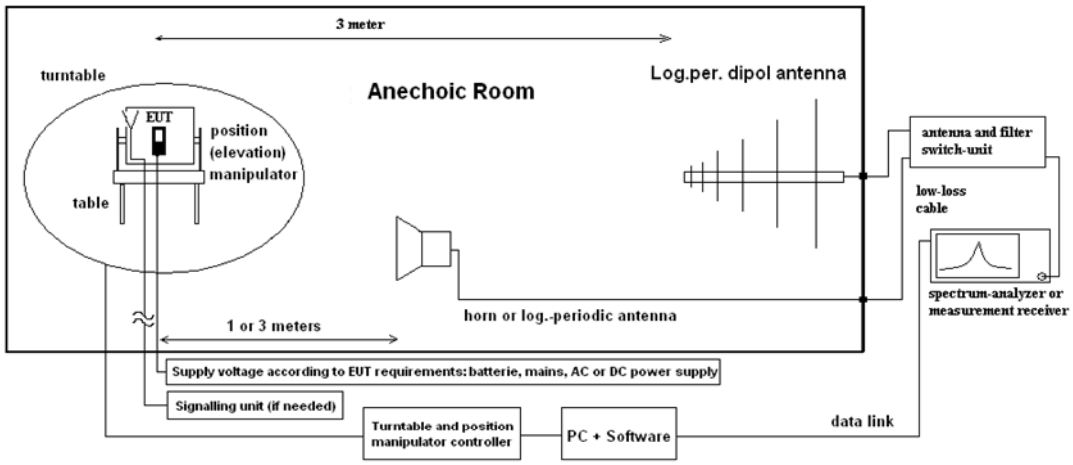
Remark: for more information and graphical plot see annex A1**CETECOM_TR20-1-0127501T01a_A1**
Remark 2): for information only

4.11 Radiated field strength emissions above 1 GHz, §15.209

4.11.1 Description of the general test setup and methodology, see below example:

Evaluating the emissions have to be done first by an exploratory emissions measurement and a final measurement for most critical frequencies. The tests are performed in a CISPR 18-1-4:2010 compliant fully anechoic room (FAR) recognized by the regulatory commission. The measurement distance was set to 3 meter for frequencies up to 18 GHz and 2 meter above 18 GHz. A logarithmic periodic antenna is used for the frequency range 30 MHz to 1 GHz. Horn antennas are used for frequency range 1 GHz to 40 GHz. The EUT is aligned within 3 dB beam width of the measurement antenna with three orthogonal axis measurements on the EUT.

Schematic:



Testing method:

The measurement is made according to relevant reference clauses:
(See Tables *Summary of Test Results* and *Summary of Test Methods* on page 6)

Exploratory, preliminary measurements

The EUT and its associated accessories are placed on a non-conductive position manipulator (tipping device) of 1.55 m height which is placed on the turntable. By rotating the turntable (range 0° to 360°, step 15°) and the EUT itself either on 3-orthogonal axis (portable equipment) or 2-orthogonal axis (defined operational position of EUT) the emission spectrum and its characteristics was recorded with an EMI-receiver, broadband antenna and software.
The measurements are performed in horizontal and vertical polarization of the measurement antennas. The results are documented in a diagram. Critical frequencies (low margin to limit) are saved within a table for further investigations. If various operating modes are supported, further investigations are made to find the worst-case of them. Also the interconnection cables and equipment position were varied in order to maximize the emissions.

Final measurement on critical frequencies

Based on the exploratory measurements, the most critical frequencies are re-measured by maintaining the EUT's worst-case operation mode, cable position, etc.

First a frequency zoom around the critical frequency is done to locate the frequency more precisely. After this step, for all identified critical frequencies, the maximum peak was determined.

Following parameters were varied: the turntable angle continuously in the range 0 to 360 degree, the EUT itself over 3-orthogonal axis, the antenna height and tilting or three axis scan for portable/small equipment.

On the determined worst-case position, a final measurement with necessary bandwidth and detector according standard has been carried out.

Formula:

$E_C = E_R + A_F + C_L + D_F - G_A$ (1)

$M = L_T - E_C$ (2)

E_C = Electrical field – corrected value
E_R = Receiver reading
M = Margin
L_T = Limit
A_F = Antenna factor
C_L = Cable loss
D_F = Distance correction factor (if used)
G_A = Gain of pre-amplifier (if used)

All units are dB-units, positive margin means value is below limit.

