

FCC Measurement/Technical Report on Wiliot GEN3 Hyper-thin Bluetooth IoT edge

FCC ID: 2AXVQ-WILIOT3
IC: 26623-WILIOT3

Report Reference: MDE_WILIOT_2301_FCC_01_rev2

Test Laboratory:

7layers GmbH
Borsigstrasse 11
40880 Ratingen
Germany



Deutsche
Akkreditierungsstelle
D-PL-12140-01-00

Note:

The following test results relate only to the devices specified in this document. This report shall not be reproduced in parts without the written approval of the test laboratory.

7layers GmbH
Borsigstraße 11
40880 Ratingen, Germany
T +49 (0) 2102 749 0
F +49 (0) 2102 749 350

Geschäftsführer/
Managing Directors:
Sebastian Doose
Bernhard Retka

Registergericht/registered:
Düsseldorf HRB 75554
USt-Id.-Nr./VAT-No. DE203159652
Steuer-Nr./TAX-No. 147/5869/0385

a Bureau Veritas
Group Company

www.7layers.com

TABLE OF CONTENTS

1. Applied Standards and Test Summary	3
1.1. Applied Standards	3
1.2. FCC-IC Correlation table	4
1.3. Measurement Summary /Signatures	5
2. Revision History / Signatures	6
3. Administrative Data	7
3.1. Testing Laboratory	7
3.2. Project Data	7
3.3. Applicant Data	7
3.4. Manufacturer Data	7
4. Test object data	8
4.1. General EUT Description	8
4.2. EUT Main components	9
4.3. Auxiliary Equipment	9
4.4. Ancillary Equipment	9
4.5. EUT Setups	10
4.6. Operating Modes / Test Channels	10
4.7. Duty Cycle calculation	11
4.8. Product labelling	13
5. Test Results	14
5.1. Field strength of Fundamental / Radiated power output	14
5.2. Field Strength of Harmonics / Spurious radiated emissions	22
5.3. Occupied bandwidth (99 %)	36
6. Test Equipment	40
6.1. Test Equipment Hardware	40
6.2. Test Equipment Software	43
7. Antenna Factors, Cable Loss and Sample Calculations	44
7.1. LISN R&S ESH3-Z5 (150 kHz – 30 MHz)	44
7.2. Antenna R&S HFH2-Z2 (9 kHz – 30 MHz)	45
7.3. Antenna R&S HL562 (30 MHz – 1 GHz)	46
7.4. Antenna R&S HF907 (1 GHz – 18 GHz)	47
7.5. Antenna EMCO 3160-09 (18 GHz – 26.5 GHz)	48
7.6. Antenna EMCO 3160-10 (26.5 GHz – 40 GHz)	49
8. Measurement Uncertainties	50
9. Photo Report	51

1. APPLIED STANDARDS AND TEST SUMMARY

1.1. APPLIED STANDARDS

Type of Authorization

Certification for an Intentional Radiator.

Applicable FCC Rules

Prepared in accordance with the requirements of FCC Rules and Regulations as listed in 47 CFR Ch.1 Parts 2 and 15 (10-1-23 Edition). The following subparts are applicable to the results in this test report.

Part 2, Subpart J - Equipment Authorization Procedures, Certification

Part 15, Subpart C – Intentional Radiators

§ 15.201 Equipment authorization requirement

§ 15.207 Conducted limits

§ 15.209 Radiated emission limits; general requirements

§ 15.249 Operation within the bands 902-928 MHz, 2400-2483.5 MHz, 5725-5875 MHz, and 24.0-24.25 GHz.

Note:

ANSI C63.10–2020 is applied.

1.2. FCC-IC CORRELATION TABLE

**Correlation of measurement requirements for
DTS (e.g. WLAN 2.4 GHz, BT LE) equipment
from
FCC and IC**

Measurement	FCC reference	IC reference
Conducted emissions on AC Mains	§ 15.207	RSS-Gen Issue 5 & AMD 1 & AMD 2: 8.8
Transmitter spurious radiated emissions	§ 15.209	RSS-Gen Issue 5 & AMD 1 & AMD 2: 6.13 / 8.9/8.10
Field strength of Fundamental	§ 15.249	RSS-210 Issue 10: 7.2 RSS-210 Issue 10: Annex B.10
Operation within the bands 902-928 MHz, 2400-2483.5 MHz, 5725-5875 MHz, and 24.0-24.25 GHz.	§ 15.249	RSS-Gen Issue 5: 6.12, 8.9 RSS-210, Issue 10: Annex B.10

1.3. MEASUREMENT SUMMARY /SIGNATURES

47 CFR CHAPTER I FCC Part 15, § 15.207 Subpart C

Conducted emissions (AC power line)

The measurement was performed according to ANSI C63.10 chapter 6.2

Final Result

OP-Mode	Setup	Date	FCC	IC
-	-		N/A	N/A

47 CFR CHAPTER I FCC Part 15, § 15.249 (a) Subpart C

Field strength of Fundamental / Radiated power output

The measurement was performed according to ANSI C63.10 chapter 6.6.5

Final Result

OP-Mode, Frequency	Setup	Date	FCC	IC
CW and PM, low	S01_AB01	2024-06-24	passed	passed
CW and PM, mid	S01_AB01	2024-06-24	passed	passed
CW and PM, high	S01_AB01	2024-06-24	passed	passed

47 CFR CHAPTER I FCC Part 15, § 15.249 (a), § 15.35 (b), § 15.209 Subpart C

Field Strength of Harmonics / Spurious radiated emissions

The measurement was performed according to ANSI C63.10 chapter 6.3, 6.4, 6.5, 6.6.5

Final Result

OP-Mode, Frequency	Setup	Date	FCC	IC
CW and PM, low	S01_AA01; S01_AB01	2024-06-24	passed	passed
CW, mid	S01_AA01; S01_AB01	2024-06-24	passed	passed
CW, high	S01_AA01; S01_AB01	2024-06-24	passed	passed

47 CFR CHAPTER I FCC Part 2, § 2.1049 Subpart J

Occupied Bandwidth 99%

The measurement was performed according to ANSI C63.10, chapter 6.9.3

Final Result

OP-Mode, Frequency	Setup	Date	FCC	IC
PM, low	S01_AB01	2024-06-26	passed	passed
PM, mid	S01_AB01	2024-06-26	passed	passed
PM, high	S01_AB01	2024-06-26	passed	passed

N/A not applicable (the EUT cannot be connected to the AC mains network)

2. REVISION HISTORY / SIGNATURES

Report version control			
Version	Release date	Change Description	Version validity
initial	2024-10-07	--	invalid
rev1	2024-11-15	- Product description is changed - Antenna gain is changed, without a influence to the test results since all measurements are performed radiated - the chapters used of the ANSI standard are added.	invalid
rev2	2024-12-18	- Added output power diagrams with modulated signal (page 17, 19, 21) - Added BE diagram with modulated signal (page 33)	valid



(responsible for accreditation scope)
Marco Kullik



(responsible for testing and report)
Robert Machulec



7 layers GmbH, Borsigstr. 11
40880 Ratingen, Germany
Phone +49 (0)2102 749 0

3. ADMINISTRATIVE DATA

3.1. TESTING LABORATORY

Company Name: 7layers GmbH
Address: Borsigstr. 11
40880 Ratingen
Germany

The test facility is also accredited by the following accreditation organisation:

Laboratory accreditation no: DAkKS D-PL-12140-01-00
FCC Designation Number: DE0015
FCC Test Firm Registration: 929146
ISED CAB Identifier: DE0007; ISED#: 3699A

Responsible for accreditation scope: Marco Kullik

Report Template Version: 2024-10-07

3.2. PROJECT DATA

Responsible for testing and report: Robert Machulec
Employees who performed the tests: documented internally at 7Layers
Date of Report: 2024-12-18
Testing Period: 2024-06-24 to 2024-06-28

3.3. APPLICANT DATA

Company Name: Wiliot Inc.
Address: 13500 Evening Creek Dr N, Suite 120
San Diego
United States

Contact Person: Mr. Steve Statler

3.4. MANUFACTURER DATA

Company Name: please see Applicant Data
Address:
Contact Person:

4. TEST OBJECT DATA

4.1. GENERAL EUT DESCRIPTION

Kind of Device product description	BTLE Transmitter operating in 2400 – 2483.5 MHz frequency band. Wiliot ultra-thin Internet of Things (IoT) stickers are IoT systems powered by Wiliot Bluetooth® Low Energy Wireless Micro Controller Unit (MCU) that offer the ability to sense, compute and communicate using Bluetooth wireless communication technology. Thanks to the ultra-low power performance of the Wireless MCU, and their physical design and packaging, they come integrated in a sticker form factor. They operate without batteries through the energy harvesting functionality incorporated in the Wireless MCU Additional available options: An optional external capacitor for additional storage in case RF energy harvesting is used to power the system. Alternatively, the Wiliot IoT sticker is powered by an external printed battery source. An optional debug interface for in-field programing, debugging or connection to external power source
Product name	Wiliot GEN3 Hyper-thin Bluetooth IoT edge
Type	-
Declared EUT data by the supplier	
Voltage Type	DC
Normal Voltage	5.0 V (only for testing purposes)
Low Voltage	-
High Voltage	-
Normal Temperature	25 °C
Low Temperature	-40 °C
High Temperature	+85 °C
The EUT provides the following ports:	Enclosure
Special software used for testing	Wiliot Test Mode Host software, provided by the manufacturer
Antenna type / gain	Internal PCB loop antenna / -2.2 dBi

4.2. EUT MAIN COMPONENTS

Sample Name	Sample Code	Description
EUT A	DE1405005aa01	radiated sample
Sample Parameter	Value	
Serial No.	7d4	
HW Version	Wiliot Gen3 tag	
SW Version	Wiliot_FW_P5.2	
Comment	Sample without additional options	

Sample Name	Sample Code	Description
EUT B	DE1405005ab01	radiated sample
Sample Parameter	Value	
Serial No.	7cf	
HW Version	Wiliot Gen3 tag	
SW Version	Wiliot_FW_P5.2	
Comment	Sample without additional options	

NOTE: The short description is used to simplify the identification of the EUT in this test report.

4.3. AUXILIARY EQUIPMENT

For the purposes of this test report, auxiliary equipment is defined as equipment which is used temporarily to enable operational and control features especially used for the tests of the EUT which is not used during normal operation or equipment that is used during the tests in combination with the EUT but is not subject of this test report. It is necessary to configure the system in a typical fashion, as a customer would normally use it. But nevertheless Auxiliary Equipment can influence the test results.

Device	Details (Manufacturer, Type Model, OUT Code)	Reason for using
AUX1	Laptop, Dell, Latitude 7420,	Running the test SW
AUX2	AC/DC Adapter, Dell,	Power supply for laptop
AUX3	Wiliot Debug Board, Wiliot_PIB_2, 144, Wiliot, PIB 2.0, WLT_015, --	Connection to laptop, power supply
AUX4	Wiliot Debug Board, Wiliot_PIB_2, 128, Wiliot, PIB 2.0, WLT_015, --	Connection to laptop, power supply

4.4. ANCILLARY EQUIPMENT

For the purposes of this test report, ancillary equipment is defined as equipment which is used in conjunction with the EUT to provide operational and control features to the EUT. It is necessary to configure the system in a typical fashion, as a customer would normally use it. But nevertheless Ancillary Equipment can influence the test results.

