

Test Report

23-1-0078001T004a

Number of pages: 29 **Date of Report:** 2023-Dez-29

Testing company: cetecom advanced GmbH
Untertuerkheimer Str. 6-10
66117 Saarbruecken
GERMANY **Applicant:** Eliko Tehnoloogia Arenduskeskus
OÜ

Product: Positioning device
Model: ELIKO TAG

FCC ID: 2AF2I-TAG **IC:** 27124-TAG

Testing has been carried out in accordance with:

FCC Regulations
Title 47 CFR, Chapter I, Subchapter A, Part 15
Subpart C Intentional Radiators
§ 15.207 Conducted limits
Subpart F Ultra-Wideband Operation
§ 15.519 Technical requirements for hand held UWB systems
§ 15.521 Technical requirements applicable to all UWB devices

ISED-Regulations
Radio Standards Specifications
RSS-Gen, Issue 5
General Requirements for Compliance of Radio Apparatus
RSS-220, Issue 1 + Amendment 1 (July 2018)
Devices Using Ultra-Wideband (UWB) Technology

Tested Technology: UWB

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:


B.Eng. Martin Nunier
Supervisor Radio Services
Authorization of test report


Dipl.-Ing. Christian Lorenz
Test Manager
Responsible of test report

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Annex 1	Test result diagrams	TR23-1-0078001T004a_A1	39
Annex 2	Internal photographs of EUT	To be supplied by applicant	--
Annex 3	External photographs of EUT	TR23-1-0114201T001a_A3	4
Annex 4	Test set-up photographs	TR23-1-0078001T004a_A4	4
The listed attachments are separate documents.			

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 advanced 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.

1.2 Attestation

I declare that all measurements were performed by me or under my supervision and that all measurements have been performed and are correct to my best knowledge and belief to Industry Canada standards. All of the above requirements are met in accordance with enumerated standards.

1.3 Summary of Test Results

The EUT integrates a UWB transmitter. Other implemented wireless technologies were not considered within this test report.

Test case	Reference Clause FCC ☒	Reference Clause ISED ☒	Page	Remark	Result
Transmission time	§15.519(a)(1)	--	10	--	Passed
10 dB bandwidth	§15.519(b)	--	11	--	Passed
Radiated field strength emissions below 30 MHz	§15.205(a) §15.209(a)	--	15	--	Passed
Radiated field strength emissions 30 MHz – 960 MHz	§15.209 §15.519(c)	--	17	--	Passed
Radiated field strength emissions above 960 MHz	§15.521(h) §15.519(c)	--	20	--	Passed
Radiated emissions in the GPS bands	§15.519(d)	--	22	--	Passed
Fundamental emission peak power	§15.519(e)	--	24	--	Passed
Antenna requirement	§15.203	--	25	--	--

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 advanced laboratory.

N/A

Not applicable

Decision Rule: cetecom advanced GmbH follows [ILAC G8:2019 chapter 4.2.1 \(Simple Acceptance Rule\)](#).

1.4 Summary of Test Methods

Test case	Test method
Transmission time	--
10 dB bandwidth	ANSI 63.10-2013, §10.1
Radiated field strength emissions below 30 MHz	ANSI C63.10-2013 §6.3, §6.4
Radiated field strength emissions 30 MHz- 1 GHz	ANSI C63.10-2013 §6.3, §6.5
Radiated field strength emissions above 1 GHz	ANSI C63.10-2013 §6.3, §6.6
Radiated emissions in the GPS bands	ANSI C63.10-2013 §6.3, §6.6
Fundamental emission peak power	ANSI C63.10-2013 §6.3, §6.6
Antenna requirement	--

And reference also to Test methods in KDB558074

2 Administrative Data

2.1 Identification of the Testing Laboratory

Company name:	cetecom advanced GmbH
Address:	Untertuerkheimer Str. 6-10 66117 Saarbruecken Germany
Responsible for testing laboratory:	Dipl.-Ing. (FH) Andreas Luckenbill M.Sc.
Accreditation scope:	DAkkS Webpage: FCC ISED
IC Lab company No. / CAB ID:	3462D / DE0001
Test location 1:	Im Teelbruch 116; 45219 Essen
Test location 2:	--

2.2 General limits for environmental conditions

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

2.3 Test Laboratories sub-contracted

Company name:	--
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2.4 Organizational Items

Responsible test manager:	Dipl.-Ing. Christian Lorenz
Receipt of EUT:	2023-Aug-29
Date(s) of test:	2023-Nov-13 to 2023-Nov-28
Version of template:	23.1003

2.5 Applicant's details

Applicant's name:	Eliko Tehnoloogia Arenduskeskus OÜ
Address:	Aiandi 13/1 12918 Tallinn Estonia
Contact Person:	Inderk Ruiso
Contact Person's Email:	info@eliko.ee

2.6 Manufacturer's details

Manufacturer's name:	Eliko Tehnoloogia Arenduskeskus OÜ
Address:	Aiandi 13/1 12918 Tallinn Estland

2.7 Equipment under Test (EUT)

EUT No. *)	Sample No.	Product	Model	Type	SN	HW	SW
EUT 1	23-1-00780S02_C01	Positioning device	ELIKO TAG	standard	KT5d34UB_000F49	KT5D34UB	4,1
EUT 2	23-1-00780S04_C01	Positioning device	ELIKO TAG	standard	KT5d34UB_000A8E	KT5D34UB	4,1

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

2.8 Untested Variant (VAR)

VAR No. *)	Sample No.	Product	Model	Type	SN	HW	SW
------------	------------	---------	-------	------	----	----	----

*) The listed additional untested model variant(s) (VAR) is/are not object of evaluation of compliance. For further information please see Annex 5: Declaration of applicant of model differences.