4.11.2 Measurement Location

Test site 1 – 18 GHz	120904 - FAC1 - Radiated Emissions

4.11.3 Limit

Radiated emissions limits, (3 meters)				
Frequency Range [MHz]	**Limit [µV/m]**	**Limit [dBµV/m]**	**Detector**	**RBW / VBW [kHz]**
Above 1000	500	54	Average	1000 / 3000
Above 1000	5000	74	Peak	1000 / 3000

4.11.4 Result

Diagram	Channel	Mode	Maximum Level [dBµV/m] Frequency Range 1 – 10 GHz	Result
8.01	Low	Op. 2	51.19 (AV) 1)	PASSED
8.02	Mid	Op. 2	50.58 (AV) 1)	PASSED
8.03	High	Op. 2	51.07 (AV) 1)	PASSED

Remark: for more information and graphical plot see annex A1**CETECOM_TR20-1-0127501T01a_A1**
Remark 1): value which is most critical in respect of the limit

4.12 Results from external laboratory

None	-

4.13 Opinions and interpretations

None	-

4.14 List of abbreviations

None	-

5 Equipment lists

ID	Description	Manufacturer	SerNo	Cal due date
	120901 - SAC - Radiated Emission <1GHz			**2025-Jul-21**
20574	Biconilog Hybrid Antenna BTA-L	Frankonia GmbH	980026L	2022-May-03
20487	CETECOM Semi Anechoic Chamber < 1GHz	ETS-Lindgren Gmbh	-	2025-Jul-15
20620	EMI Test Receiver ESU26	Rohde & Schwarz Messgerätebau GmbH	100362	2022-May
20482	filter matrix Filter matrix SAR 1	CETECOM GmbH	-	
25038	Loop Antenna HFH2-Z2	Rohde & Schwarz Messgerätebau GmbH	879824/13	2022-Apr
20885	Power Supply EA3632A	Agilent Technologies Deutschland GmbH	75305850	
	120904 - FAC1 - Radiated Emissions			
20341	Digital Multimeter Fluke 112	Fluke Deutschland GmbH	81650455	2022-May-25
20720	EMC32 [FAC]	Rohde & Schwarz Messgerätebau GmbH	V10.xx	
20489	EMI Test Receiver ESU40	Rohde & Schwarz Messgerätebau GmbH	1000-30	2022-May
20868	High Pass Filter AFH-07000	AtlanTecRF	16071300004	
20291	High Pass Filter WHJ 2200-4EE (GSM 850/900)	Wainwright Instruments GmbH	14	
20549	Log.Per-Antenna HL025	Rohde & Schwarz Messgerätebau GmbH	1000060	2024-Aug
20611	Power Supply E3632A	Agilent Technologies Deutschland GmbH	KR 75305854	
20338	Pre-Amplifier 100MHz - 26GHz JS4-00102600-38-5P	Miteq Inc.	838697	
20484	Pre-Amplifier 2,5GHz - 18GHz AMF-5D-02501800-25-10P	Miteq Inc.	1244554	
20287	Pre-Amplifier 25MHz - 4GHz AMF-2D-100M4G-35-10P	Miteq Inc.	379418	
20690	Spectrum Analyzer FSU	Rohde & Schwarz Messgerätebau GmbH	100302/026	2023-May

ID	Description	Manufacturer	SerNo	Cal due date
20439	UltraLog-Antenna HL 562	Rohde & Schwarz Messgerätebau GmbH	100248	2023-Mar-10

6 Measurement Uncertainty valid for conducted/radiated measurements

The reported uncertainties are calculated based on the standard uncertainty multiplied with the appropriate coverage factor **k**, such that a confidence level of approximately 95% is achieved. For uncertainty determination, each component used in the concrete measurement set-up was taken in account and it contribution to the overall uncertainty according its statistical distribution calculated.

RF-Measurement	Reference	Frequency range	Calculated uncertainty based on a confidence level of 95%						Remarks
Conducted emissions (U_{CISPR})	-	9 kHz - 150 kHz 150 kHz - 30 MHz	4.0 dB 3.6 dB						-
Power Output radiated	-	30 MHz - 4 GHz	3.17 dB						Substitution method
Power Output conducted	-	Set-up No.	Cel-C1	Cel-C2	BT1	W1	W2	--	
		9 kHz - 12.75 GHz	N/A	0.60	0.7	0.25	N/A	--	-
		12.75 GHz - 26.5 GHz	N/A	0.82	--	N/A	N/A	--	
Conducted emissions on RF-port	-	9 kHz - 2.8 GHz	0.70	N/A	0.70	N/A	0.69	--	N/A - not applicable
		2.8 GHz - 12.75 GHz	1.48	N/A	1.51	N/A	1.43	--	
		12.75 GHz – 18 GHz	1.81	N/A	1.83	N/A	1.77	--	
		18 GHz - 26.5 GHz	1.83	N/A	1.85	N/A	1.79	--	
Occupied bandwidth	-	9 kHz - 4 GHz	0.1272 ppm (Delta Marker)						Frequency error
			1.0 dB						Power
Emission bandwidth	- -	9 kHz - 4 GHz	0.1272 ppm (Delta Marker)						Frequency error
			See above: 0.70 dB						Power
Frequency stability	-	9 kHz - 20 GHz	0.0636 ppm						-
Radiated emissions Enclosure	-	150 kHz - 30 MHz	5.01dB						Magnetic field strength
		30 MHz - 1 GHz 1 GHz - 18 GHz 18-26.5 GHz	5.83 dB 4.91 dB 5.06 dB						Electrical Field strength

7 Versions of test reports (change history)

Version	Applied changes	Date of release
--	Initial release	2022-May-31
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End of Test Report