Device	Details (Manufacturer, HW, SW, S/N)	Description
---	---	---

4.5. EUT SETUPS

This chapter describes the combination of EUTs and equipment used for testing. The rationale for selecting the EUTs, ancillary and auxiliary equipment and interconnecting cables, is to test a representative configuration meeting the requirements of the referenced standards.

Setup	Combination of EUTs	Description and Rationale
S01_AA01	EUT A, AUX1, AUX2, AUX3	

Setup	Combination of EUTs	Description and Rationale
S01_AB01	EUT B, AUX1, AUX2, AUX4	

4.6. OPERATING MODES / TEST CHANNELS

This chapter describes the operating modes of the EUTs used for testing.

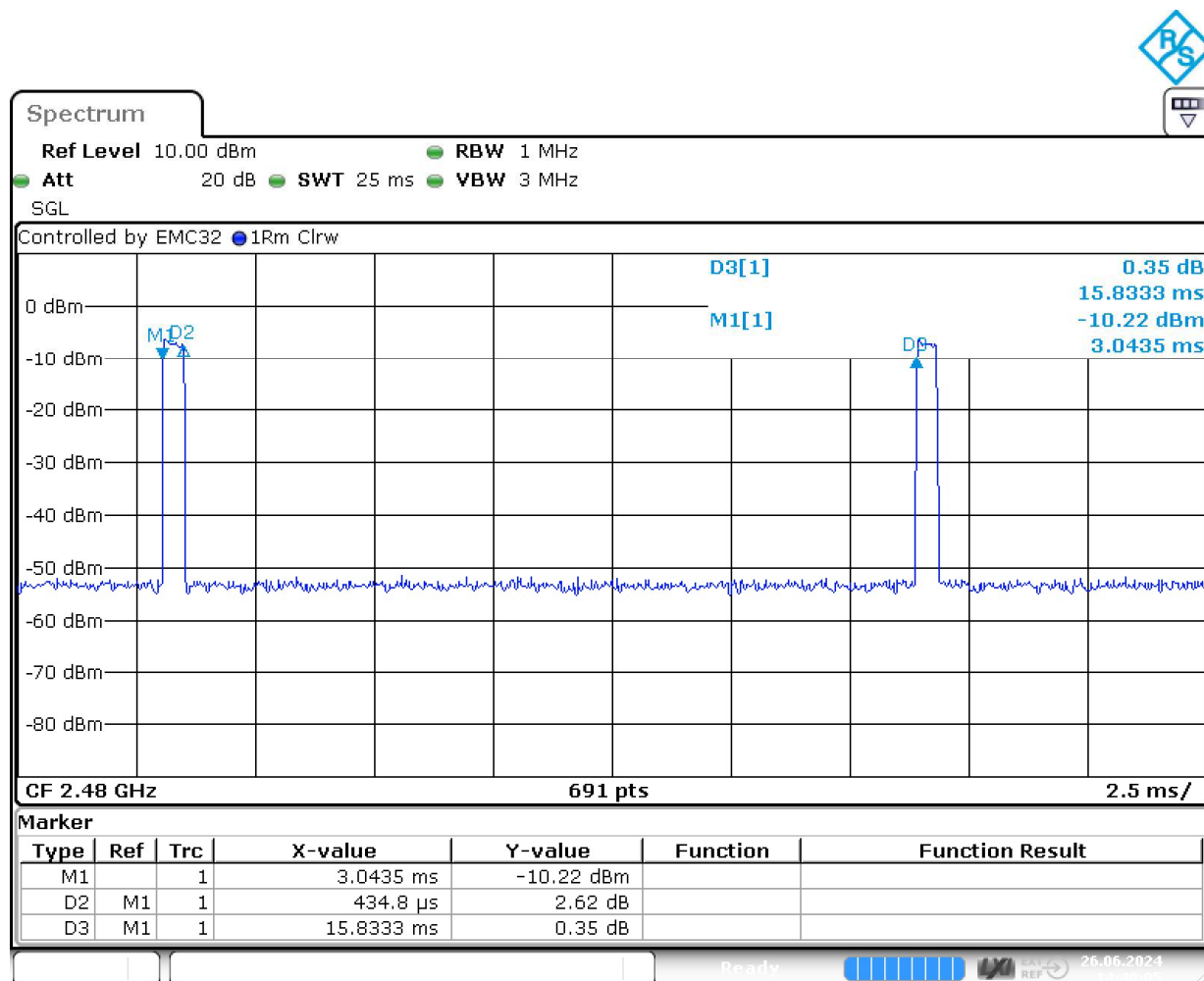
Op. Mode	Description of Operating Modes	Remarks
CW	Continuous Wave signal	EUT transmits continuously an unmodulated signal.
PM	Pulsed Modulated signal	EUT transmits a modulated signal with maximum possible duty cycle

BT LE Test Channels:
Channel:
Frequency [MHz]

low	mid	high
0	18	39
2402	2442	2480

4.7. DUTY CYCLE CALCULATION

The calculation of the duty cycle and duty cycle correction value was done according to ANSI C63.10: 2013, chapter 7.5, equation (11)

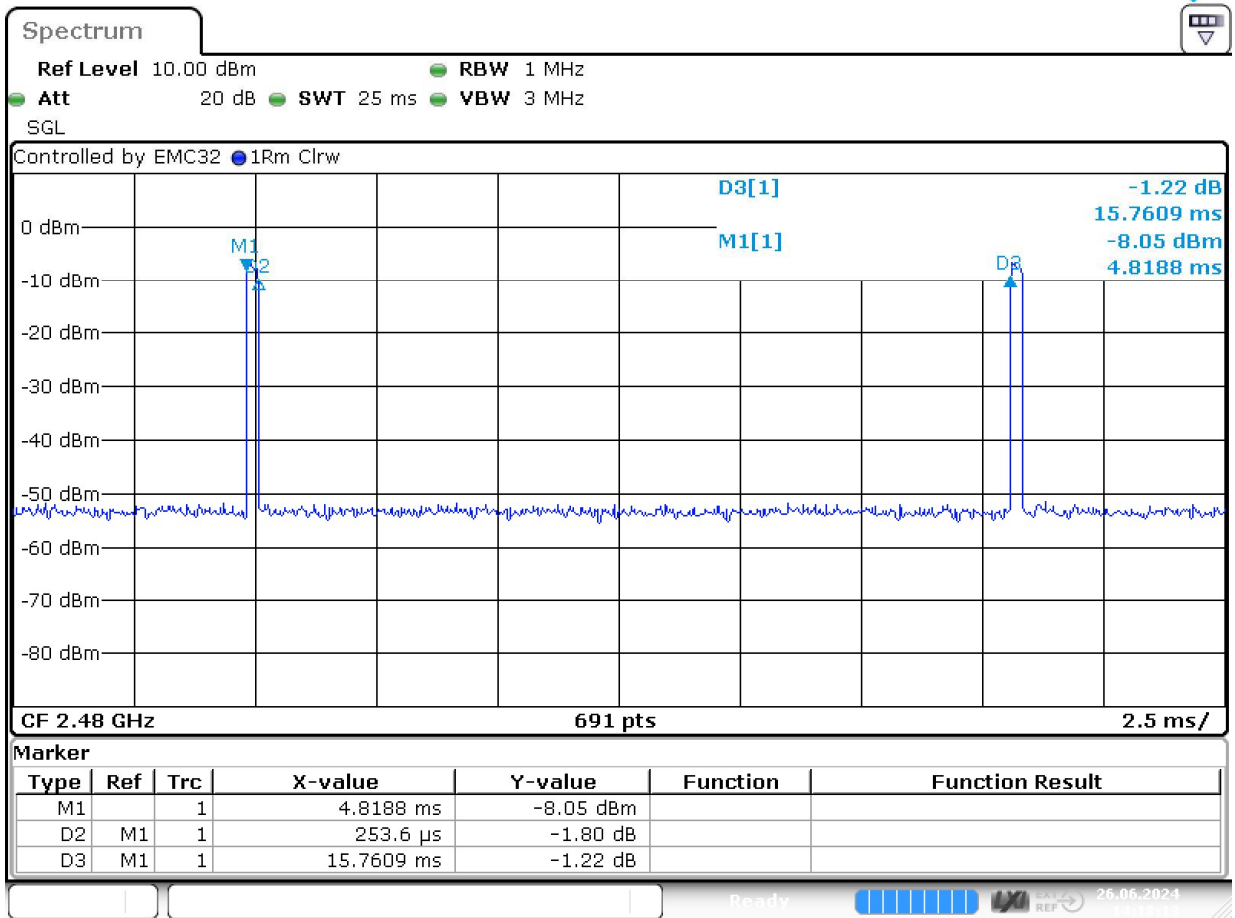


Date: 26 JUN.2024 14:40:05

Operating mode: 1Mbit

$$DC = 0.4348 \text{ ms} / 15.83 \text{ ms} = 0.027466835$$

$$\text{Duty cycle correction factor: } \delta = 20 \text{ LOG}(0.027466835) = -31.22 \text{ dB}$$



Date: 26.JUN.2024 14:18:13

Operating mode: 2Mbit

DC = 0.2536 ms / 15.7609 ms = 0.016090452

Duty cycle correction factor: $\delta = 20 \text{ LOG}(0.03997) = -35.87 \text{ dB}$

4.8. PRODUCT LABELLING

4.8.1. FCC ID LABEL

Please refer to the documentation of the applicant.

4.8.2. IC LABEL

Please refer to the documentation of the applicant.

4.8.3. LOCATION OF THE LABEL ON THE EUT

Please refer to the documentation of the applicant.

5. TEST RESULTS

5.1. FIELD STRENGTH OF FUNDAMENTAL / RADIATED POWER OUTPUT

Standard FCC Part 15, Subpart C

The test was performed according to ANSI C63.10 – chapter 6.6.5

5.1.1. TEST DESCRIPTION

Please refer to the description at sub-clause 5.2.1, especially item no. 3. (Above 1 GHz)

5.1.2. TEST REQUIREMENTS / LIMITS

FCC Part 15, Subpart C, §15.249

(a) Except as provided in paragraph (b) of this section, the field strength of emissions from intentional radiators operated within these frequency bands shall comply with the following:

Fundamental frequency	Field strength of fundamental (millivolts/meter)	Field strength of harmonics (microvolts/meter)
902-928 MHz	50 (94.0 dBμV/m)	500 (54.0 dBμV/m)
2400-2483.5 MHz	50 (94.0 dBμV/m)	500 (54.0 dBμV/m)
5725-5875 MHz	50 (94.0 dBμV/m)	500 (54.0 dBμV/m)
24.0-24.25 GHz	250 (108.0 dBμV/m)	2500 (68.0 dBμV/m)

Used conversion factor: Limit (dBμV/m) = 20 log (Limit (μV/m)/1μV/m)

(c) Field strength limits are specified at 3 meters.