If the table above does not show any other line than the headline, no untested variants are available.

2.1 Auxiliary Equipment (AE)

AE No. *)	Sample No.	Auxiliary Equipment	Model	SN	HW	SW
1	23-1-00780S13_C01	Notebook Samsung	NP900X3C	J9VZ91DCB00064B	--	--
2	23-1-00780S08_C01 ("Testsetup B/D")	Positioning device	ELIKO ANCHOR	KA4D37UEW_0009D4	KA4D37UEW	4.1

2.2 Connected cables (CAB)

CAB No. *)	Sample No.	Cable Type	Connectors / Details	Length
1	#1	USB cable	microUSB	1.5m

*) CAB short description is used to simplify the identification of the connected cables in this test report. If the table above does not show any other line than the headline, no cable was used during testing nor was taken into account for evaluation

2.3 Software (SW)

SW No. *)	Sample No.	SW Name	Description	SW Status
1	--	Configuration Tool V1.1	Software for configuration of device	V1.1.

*) SW short description is used to simplify the identification of the used software in this test report. If the table above does not show any other line than the headline, no SW was used during testing nor was taken into account for evaluation.

2.4 EUT set-ups

set-up no. *)	Combination of EUT and AE	Description
1	EUT 1 + (AE1) + CAB1	Used for radiated measurements AE1 used temporary for setting up the connection.
2	EUT 1 + (AE1) + CAB1 + AE2	Used for radiated timing measurements. Regular communication to tag (AE2).

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

2.5 EUT operation modes

EUT operating mode no. *)	Operating modes	Additional information
op. 1	TX-Mode 1	With help of special test firmware TX-mode was set-up. Compliant max. power setting: 0x12121212 We refer to applicants information/papers for details about necessary commands. SW1 to be used. 6.8MBit/s data rate, PRF:64MHz, 128Symbols, Packet size:56
op. 2	TX-Mode 2	TX-mode (regular mode) was set-up. EUT 2 set as Anchor operational mode. (normal mode) We refer to applicants information/papers for details about necessary commands.

*) 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

Firmware	☒ for normal use (Set-up2)	☒ Special version for test execution (Set-up1)	
Power supply	☐ AC Mains	-	
	☐ DC Mains	--	
	☒ Battery	Lithium Ion battery	
Operational conditions	T _{nom} =21 °C	T _{min} =-10 °C	T _{max} =60 °C
EUT sample type	Pre-Production		
Weight	--kg		
Size [LxWxH]	See pictures or applicants info		
Interfaces/Ports	DC/signal over microUSB		
For further details refer Applicants Declaration & following technical documents			

3.2 Detailed Technical data of Main EUT as Declared by Applicant

Main function	Positioning device	
Frequency range [MHz]	Channel 5 (6489.6MHz)	
Type of modulation used	BPSK/BPM	
Number of channels	1	
Emission designator	M7D	
Equipment type	☐ Imaging Short-Range communication device ☒ a) Indoor ☒ b) Outdoor ☐ Field disturbance sensor ☐ Short-Range automotive radar	
Antenna Type	☒ Integrated ☐ External, no RF- connector ☐ External, separate RF-connector	
Max. mean power density per MHz (radiated)	-41.85 dBm@3m distance and 1 MHz RBW	
FCC label attached	No	
For further details refer Applicants Declaration & following technical documents		
Description of Reference Document (supplied by applicant)	Version	Total Pages
"Test plan for ELIKO anchor and TAG UWB Ch5 FCC testing"	1.0	16