(e) As shown in §15.35(b), for frequencies above 1000 MHz, the field strength limits in paragraphs (a) and (b) of this section are based on average limits. However, the peak field strength of any emission shall not exceed the maximum permitted average limits specified above by more than 20 dB under any condition of modulation.

5.1.3. TEST PROTOCOL

Temperature: 22 °C
 Air Pressure: 1007 hPa
 Humidity: 42 %

Op. Mode	Setup	Port
CW	S01_AB01	Enclosure

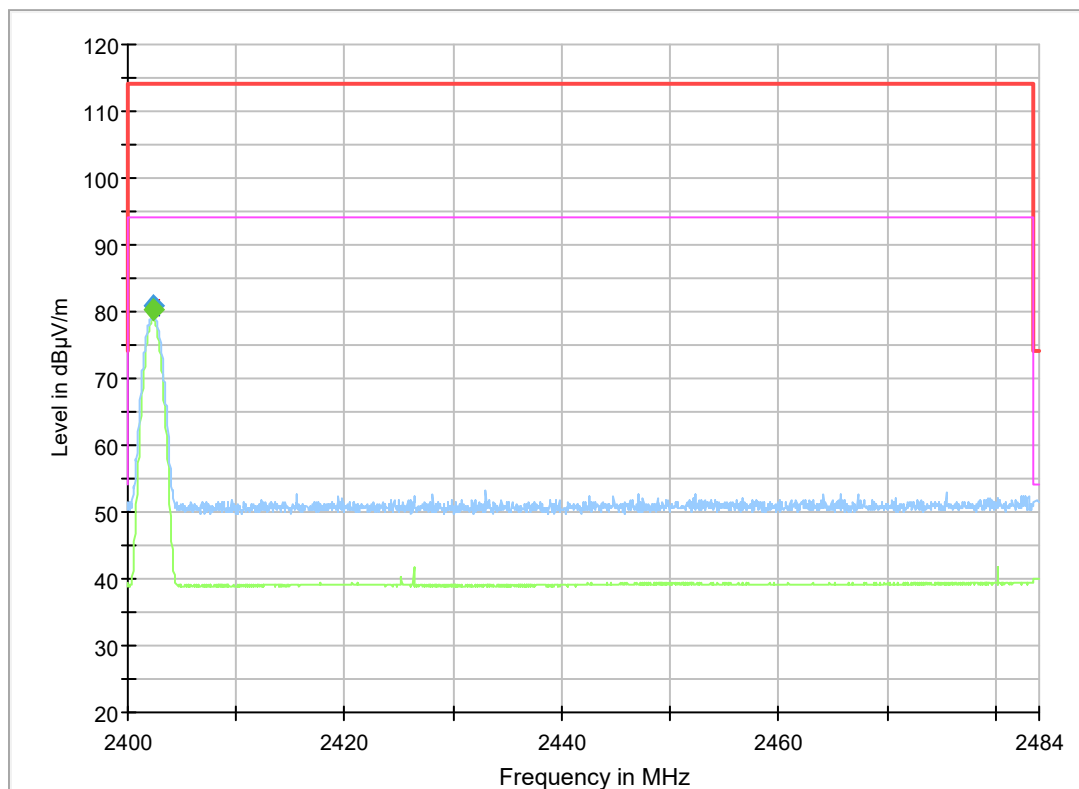
Frequency [MHz]	MaxPeak (dBμV/m)	Limit [dBμV/m]	Margin to Limit [dB]	Remarks
2402	81.0	113.98	32.97	-
2442	80.8	113.98	33.19	-
2480	81.8	113.98	32.13	-

Notes:

- No duty cycle correction applied.
- The measured values are below the AV Limit of 93.98 dBμV/m.
- Due to the low duty cycle tested in absence of modulation (CW)

5.1.4. MEASUREMENT PLOTS

Radio Technology = BTLE, Operating Frequency = Low
(S01_AB01)



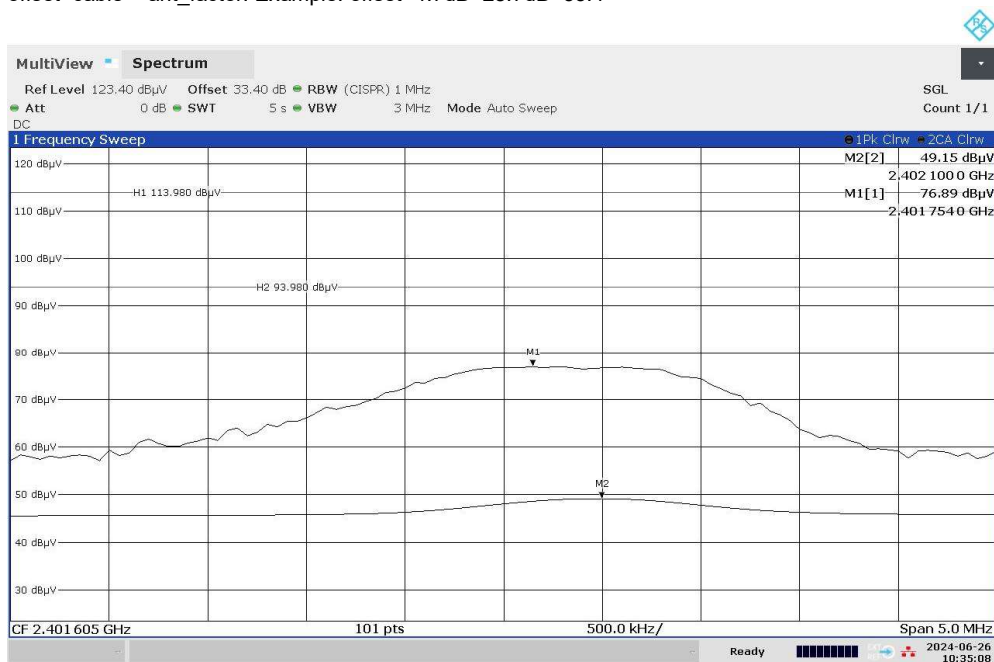
Final Result

Frequency (MHz)	MaxPeak (dBμV/m)	CAverage (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Elevation (deg)	Corr. (dB/m)
2402.296	81.0	---	113.9	32.97	1000.0	1000.000	150.0	H	-34.0	22.0	7.4



10:25:42 AM 06/26/2024

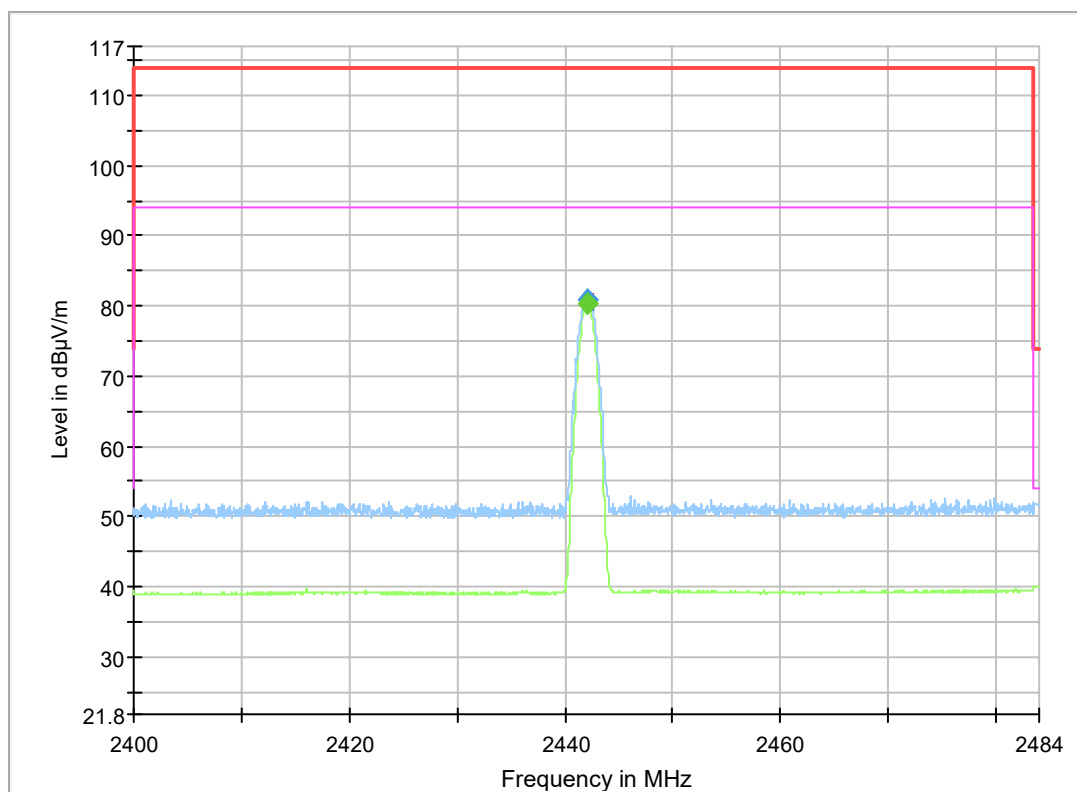
Output power measurement using PM mode. The offset in the plot is used for measurement path loss compensation.
 offset=cable + ant_factor. Example: offset=4.7dB+28.7dB=33.4



10:35:08 AM 06/26/2024

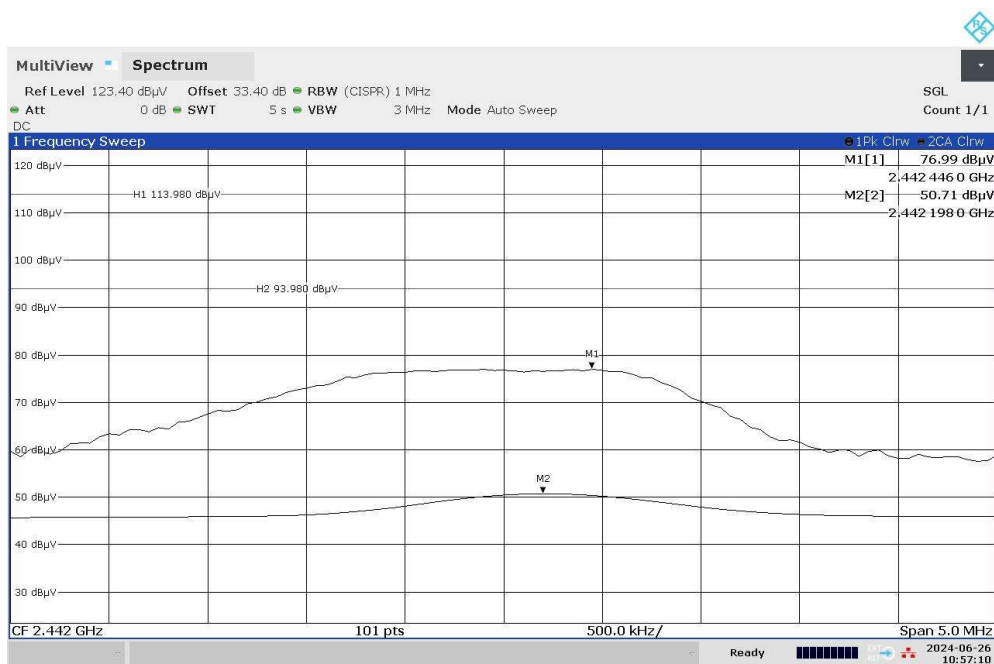
Output power measurement using PM mode. The offset in the plot is used for measurement path loss compensation.
 offset=cable + ant_factor. Example: offset=4.7dB+28.7dB=33.4

Radio Technology = BTLE, Operating Frequency = Mid
(S01_AB01)



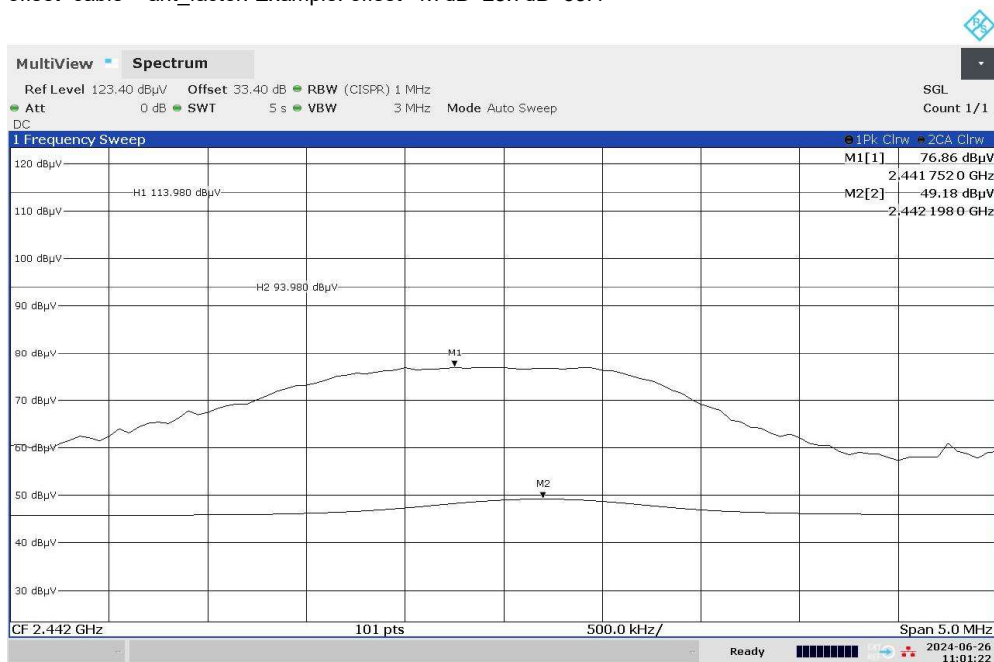
Final Result

Frequency (MHz)	MaxPeak (dBμV/m)	CAverage (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Elevation (deg)	Corr. (dB/m)
2442.084	80.8	---	113.9	33.19	1000.0	1000.000	150.0	V	-91.0	94.0	7.6



10:57:11 AM 06/26/2024

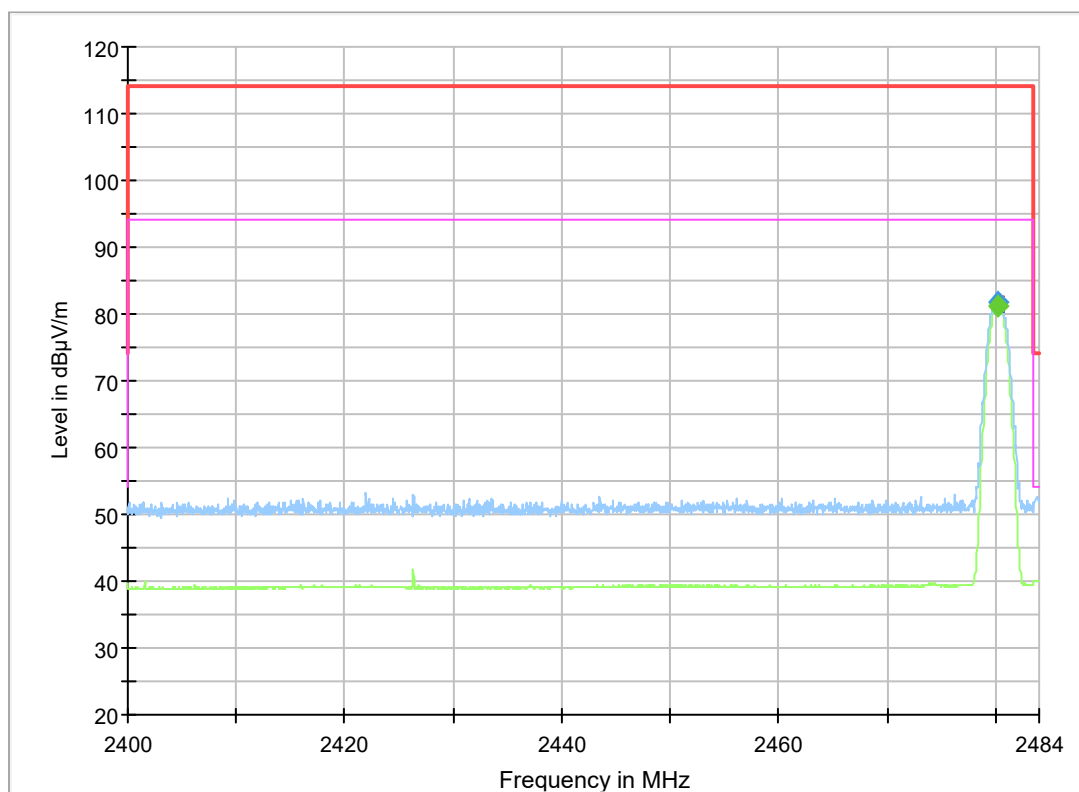
Output power measurement using PM mode. The offset in the plot is used for measurement path loss compensation
 offset=cable + ant_factor. Example: offset=4.7dB+28.7dB=33.4



11:01:23 AM 06/26/2024

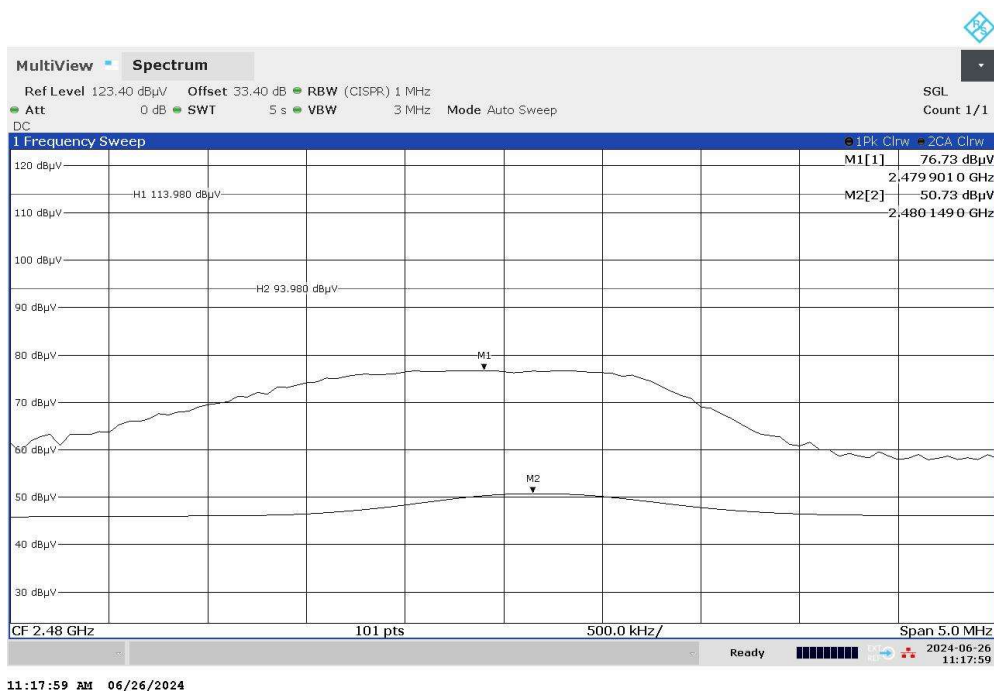
Output power measurement using PM mode. The offset in the plot is used for measurement path loss compensation
 offset=cable + ant_factor. Example: offset=4.7dB+28.7dB=33.4

Radio Technology = BTLE, Operating Frequency = High
(S01_AB01)

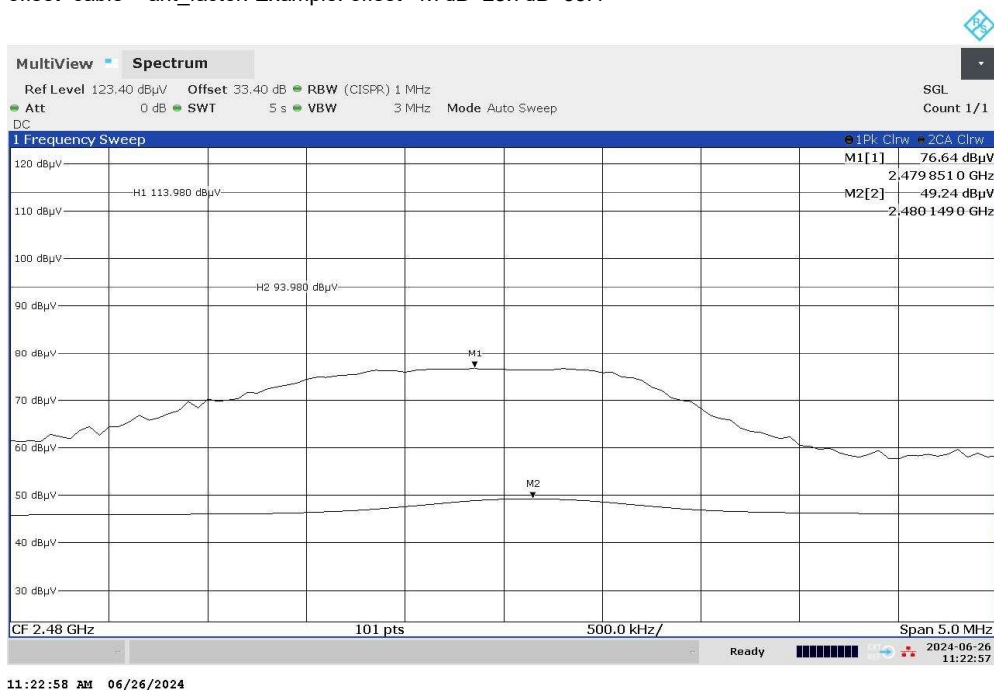


Final Result

Frequency (MHz)	MaxPeak (dBμV/m)	CAverage (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Elevation (deg)	Corr. (dB/m)
2480.118	81.8	---	113.9	32.13	1000.0	1000.000	150.0	H	-90.0	7.0	7.8



Output power measurement using PM mode. The offset in the plot is used for measurement path loss compensation
offset=cable + ant_factor. Example: offset=4.7dB+28.7dB=33.4