3.3 Modifications on Test sample

Additions/deviations or exclusions	--
------------------------------------	----

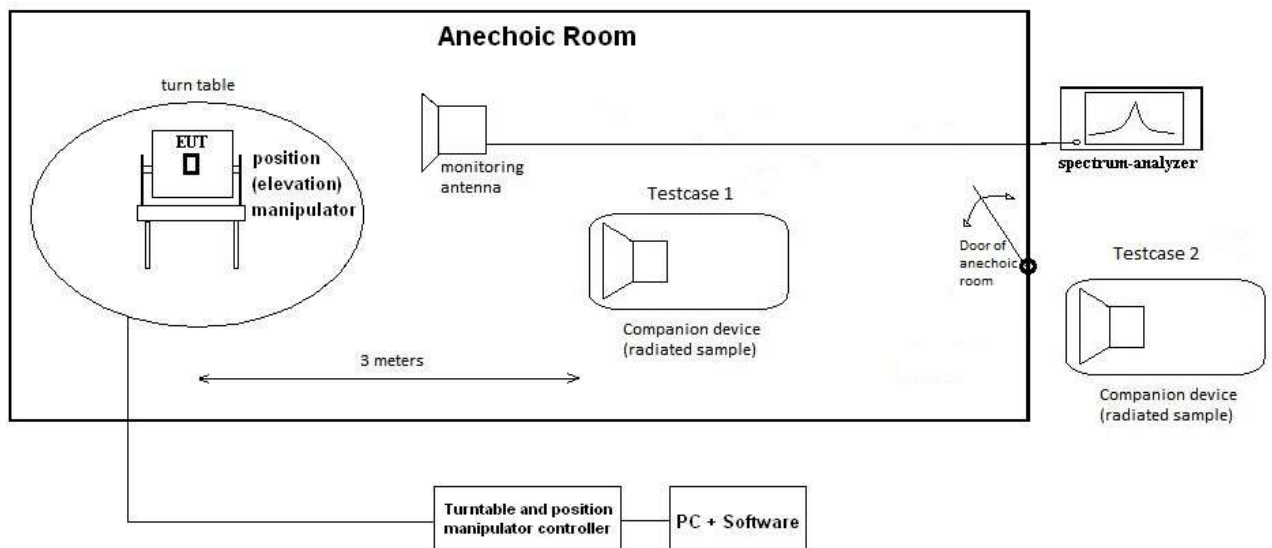
4 Measurements

4.1 Transmission time measurement

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

The tests are performed in a CISPR 16-1-4:2010 compliant fully anechoic room (FAR). The measurement distance was set to a proper valuable distance for good traffic link communication between the main EUT/DUT and the companion device.

4.1.2 Schematic:



4.1.3 Testing method:

- The tests have been performed in a Fully-Anechoic-Chamber of normative 3m measurement distance or other suitable distance as indicated as typical distance of the system by the applicant. Constraints are the physical distance of the anechoic room.
- Radiated tests at nominal environmental conditions have been performed
- A monitoring horn antenna (1GHz-18GHz) is connected to an spectrum-analyzer (time domain) and is placed near-by the EUT/DUT. Therefore its regular transmission and reaction is captured for two possible test cases: Tag companion device placed near-by DUT/EUT and a second test case tag companion device not placed near-by DUT/EUT or switched-off. For both cases a timing diagram is recorded to show the RF-transmissions. In case the communication link system can't communicate (Anechoic-room door closed) no other transmissions are allowed except for physical detection of the device. In no case data transmissions are allowed.

4.1.4 Measurement Location

Test site	120907 - FAC2 - Radiated Emissions
-----------	------------------------------------

4.1.5 Result

The EUT stops to transmit approximately [s] later after the intentional radiator is switched off	Result
9.8499774997819447009	Passed

Remark: for more information and graphical plot see annex A1 **TR23-1-0078001T004a_A1**

4.2 10 dB bandwidth measurement

Testing method:

The frequency at which the maximum power level is measured with the peak detector is designated f_M (RBW=1 MHz, VBW= 3 MHz, peak detection, maxhold). The outermost 1 MHz segments above and below f_M , where the peak power falls by 10 dB relative to the level at f_M , are designated as f_H and f_L . The UWB transmission, and the -10 dB bandwidth (B - 10), is defined as ($f_H - f_L$). -10 dB bandwidth should be ≥ 500 MHz and must be contained between 3100 MHz and 10.600 MHz.

Test method	Radiated, 3m distance
Remarks	--

EUT settings

The measurement is made radiated. The EUT was instructed to transmit continuously with maximum power (if adjustable) according applicants declared and applicable settings.

Different characteristics have been checked, e.g. data rates which EUT can operate if applicable.

4.2.1 Measurement Location

Test site	120907 - FAC2 - Radiated Emissions
-----------	------------------------------------

4.2.2 Limit

Test limit [GHz]
3.1 – 10.6

4.2.3 Spectrum-Analyzer Settings

Span	1.5 GHz
Resolution Bandwidth (RBW)	ANSI 63.10-2013, chapter 10.1
Video Bandwidth (VBW)	Minimum 3 times the resolution bandwidth
Sweep time	Auto-coupled
Detector	Peak detector
Sweep mode	Repetitive Mode, MAX-HOLD, trace stabilization

4.2.4 Result

Mode	Frequency with the maximum power f_M [MHz]	Power at the frequency f_M [dBm]	Lowest frequency bound f_L [MHz]	Highest frequency bound f_H [MHz]	-10 dB bandwidth [MHz]	Result
1	6490.599	-10.13	6144.899	6833.599	688.7	Passed

Remark: for more information and graphical plot see annex A1 **TR23-1-0078001T004a_A1**

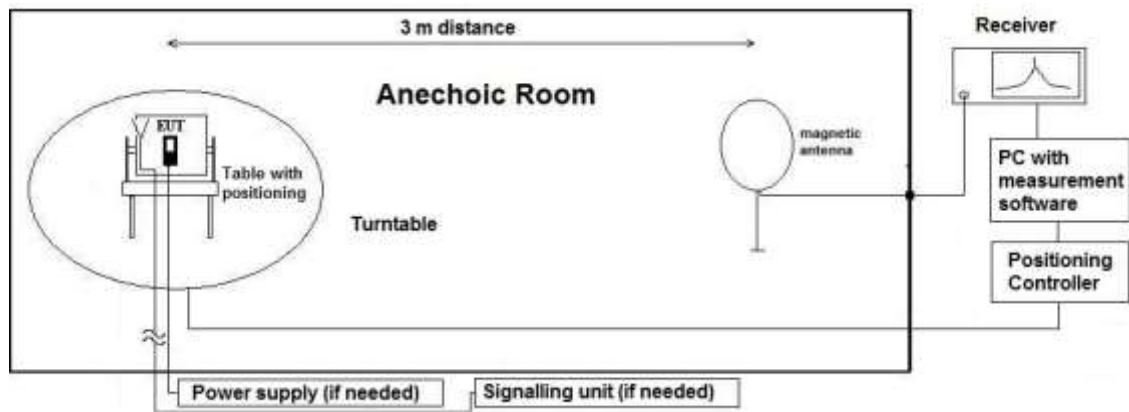
4.3 Radiated field strength emissions below 30 MHz

4.3.1 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 5)

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.