Output power measurement using PM mode. The offset in the plot is used for measurement path loss compensation
offset=cable + ant_factor. Example: offset=4.7dB+28.7dB=33.4

5.1.5. TEST EQUIPMENT USED

- Radiated Emissions FAR 2.4 GHz FCC

5.2. FIELD STRENGTH OF HARMONICS / SPURIOUS RADIATED EMISSIONS

Standard **FCC Part 15 Subpart C**

The test was performed according to ANSI C63.10 – chapter 6.3, 6.4, 6.5, 6.6.5

5.2.1. TEST DESCRIPTION

The test set-up was made in accordance to the general provisions of ANSI C63.10 in a typical installation configuration. The measurements were performed according the following sub-chapters of ANSI C63.10:

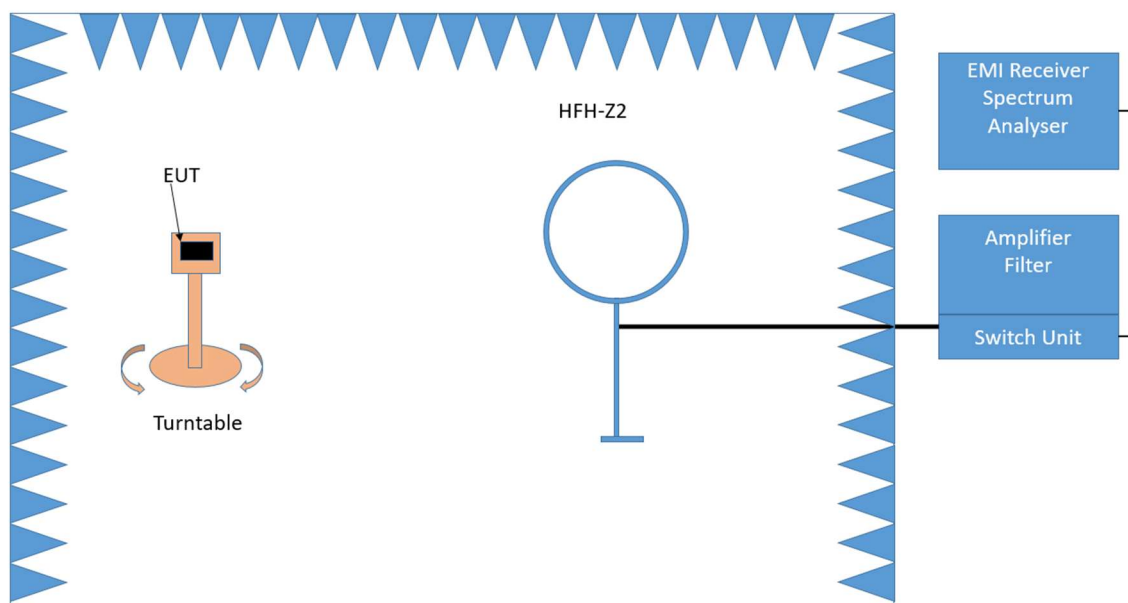
- < 30 MHz: Chapter 6.4
- 30 MHz – 1 GHz: Chapter 6.5
- > 1 GHz: Chapter 6.6 (procedure according 6.6.5 used)

The measurement procedure is implemented into the EMI test software EMC32 from R&S. Exploratory tests are performed at 3 orthogonal axes to determine the worst-case orientation of a body-worn or handheld EUT. The final test on all kind of EUTs is also performed at 3 axes. A pre-check is performed while the EUT is powered.

Below 1 GHz:

The Equipment Under Test (EUT) was set up on a non-conductive table in the semi-anechoic chamber. The influence of the EUT support table that is used between 30–1000 MHz was evaluated.

1. Measurement up to 30 MHz



Test Setup; Spurious Emission Radiated (SAC), 9 kHz – 30 MHz

The Loop antenna HFH2-Z2 is used.

Step 1: pre measurement

- Anechoic chamber
- Antenna distance: 3 m
- Antenna height: 1 m
- Detector: Peak-Maxhold
- Frequency range: 0.009 - 0.15 MHz and 0.15 - 30 MHz
- Frequency steps: 0.05 kHz and 2.25 kHz
- IF-Bandwidth: 0.2 kHz and 9 kHz
- Measuring time / Frequency step: 100 ms (FFT-based)

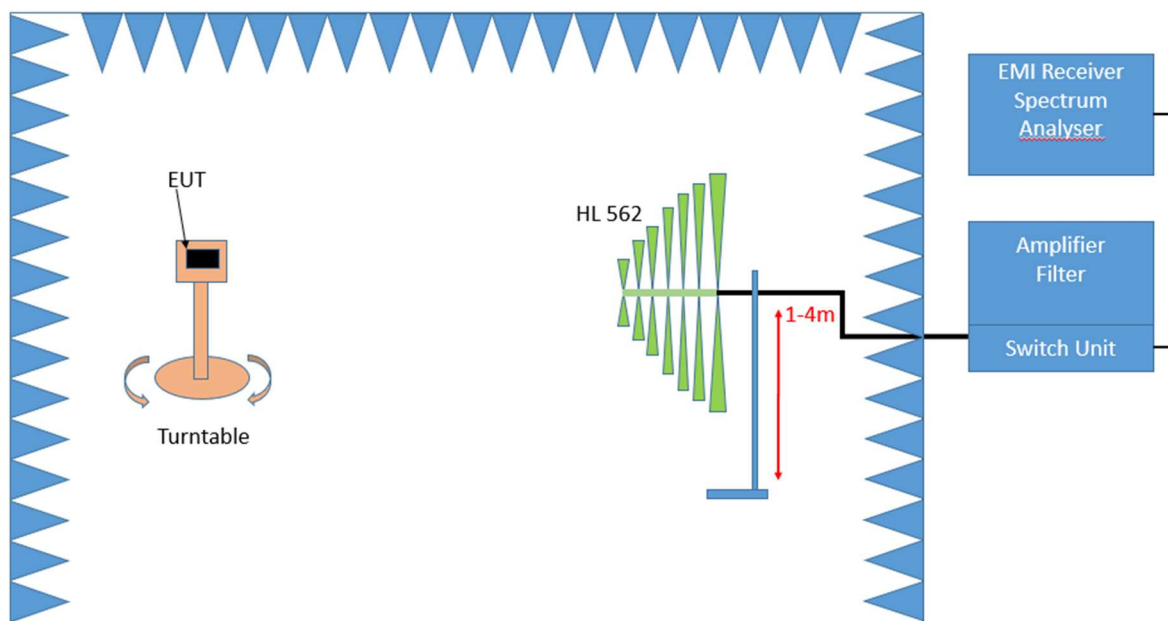
Intention of this step is, to determine the radiated EMI-profile of the EUT. Afterwards the relevant emissions for the final measurement are identified.

Step 2: final measurement

For the relevant emissions determined in step 1, an additional measurement with the following settings will be performed. Intention of this step is to find the maximum emission level.

- Detector: Quasi-Peak (9 kHz - 150 kHz, Peak / Average 150 kHz- 30 MHz)
- Frequency range: 0.009 - 30 MHz
- Frequency steps: measurement at frequencies detected in step 1
- IF-Bandwidth: 0.2 - 10 kHz
- Measuring time / Frequency step: 1 s

2. Measurement above 30 MHz and up to 1 GHz



Test Setup; Spurious Emission Radiated (SAC), 30 MHz- 1GHz

Step 1: Preliminary scan

This is a preliminary test to identify the highest amplitudes relative to the limit.

Settings for step 1:

- Antenna distance: 3 m
- Detector: Peak-Maxhold / Quasipeak (FFT-based)
- Frequency range: 30 – 1000 MHz
- Frequency steps: 30 kHz
- IF-Bandwidth: 120 kHz
- Measuring time / Frequency step: 100 ms
- Turntable angle range: -180° to 90°
- Turntable step size: 90°
- Height variation range: 1 – 4 m
- Height variation step size: 1.5 m
- Polarisation: Horizontal + Vertical

Intention of this step is, to determine the radiated EMI-profile of the EUT. Afterwards the relevant emissions for the final measurement are identified.

Step 2: Adjustment measurement

In this step the accuracy of the turntable azimuth and antenna height will be improved.

This is necessary to find out the maximum value of every frequency.

For each frequency, which was determined the turntable azimuth and antenna height will be adjusted. The turntable azimuth will slowly vary by 360° . During this action, the value of emission is continuously measured. The turntable azimuth at the highest emission will be recorded and adjusted. In this position, the antenna height will also slowly vary between 1 – 4 m. During this action, the value of emission is also continuously measured. The antenna height of the highest emission will also be recorded and adjusted.

- Detector: Peak – Maxhold
- Measured frequencies: in step 1 determined frequencies
- IF – Bandwidth: 120 kHz
- Measuring time: 100 ms
- Turntable angle range: 360°
- Height variation range: 1 – 4 m
- Antenna Polarisation: max. value determined in step 1

Step 3: Final measurement with QP detector

With the settings determined in step 2, the final measurement will be performed:

EMI receiver settings for step 3:

- Detector: Quasi-Peak (< 1 GHz)
- Measured frequencies: in step 1 determined frequencies
- IF – Bandwidth: 120 kHz
- Measuring time: 1 s

After the measurement a plot will be generated which contains a diagram with the results of the preliminary scan and a chart with the frequencies and values of the results of the final measurement.

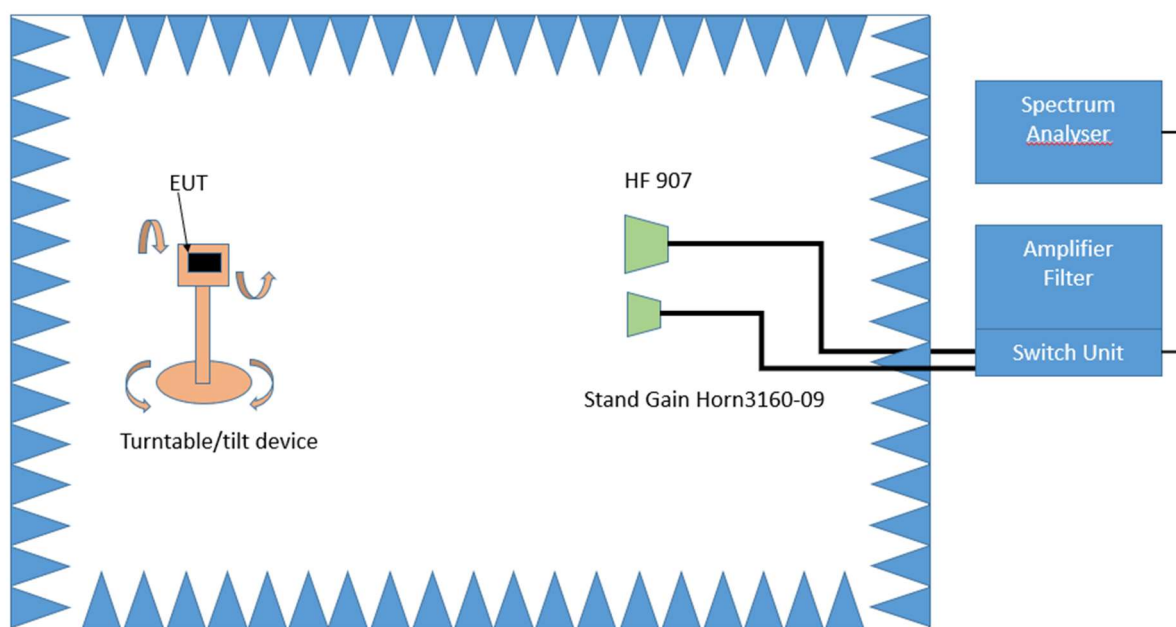
Above 1 GHz:

The following changes apply to the measurement procedure for the frequency range above 1 GHz:

The Equipment Under Test (EUT) was set up on a non-conductive support (tilt device) at 1.5 m height in the fully-anechoic chamber.

All steps were performed with one height (1.5 m) of the receiving antenna only.

3. Measurement above 1 GHz



Test Setup; Spurious Emission Radiated (FAC), 1 GHz-26.5 GHz

Step 1:

The EUT is turned during the preliminary measurement across the elevation axis, with a step size of 90 °.

The turn table step size (azimuth angle) for the preliminary measurement is 45 °.

Spectrum analyser settings:

- Detector: Peak, Average
- RBW = 1 MHz
- VBW = 3 MHz

Step 2:

The turn table azimuth will slowly vary by $\pm 22.5^\circ$.

The elevation angle will slowly vary by $\pm 45^\circ$

Spectrum analyser settings:

- Detector: Peak

Step 3:

Spectrum analyser settings for step 3:

- Detector: Peak / CISPR Average
- Measured frequencies: in step 1 determined frequencies
- RBW = 1 MHz
- VBW = 3 MHz
- Measuring time: 1 s

5.2.2. TEST REQUIREMENTS / LIMITS

FCC Part 15, Subpart C, §15.249

(a) Except as provided in paragraph (b) of this section, the field strength of emissions from intentional radiators operated within these frequency bands shall comply with the following:

Fundamental frequency	Field strength of fundamental (millivolts/meter)	Field strength of harmonics (microvolts/meter)
902-928 MHz	50 (94.0 dBμV/m)	500 (54.0 dBμV/m)
2400-2483.5 MHz	50 (94.0 dBμV/m)	500 (54.0 dBμV/m)
5725-5875 MHz	50 (94.0 dBμV/m)	500 (54.0 dBμV/m)
24.0-24.25 GHz	250 (108.0 dBμV/m)	2500 (68.0 dBμV/m)

Used conversion factor: Limit (dBμV/m) = 20 log (Limit (μV/m)/1μV/m)

(c) Field strength limits are specified at a distance of 3 meters.

(d) Emissions radiated outside of the specified frequency bands, except for harmonics, shall be attenuated by at least 50 dB below the level of the fundamental or to the general radiated emission limits in §15.209, whichever is the lesser attenuation.

(e) As shown in §15.35(b), for frequencies above 1000 MHz, the field strength limits in paragraphs (a) and (b) of this section are based on average limits. However, the peak field strength of any emission shall not exceed the maximum permitted average limits specified above by more than 20 dB under any condition of modulation.

FCC Part 15, Subpart C, §15.209, Radiated Emission Limits

Frequency (MHz)	Limit (μV/m)	Measurement distance (m)	Calculate Limit (dBμV/m @10m)	Limit (dBμV/m) @10m
0.009 – 0.49	2400/F (kHz)	300	(48.5 – 13.8) + 59.1 dB	107.6 – 72.9
0.49 – 1.705	24000/F (kHz)	30	(33.8 – 23.0) + 19.1 dB	52.9 – 42.1
1.705 – 30	30	30	29.5 + 19.1 dB	39.5

Frequency in MHz	Limit (μV/m)	Measurement distance (m)	Limit (dBμV/m)
30 – 88	100	3	40.0
88 – 216	150	3	43.5
216 – 960	200	3	46.0
above 960	500	3	54.0

§15.35(b)

..., there is also a limit on the radio frequency emissions, as measured using instrumentation with a peak detector function, corresponding to 20 dB above the maximum permitted average limit....

Used conversion factor: Limit (dBμV/m) = 20 log (Limit (μV/m)/1μV/m)

§15.35(b) ..., there is also a limit on the radio frequency emissions, as measured using instrumentation with a peak detector function, corresponding to 20 dB above the maximum permitted average limit ...

Used conversion factor: Limit (dBµV/m) = 20 log (Limit (µV/m)/1µV/m)

§15.35(c):

[...] when the radiated emission limits are expressed in terms of the average value of the emission, and pulsed operation is employed, the measurement field strength shall be determined by averaging over one complete pulse train, including blanking intervals, as long as the pulse train does not exceed 0.1 seconds.

As an alternative (provided the transmitter operates for longer than 0.1 seconds) or in cases where the pulse train exceeds 0.1 seconds, the measured field strength shall be determined from the average absolute voltage during a 0.1 second interval during which the field strength is at its maximum value. The exact method of calculating the average field strength shall be submitted [...].

5.2.3. TEST PROTOCOL

MEASUREMENT 9 kHz to 30 MHz

Temperature: 22 °C
 Air Pressure: 1007 hPa
 Humidity: 42 %

Op. Mode	Setup	Port
CW	S01_AA01	Enclosure

Measuring Antenna Polarisation	Spurious Emission Frequency [MHz]	Corrected value [dBµV/m]			Limit [dBµV/m]		Limit [dBµV/m]	Margin to limit [dB]	Margin to limit [dB]
		QP	Peak	AV	QP	Peak	AV	QP/Peak	AV
X-axis*	---	---	---	---	---	---	---	---	---
Y-axis*	---	---	---	---	---	---	---	---	---
Z-axis*	---	---	---	---	---	---	---	---	---

Remark:

- In step 1 no spurious emissions in the range 20 dB below the limit found.
- Due to the low duty cycle tested in absence of modulation (CW)

* See CISPR16-1-4 for the definition of the axis

MEASUREMENT 30 MHz to 1 GHz

Temperature: 22 °C
Air Pressure: 1007 hPa
Humidity: 42 %

Op. Mode	Setup	Port
CW	S01_AA01	Enclosure

Low channel:

Frequency (MHz)	QuasiPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
38.310000	39.71	40.00	0.29	1000.0	120.000	103.0	V	50.0	14.7
84.000000	37.23	40.00	2.77	1000.0	120.000	110.0	V	168.0	10.4
96.000000	37.19	43.50	6.31	1000.0	120.000	118.0	V	169.0	11.1
132.000000	27.37	43.50	16.13	1000.0	120.000	117.0	V	-11.0	11.0
216.000000	29.82	43.50	13.68	1000.0	120.000	189.0	V	2.0	11.6
276.000000	28.13	46.00	17.87	1000.0	120.000	142.0	V	-172.0	13.6
839.430000	20.14	46.00	25.86	1000.0	120.000	302.0	V	-54.0	26.7

Mid channel:

Frequency (MHz)	QuasiPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
38.250000	37.93	40.00	2.07	1000.0	120.000	121.0	V	82.0	14.7
46.200000	31.32	40.00	8.68	1000.0	120.000	122.0	V	73.0	9.5
48.000000	28.67	40.00	11.33	1000.0	120.000	123.0	V	108.0	8.3
84.000000	36.87	40.00	3.13	1000.0	120.000	144.0	V	220.0	10.4
96.000000	34.68	43.50	8.82	1000.0	120.000	218.0	V	179.0	11.1
192.000000	25.47	43.50	18.03	1000.0	120.000	263.0	V	131.0	10.1
264.000000	19.87	46.00	26.13	1000.0	120.000	400.0	H	125.0	13.2
422.160000	17.29	46.00	28.71	1000.0	120.000	104.0	V	169.0	18.5

High channel:

Frequency (MHz)	QuasiPeak (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
38.250000	38.33	40.00	1.67	1000.0	120.000	106.0	V	58.0	14.7
84.000000	36.86	40.00	3.14	1000.0	120.000	152.0	V	-162.0	10.4
96.000000	35.56	43.50	7.94	1000.0	120.000	149.0	V	-168.0	11.1
173.670000	27.70	43.50	15.80	1000.0	120.000	151.0	V	-173.0	10.2
240.030000	29.90	46.00	16.10	1000.0	120.000	133.0	V	14.0	12.3
422.370000	16.53	46.00	29.47	1000.0	120.000	113.0	V	-58.0	18.5

Remark:

- Due to the low duty cycle tested in absence of modulation (CW)

MEASUREMENT 1 GHz – 26.5 GHz

Temperature: 22 °C
Air Pressure: 1007 hPa
Humidity: 42 %

Op. Mode	Setup	Port
CW	S01_AB01	Enclosure

Low channel:

Frequency (MHz)	MaxPeak (dBμV/m)	CAverage (dBμV/m)	Limit (dBμV/)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Pol	Azimuth (deg)	Elevation (deg)	Corr. (dB/m)
1732.200	---	35.2	53.98	18.74	1000.0	1000.000	V	-146.0	18.0	5.5
1732.550	49.8	---	73.98	24.14	1000.0	1000.000	V	-140.0	1.0	5.5
2402.296	81.0	---	113.98	32.97	1000.0	1000.000	H	-34.0	22.0	7.4
2402.296	---	80.4	93.98	13.53	1000.0	1000.000	H	-34.0	22.0	7.4
4804.800	61.6	---	73.98	12.41	1000.0	1000.000	V	-34.0	68.0	6.1
4804.800	---	27.08 (*)	53.98	26.9	1000.0	1000.000	V	-36.0	72.0	6.1
7207.167	59.6	---	73.98	14.40	1000.0	1000.000	H	-172.0	-6.0	-12.9
7207.167	---	25.18 (*)	53.98	28.8	1000.0	1000.000	H	-186.0	72.0	-12.9
12012.333	---	51.2	53.98	2.77	1000.0	1000.000	H	-169.0	72.0	-6.0
12012.333	56.3	---	73.99	17.73	1000.0	1000.000	H	-169.0	72.0	-6.0

Mid channel:

Frequency (MHz)	MaxPeak (dBμV/m)	CAverage (dBμV/m)	Limit (dBμV/)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Pol	Azimuth (deg)	Elevation (deg)	Corr. (dB/m)
2442.084	---	80.5	93.98	13.53	1000.0	1000.000	V	-90.0	93.0	7.6
2442.084	80.8	---	113.98	33.19	1000.0	1000.000	V	-91.0	94.0	7.6
4884.000	---	28.98 (*)	53.98	25.0	1000.0	1000.000	V	-6.0	72.0	5.9
4884.000	63.1	---	73.98	10.88	1000.0	1000.000	V	-7.0	68.0	5.9
7325.967	59.6	---	73.98	14.35	1000.0	1000.000	H	-171.0	88.0	-13.4
7325.967	---	24.98 (*)	53.98	29.0	1000.0	1000.000	H	-178.0	87.0	-13.4
12209.967	---	51.4	53.98	2.63	1000.0	1000.000	H	-184.0	72.0	-5.6
12209.967	57.3	---	73.99	16.64	1000.0	1000.000	H	-180.0	68.0	-5.6