4.3.2 Sample calculation

Raw-Value [dBuV/m]	Antenna factor	Distance Correction [dB]	Cable Loss	Preamplifier	Resulting correction value [dB]	Final result [dBuV/m]	Remarks
19.83	18.9	-70.75	0.18	--	-51.67	-31.83	30 to 3 m correction used according ANSI C63.10-2013

Remark: This calculation is based on an example value at 458 kHz

4.3.3 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)	2nd Condition (Limit distance bigger dnear-field)	Distance Correction accord. Formula
kHz	9	33333.33	5305.17	300	fulfilled	not fulfilled	-80.00
	10	30000.00	4774.65		fulfilled	not fulfilled	-80.00
	20	15000.00	2387.33		fulfilled	not fulfilled	-80.00
	30	10000.00	1591.55		fulfilled	not fulfilled	-80.00
	40	7500.00	1193.66		fulfilled	not fulfilled	-80.00
	50	6000.00	954.93		fulfilled	not fulfilled	-80.00
	60	5000.00	795.78		fulfilled	not fulfilled	-80.00
	70	4285.71	682.09		fulfilled	not fulfilled	-80.00
	80	3750.00	596.83		fulfilled	not fulfilled	-80.00
	90	3333.33	530.52		fulfilled	not fulfilled	-80.00
	100	3000.00	477.47		fulfilled	not fulfilled	-80.00
	125	2400.00	381.97		fulfilled	not fulfilled	-80.00
	200	1500.00	238.73		fulfilled	fulfilled	-78.02
	300	1000.00	159.16		fulfilled	fulfilled	-74.49
	400	750.00	119.37		fulfilled	fulfilled	-72.00
	490	612.24	97.44		fulfilled	fulfilled	-70.23
	500	600.00	95.49	30	fulfilled	not fulfilled	-40.00
	600	500.00	79.58		fulfilled	not fulfilled	-40.00
	700	428.57	68.21		fulfilled	not fulfilled	-40.00
	800	375.00	59.68		fulfilled	not fulfilled	-40.00
	900	333.33	53.05		fulfilled	not fulfilled	-40.00
MHz	1.00	300.00	47.75		fulfilled	not fulfilled	-40.00
	1.59	188.50	30.00		fulfilled	not fulfilled	-40.00
	2.00	150.00	23.87		fulfilled	fulfilled	-38.02
	3.00	100.00	15.92		fulfilled	fulfilled	-34.49
	4.00	75.00	11.94		fulfilled	fulfilled	-32.00
	5.00	60.00	9.55		fulfilled	fulfilled	-30.06
	6.00	50.00	7.96		fulfilled	fulfilled	-28.47
	7.00	42.86	6.82		fulfilled	fulfilled	-27.13
	8.00	37.50	5.97		fulfilled	fulfilled	-25.97
	9.00	33.33	5.31		fulfilled	fulfilled	-24.95
	10.00	30.00	4.77		fulfilled	fulfilled	-24.04
	10.60	28.30	4.50		fulfilled	fulfilled	-23.53
	11.00	27.27	4.34		fulfilled	fulfilled	-23.21
	12.00	25.00	3.98		fulfilled	fulfilled	-22.45
	13.56	22.12	3.52		fulfilled	fulfilled	-21.39
	15.00	20.00	3.18		fulfilled	fulfilled	-20.51
	15.92	18.85	3.00		fulfilled	fulfilled	-20.00
	17.00	17.65	2.81		not fulfilled	fulfilled	-20.00
	18.00	16.67	2.65		not fulfilled	fulfilled	-20.00
	20.00	15.00	2.39		not fulfilled	fulfilled	-20.00
	21.00	14.29	2.27		not fulfilled	fulfilled	-20.00
	23.00	13.04	2.08		not fulfilled	fulfilled	-20.00
	25.00	12.00	1.91		not fulfilled	fulfilled	-20.00
	27.00	11.11	1.77		not fulfilled	fulfilled	-20.00
	29.00	10.34	1.65		not fulfilled	fulfilled	-20.00
	30.00	10.00	1.59		not fulfilled	fulfilled	-20.00

4.3.4 Measurement Location

Test site	120901 - SAC3 - Radiated Emission <1GHz
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4.3.5 Limit

Radiated emissions limits (3 meters)					
Frequency Range [MHz]	Limit [$\mu\text{V}/\text{m}$]	Limit [$\text{dB}\mu\text{V}/\text{m}$]	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

4.3.6 Result

Diagram	Channel	Mode	Maximum Level [$\text{dB}\mu\text{V}/\text{m}$] Frequency Range 0.009 – 30 MHz	Result
TID147a	5	1	20.07	Passed
TID147b	5	1	20.45	Passed

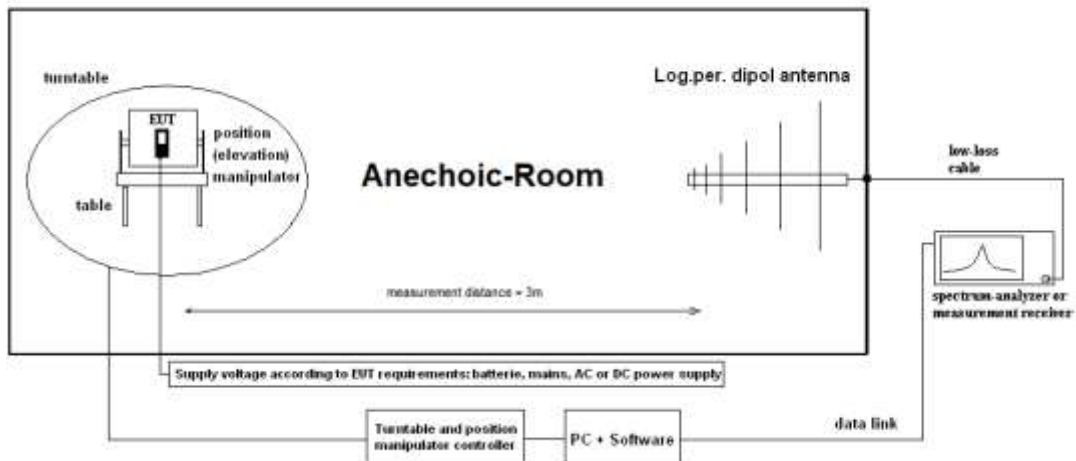
Remark: for more information and graphical plot see annex A1 **TR23-1-0078001T004a_A1**

4.4 Radiated field strength emissions 30 MHz – 960 MHz

4.4.1 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 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 5)

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 it's 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:

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

$$M = L_T - E_C \quad (2)$$

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.

4.4.2 Sample calculation

Raw-Value [dBuV/m]	Antenna factor	Distance Correction [dB]	Cable Loss	Preamplifier	Resulting correction value [dB]	Final result [dBuV/m]	Remarks
32.7	22.25	--	3.1	--	25.35	58.05	--

Remark: This calculation is based on an example value at 800.4 MHz

4.4.3 Measurement Location

Test site	120901 - SAC3 - Radiated Emission <1GHz
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4.4.4 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

4.4.5 Result

Diagram	Channel	Mode	Maximum Level [dBμV/m] Frequency Range 30 – 960 MHz	Result
TID0146a	5	1	39.02@925.35MHz	Passed
TID0146b	5	1	41.18@925.47MHz	Passed

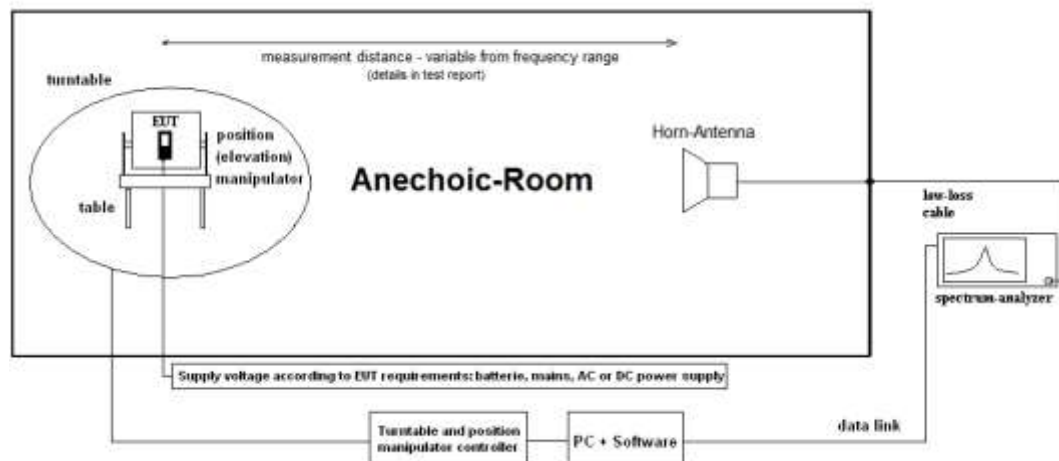
Remark: for more information and graphical plot see annex A1 **TR23-1-0078001T004a_A1**

4.5 Radiated field strength emissions above 960 MHz

4.5.1 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 5)

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 it's 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 and the height for EUT with large dimensions 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:

$$P_{EIRP} = P_{MEAS} + C_L + FSL - G_A \quad (1)$$

P_{MEAS} = measured power at instrument

M = Margin

L_T = Limit

FSL = Free Space loss = Function(frequency, measurement distance)

$$M = L_T - P_{EIRP}$$

C_L = cable loss

G_A = Gain of pre-amplifier (if used)

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

4.5.2 Sample calculation

Raw-Value [dBuV/m]	Antenna factor	Distance Correction [dB]	Cable Loss + Preamplifier	Resulting correction value [dB]	Final result [dBuV/m]	Remarks
29.37	41.20	--	24.28	16.92	46.3	CableLoss and PreAmp data in one data correction file

Remark: This calculation is based on an example value at 10 GHz

4.5.3 Measurement Location

Test site	120907 - FAC2 - Radiated Emissions
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4.5.4 Limit

Frequency Range [MHz]	EIRP [dBm]	Detector	RBW / VBW [kHz]
960-1610	-75.3	RMS	1000 / 3000
1610-1990	-63.3	RMS	1000 / 3000
1990-3100	-61.3	RMS	1000 / 3000
3100-4750	-41.3	RMS	1000 / 3000
4750-10600	-41.3	RMS	1000 / 3000
10600- 40000	-61.3	RMS	1000 / 3000

4.5.5 Measurement distance

Frequency Range [MHz]	Measurement distance [m]
960-1610	2.0 (SAC3)
1610-1990	2.0 (SAC3)
1990-3100	2.0 (SAC3)
3100 - 4750	1.0 (SAC3)
3100-10600	3.0 (FAC2)
18000-33000	1.23 (FAC2)
33000-40000	1.0 (FAC2)