High channel:

Frequency (MHz)	MaxPeak (dBμV/m)	CAverage (dBμV/m)	Limit (dBμV/)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Pol	Azimuth (deg)	Elevation (deg)	Corr. (dB/m)
2480.118	---	81.3	93.98	12.66	1000.0	1000.000	H	-91.0	3.0	7.8
2480.118	81.8	---	113.98	32.13	1000.0	1000.000	H	-90.0	7.0	7.8
4960.800	---	27.68 (*)	53.98	26.3	1000.0	1000.000	V	90.0	87.0	5.9
4960.800	62.2	---	73.98	11.78	1000.0	1000.000	V	90.0	89.0	5.9
7440.000	---	26.28 (*)	53.98	27.7	1000.0	1000.000	H	-169.0	5.0	-12.1
7440.000	60.1	---	73.98	13.92	1000.0	1000.000	H	-169.0	0.0	-12.1
12401.367	---	53.7	53.98	0.28	1000.0	1000.000	H	-184.0	68.0	-4.8
12401.367	58.1	---	73.99	15.93	1000.0	1000.000	H	-180.0	68.0	-4.8

Remark:

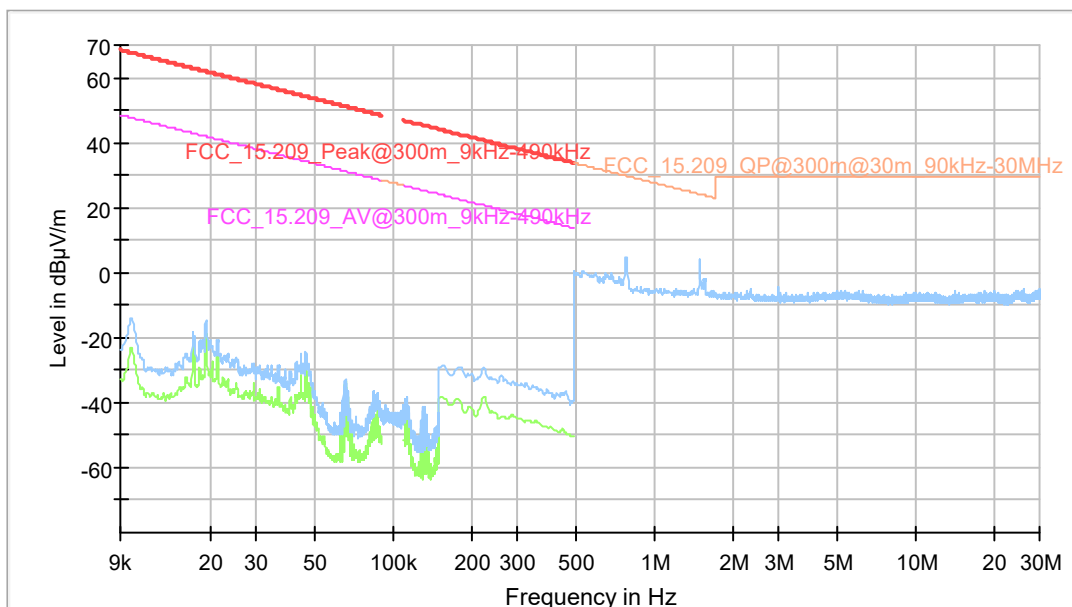
- Due to the low duty cycle tested in absence of modulation (CW)

The average value has only been calculated for values, where the measured Max Peak value is above the average limit

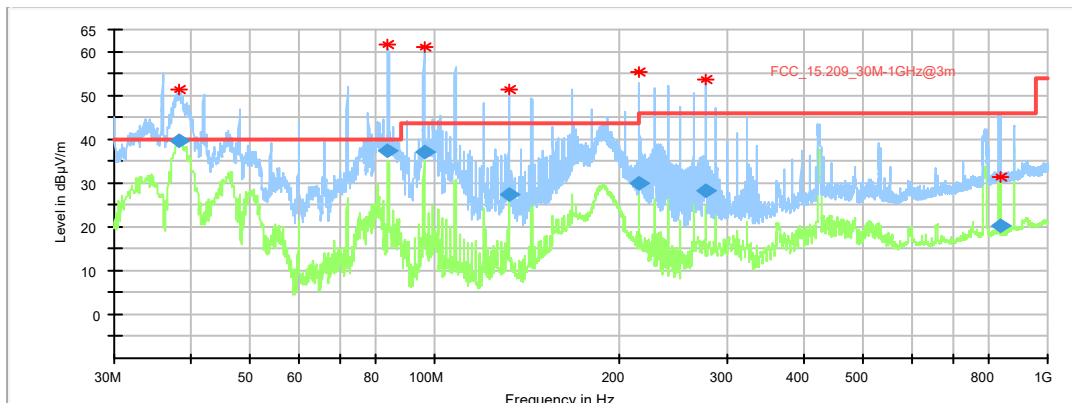
(*) calculated according ANSI C63.10: chapter 7.5, equation (11), with a duty cycle correction factor: $\delta = -31.22$ (calculation see chapter 4.7)

5.2.4. MEASUREMENT PLOTS

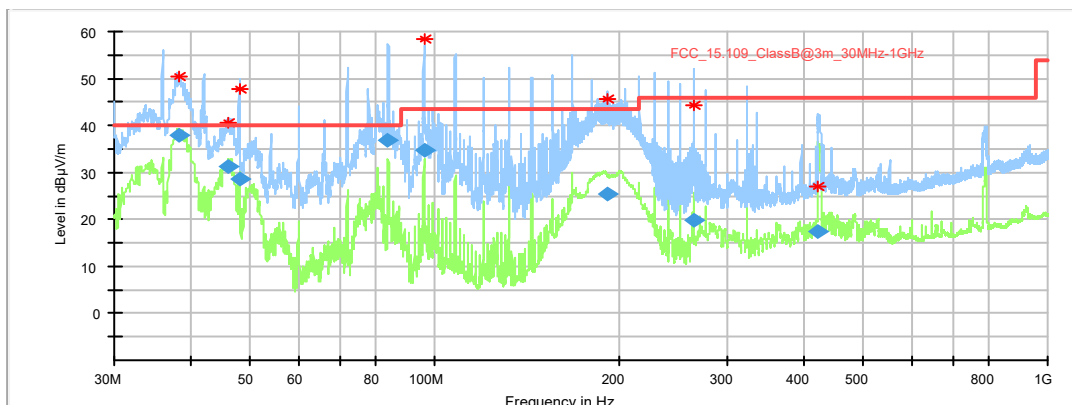
Radio Technology = BTLE, Operating Frequency = Mid, Frequency Range 9 kHz – 30 MHz
(S01_AA01)



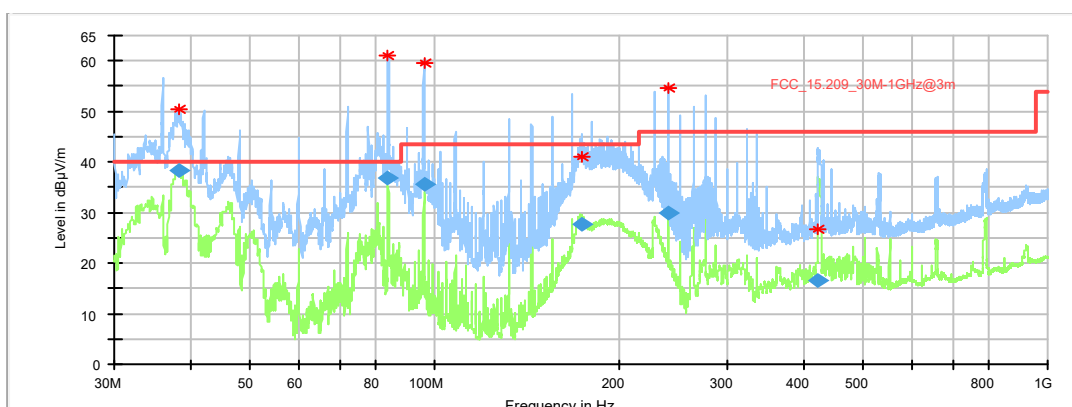
Radio Technology = BTLE, Operating Frequency = Low, Frequency Range 30 MHz – 1 GHz
(S01_AA01)



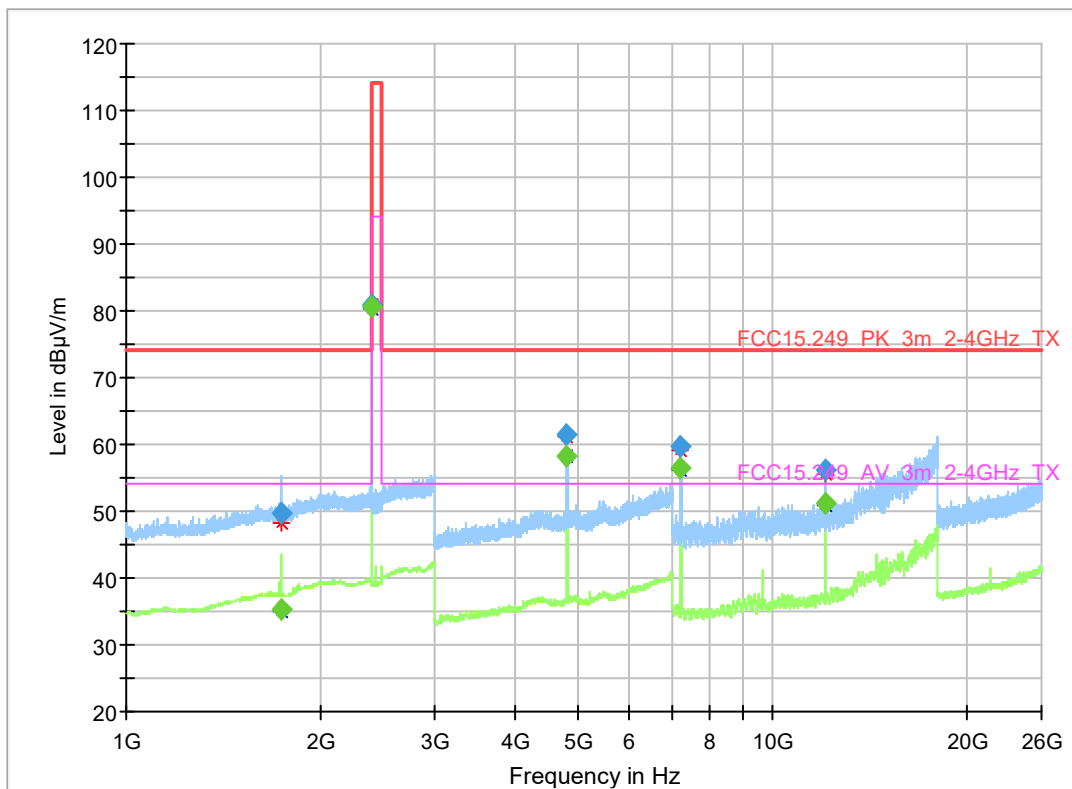
Radio Technology = BTLE, Operating Frequency = Mid, Frequency Range 30 MHz – 1 GHz
(S01_AA01)