4.5.6 Results

Diagram	Frequency range [MHz]	Mode	Remark	Result
TID0139a_04	960 – 1610	1	AntH, EUT laying	Passed
TID0139a_01	1610 - 3100	1	AntH, EUT standing	Passed
TID0139b_03	960 – 1610	1	AntV, EUT laying	Passed
TID0139b_02	1610 - 3100	1	AntV, EUT standing	Passed
TID0148a_04	3100 - 4750	1	Canada only (more critical limits): AntH, EUT laying	Passed
TID0148a_01		1	Canada only (more critical limits): AntH, EUT standing	Passed
TID0148b_03	3100 - 4750	1	Canada only (more critical limits): AntV, EUT laying	Passed
TID0148b_02		1	Canada only (more critical limits): AntV, EUT standing	Passed
TID141a	6000 - 7000	1	Max. PSD per [MHz]: AntH: -43.04 dBm	Passed
TID141b			Max. PSD per [MHz]: AntV: -41.85 dBm	Passed
TID142a	3100 - 10600	1	Ant H	Passed
TID142b		1	AntV	Passed
TID0149a	10600-12400	1	Ant H	Passed
TID0149b		1	AntV	Passed
TID0150a	12400-18000	1	Ant H Max-Value: -61.72dBm	Passed
TID0150b		1	AntV Max-Value: -64.78dBm	Passed
TID0151a	18000-33000	1	Ant H	Passed
TID0151b		1	AntV	Passed
TID0152a	33000-40000	1	Ant H	Passed
TID0152b		1	AntV	Passed

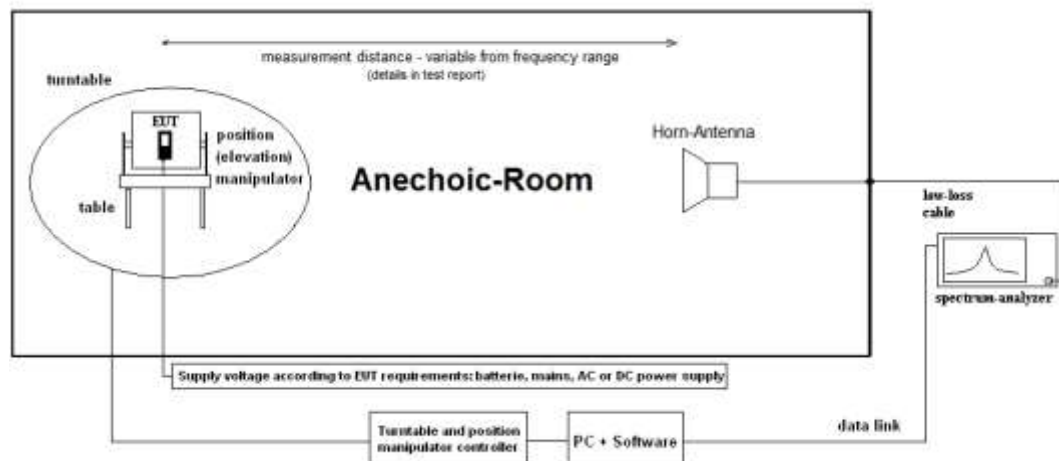
Remark: for more information and graphical plot see annex A1 **TR23-1-0078001T004a_A1**

4.6 Radiated emissions in the GPS bands

4.6.1 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 5)

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 it's 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 and the height for EUT with large dimensions 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:

$$P_{EIRP} = P_{MEAS} + C_L + FSL - G_A \quad (1)$$

P_{MEAS} = measured power at instrument

M = Margin

L_T = Limit

FSL = Free Space loss = Function(frequency, measurement distance)

$$M = L_T - P_{EIRP}$$

C_L = cable loss

G_A = Gain of pre-amplifier (if used)

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

4.6.2 Measurement Location

Test site	120907 - FAC2 - Radiated Emissions
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4.6.3 Limit

Radiated emissions limits (3 meters)			
Frequency Range [MHz]	EIRP [dBm]	Detector	RBW / VBW [kHz]
1164-1240	-85.3	RMS	1 / 3
1559-1610	-85.3	RMS	1 / 3

4.6.4 Result

Diagram	Frequency range [MHz]	Mode	Remark	Result
TID144a	1164-1240	1	Ant H	Passed
TID144b		1	Ant V	Passed
TID145a	1559-1610	1	Ant H	Passed
TID145b		1	AntV	Passed

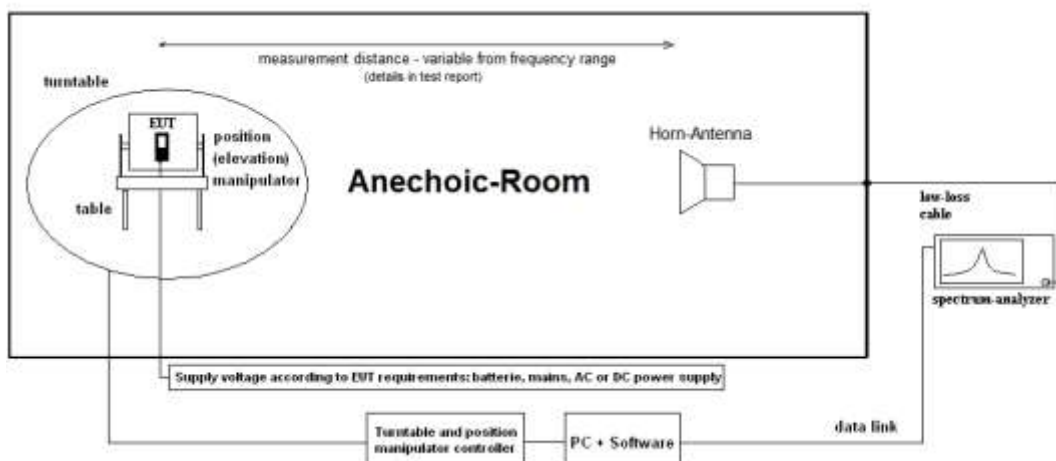
Remark: for more information and graphical plot see annex A1 **TR23-1-0078001T004a_A1**

4.7 Fundamental emission peak power

4.7.1 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 5)

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. 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 and the height for EUT with large dimensions 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:

$$P_{EIRP} = P_{MEAS} + C_L + FSL - G_A \quad (1)$$

P_{MEAS} = measured power at instrument

M = Margin

L_T = Limit

FSL = Free Space loss = Function(frequency, measurement distance)

$$M = L_T - P_{EIRP}$$

C_L = cable loss

G_A = Gain of pre-amplifier (if used)

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

4.7.2 Measurement Location

Test site	120907 - FAC2 - Radiated Emissions
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4.7.3 Limit

Radiated emissions limits (3 meters)			
Frequency Range [MHz]	EIRP [dBm]	Detector	RBW / VBW [MHz]
Frequency with the highest radiated emission contained within a 50 MHz bandwidth	0	MaxPeak	50 / 80

4.7.4 Result

Diagram	fc [MHz]	fmax [MHz] _{1..}	Pmax [dBm]	Mode	Remark	Result
TID143a	6489.6	6486.0	-2.41	1	Ant H	Passed
TID0143b	6489.6	6486.0	-1.36	1	Ant V	Passed

Remark1: frequency with the highest radiated emission contained within a 50 MHz bandwidth from the measurement is the frequency inside of the fundamental emission.

Remark2: for more information and graphical plot see annex A1 **TR23-1-0078001T004a_A1**

4.8 Antenna requirement

The antenna is integral.

4.9 Equipment lists

ID	Description	Manufacturer	SerNo	CheckType	Last Check	Interval	Next Check
	120901 - SAC3 - Radiated Emission <1GHz			calchk	cal: 2015-Jul-21 chk: 2021-Jul-27	cal: 10Y chk: 12M	cal: 2025-Jul-21 chk: 2022-Jul-27
20341	Digital Multimeter Fluke 112	Fluke Deutschland GmbH / Glottertal	81650455	cal	cal: 2022-May-18	cal: 24M	cal: 2024-May-18
20442	Semi Anechoic Chamber	ETS-Lindgren GmbH / Taufkirchen	-	cnn	cal: - chk: -	cal: - chk: -	cal: - chk: -
20482	filter matrix Filter matrix SAR 1	CETECOM GmbH	-	cnn	cal: - chk: -	cal: - chk: -	cal: - chk: -
20574	Biconilog Hybrid Antenna BTA-L	Frankonia GmbH / Heideck	980026L	cal	cal: 2022-Jun-15	cal: 36M	cal: 2025-Jun-15
20620	Test Receiver ESU26	Rohde & Schwarz Messgerätebau GmbH / Memmingen	100362	cal	cal: 2023-May-24	cal: 12M	cal: 2024-May-24
20885	Power Supply EA3632A	Agilent Technologies Deutschland GmbH	75305850	cnn	cal: - chk: -	cal: - chk: -	cal: - chk: -
25038	Loop Antenna HFH2-Z2	Rohde & Schwarz Messgerätebau GmbH / Memmingen	879824/13	cal	cal: 2022-Jul-04	cal: 24M	cal: 2024-Jul-04
	120907 - FAC2 - Radiated Emissions			chk	chk: 2023-Feb-21	chk: 12M	chk: 2024-Feb-21
20005	AC - LISN 50 Ohm/50µH ESH2-Z5	Rohde & Schwarz Messgerätebau GmbH / Memmingen	861741/005	cal	cal: 2023-May-25	cal: 12M	cal: 2024-May-25
20133	Horn Antenna 3115 (Meas 1)	EMCO Elektronik GmbH / Gilching	9012-3629	cal	cal: 2023-May-22	cal: 36M	cal: 2026-May-22
20302	Horn Antenna BBHA9170 (Meas 1)	Schwarzbeck Mess-Elektronik OHG / Schönau	155	cpu	chk: 2020-Apr-15	chk: 12M	
20412	Fully Anechoic Chamber 2	ETS-Lindgren GmbH / Taufkirchen	without	chk	chk: 2023-Apr-14	chk: 6M	chk: 2023-Oct-14
20732	Signal- and Spectrum Analyzer FSW67	Rohde & Schwarz Messgerätebau GmbH / Memmingen	104023	cal	cal: 2023-May-25	cal: 12M	cal: 2024-May-25
20767	Pickett-Potter Horn Antenna FH-PP 140-220	RPG-Radiometer Physics GmbH / Meckenheim	010011	cnn	cal: - chk: -	cal: - chk: -	cal: - chk: -
20811	Horn Antenna ASY-SGH-124-SMA	Antenna Systems Solutions S.L	29F14182337	cal	cal: 2021-Oct-20	cal: 36M	cal: 2024-Oct-20
20812	Pickett-Potter Horn Antenna FH-PP-325	RPG-Radiometer Physics GmbH	10024	cnn	cal: - chk: -	cal: - chk: -	cal: - chk: -
20814	Pickett-Potter Horn Antenna FH-PP 140	RPG-Radiometer Physics GmbH	10008	cnn	cal: - chk: -	cal: - chk: -	cal: - chk: -
20836	1-18 GHz Amplifier	Wright Technologies, Inc. / Roseville	0001	chk		chk: 36M	
20877	JS42-08001800-16-8P Verstärker	Miteq Inc.	2079991 / 2079992	chk	chk: 2023-Feb-27	chk: 6M	chk: 2023-Aug-27
20909	Waveguide Horn Antenna PE9881-24	Pasternack Enterprises, Inc.	37/2016	cnn	cal: - chk: -	cal: - chk: -	cal: - chk: -
20912	Low noise Amplifier Module 0.5-4GHz	RF-Lambda Europe GmbH / Rüsselsheim	19041200083	cpu	chk: 2020-Dec-01	chk: 6M	chk: 2021-Jun-01
20913	Phase Amplitude Stable Cable Assembly DC-40GHz	RF-Lambda Europe GmbH	AC19040001	cnn	cal: - chk: -	cal: - chk: -	cal: - chk: -
25457	DRG Horn Antenna SAS-574	A.H. Systems, Inc. / Chatsworth	383	cal	cal: 2022-Mar-28	cal: 36M	cal: 2025-Mar-28

Tools used in *P1M1*

4.9.1 Legend

Note / remarks	Interval of calibration & Verification
12M	12 months
24M	24 months
36M	36 months
10Y	10 Years

Abbreviation Check Type	Description
cnn	Calibration and verification not necessary
cal	Calibration
calchk	Calibration plus intermediate Verification
chk	Verification
cpu	Verification before usage

5 Results from external laboratory

None	-
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6 Opinions and interpretations

None	-
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7 List of abbreviations

None	-
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8 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 its contribution to the overall uncertainty according its statistical distribution calculated.

Issue No.	Measurement type	Reference	Frequency range of measurement		Calculated Uncertainty based on confidence level of 95.54%	Remarks
			Start [MHz]	Stop [MHz]		
1	Magnetic field strength	FCC15/18/22/24/27/90, ISED	0.009	30	4.86	Magnetic loop antenna, Pre-Amp on
2	RF-Output power (eirp) Unwanted emissions (eirp) [dB]	FCC15/18 / ISED	30	100	4.57	without Pre-Amp
			30	100	4.91	with Pre-Amp
			100	1000	4.02	without Pre-Amp
			100	1000	4.26	with Pre-Amp
			1000	18000	4.36	without Pre-Amp
			1000	18000	5.23	with Pre-Amp
			18000	33000	4.92	Schwarzbeck BBHA9170 (#20302) Antenna set-up non-waveguide antenna
			33000	50000	4.17	Set-up for Q-Band (WR-22), non-wave guide antenna
			40000	60000	4.69	Set-up U-Band (WR-19), non-waveguide antenna
			50000	75000	4.06	External Mixer set-up V-Band (WR-15)
			75000	110000	4.17	External Mixer set-up W-Band (WR-6)
			90000	140000	5.49	External Mixer set-up F-Band (WR-8)
			140000	225000	6.22	External Mixer set-up G-Band (WR-5)
			225000	325000	7.04	External Mixer set-up (WR-3)
			325000	500000	8.84	External Mixer set-up (WR-2.2)
3	Radiated Blocking [dB]	EN 303 883	1000	18000	2.85	Typical set-up with microwave generator and antenna, value for 7 GHz calculated
			18000	33000	4.66	Typical set-up with microwave generator and antenna
			33000	50000	3.48	WR-22 set-up
			50000	75000	3.73	WR-15 set-up
			75000	110000	4.26	WR-6 set-up
4	Frequency Error / UWB+FMCW [kHz]	EN 303 883 FCC 15	40000	77000	276.19	calculated for 77 GHz (FMCW) carrier
	Frequency Error / NFC [Hz]	FCC 15	6000	7000	33.92	calculated for 6.5 GHz UWB Ch.5
			11.00	14.00	20.76	calculated for 13.56 MHz NFC carrier
5	TS 8997 conducted Parameters	FCC15/18 / ISED	30	6000	1.11	1. Power measurement with Fast-sampling-detector
			30	6000	1.20	2. Power measurement with Spectrum-Analyzer
			30	6000	1.20	3. Power Spectrum-Density measurement
			30	7500	1.20	4. Conducted Spurious emissions:
			0.009	30	2.56	5. Conducted Spurious emissions:
			2.4	2.48	1.95 ppm	6a. Bandwidth / 2-Marker Method for 2.4 GHz ISM
			5.18	5.825	7.180 ppm	6b. Bandwidth / 2-Marker Method for 5 GHz WLAN
			5.18	5.825	1.099 ppm	7. Frequency (Marker method) for 5 GHz WLAN
			30	6000	0.11561µs	8. Medium-Utilization factor / Timing
			30	6000	1.85	9a. Blocking-Level of companion device
			30	6000	1.62	9b. Blocking Generator level
			0.009	30	3.57	--
6	Conducted emissions	EN 303 883 FCC 15	--	--	--	--

9 Versions of test reports (change history)

Version	Applied changes	Date of release
--	Initial release	2023-Dez-29
--	--	--
--	--	--

End Of Test Report