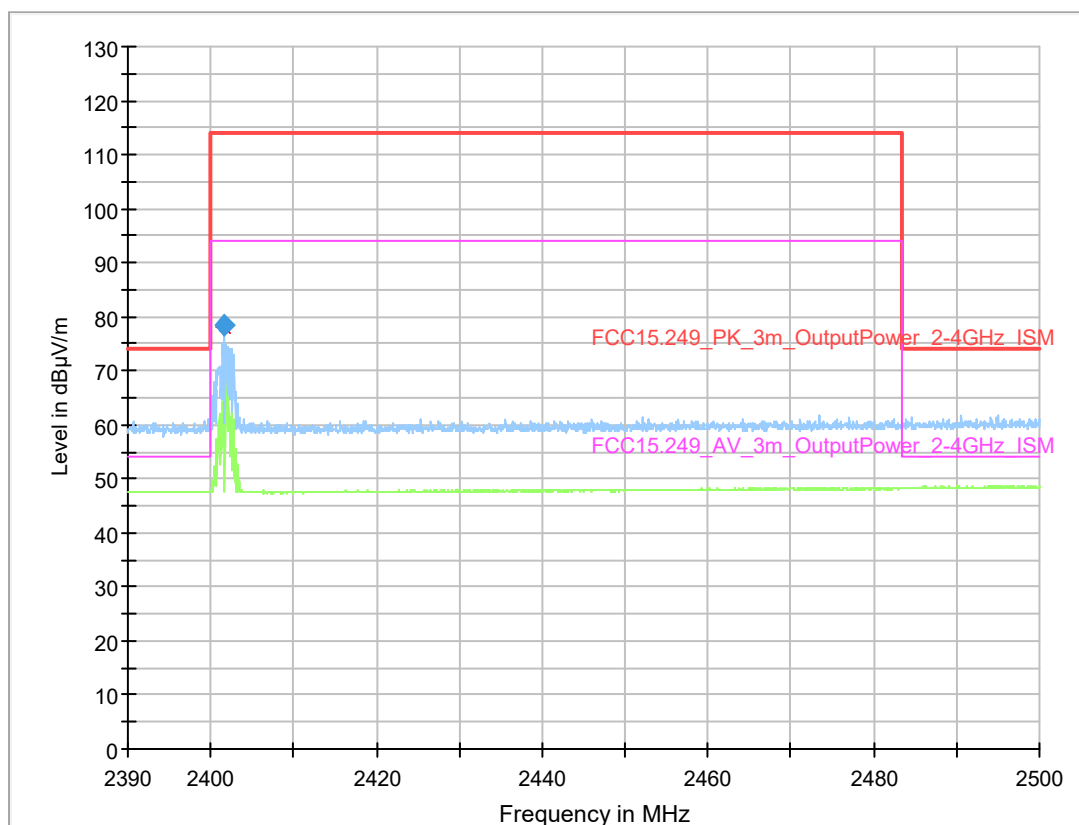


Radio Technology = BTLE, Operating Frequency = High, Frequency Range 30 MHz – 1 GHz
(S01_AA01)



Radio Technology = BTLE, Operating Frequency = Low, Frequency Range 1 - 24.5 GHz
(S01_AB01)

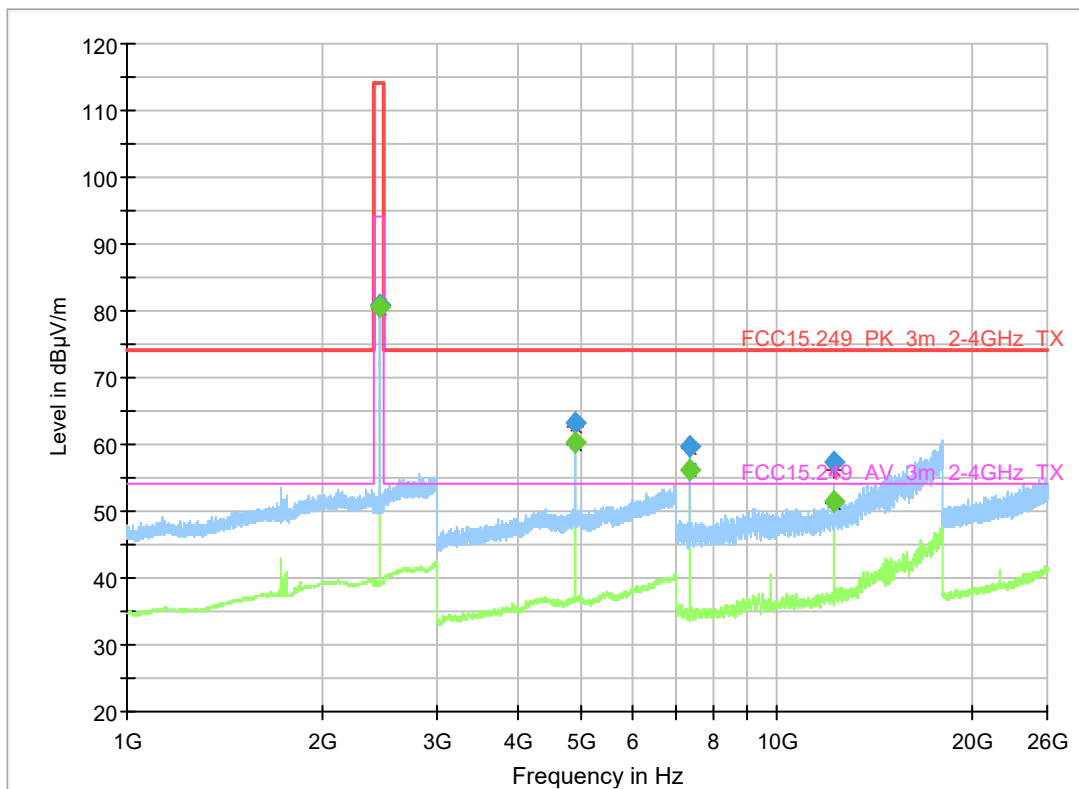




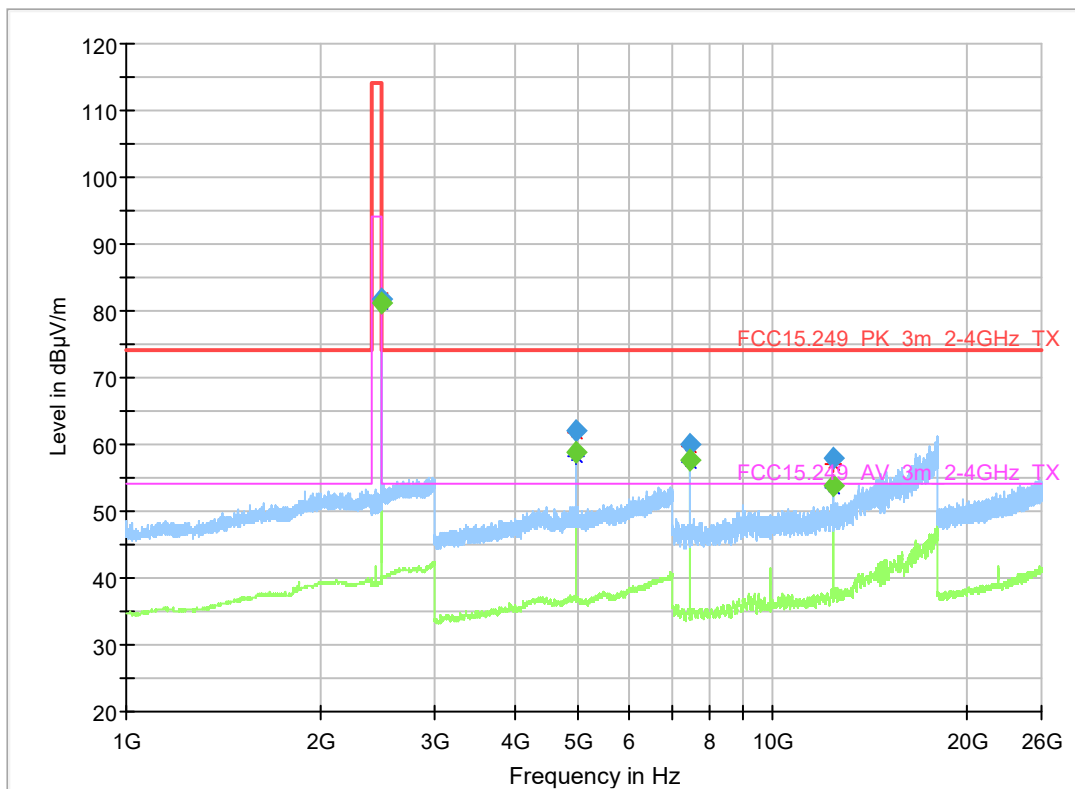
Frequency (MHz)	MaxPeak (dB μ V/m)	CAverage (dB μ V/m)	Limit (dB μ V/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Elevation (deg)	Corr. (dB/m)
2401.605	78.4	---	113.9	35.61	1000.0	1000.000	150.0	H	-31.0	11.0	33.4

Measurement plot using PM to show compliance at the band edge

Radio Technology = BTLE, Operating Frequency = Mid, Frequency Range 1 – 24.5 GHz
(S01_AB01)



Radio Technology = BTLE, Operating Frequency = High, Frequency Range 1 – 26.0 GHz
(S01_AB01)



5.2.5. TEST EQUIPMENT USED

- Radiated Emissions SAC H-Field
- Radiated Emissions SAC up to 1 GHz
- Radiated Emissions FAR 2.4 GHz FCC

5.3. OCCUPIED BANDWIDTH (99 %)

Standard **FCC Part 15 Subpart C**

The test was performed according to ANSI C63.10 – chapter 6.9.3

5.3.1. TEST DESCRIPTION

The Equipment Under Test (EUT) was set up to perform the occupied bandwidth measurements.

The reference level is the level of the highest amplitude signal observed from the transmitter at either the fundamental frequency or first-order modulation products in all typical modes of operation, including the unmodulated carrier, even if atypical.

The EUT was connected to the spectrum analyser via a broadband antenna. The complete setup and the broadband antenna were located in a shielded box

Analyser settings:

- Resolution Bandwidth (RBW): 1 to 5 % of the OBW
- Video Bandwidth (VBW): ≥ 3 times the RBW
- Span: 1.5 to 5 times the OBW
- Trace: Maxhold
- Sweeps: Till stable
- Sweep time: 5 ms
- Detector: Peak

5.3.2. TEST REQUIREMENTS / LIMITS

No applicable limit.

5.3.3. TEST PROTOCOL

Temperature: 23 °C
 Air Pressure: 1011 hPa
 Humidity: 40 %

Op. Mode	Setup	Port
PM	S01_AB01	Enclosure

Frequency [MHz]	99 % OBW [MHz]	Limit [MHz]	Margin to Limit [MHz]	Remarks
2402	1.302	-	-	1 Mbps
2442	1.408	-	-	1 Mbps
2480	1.448	-	-	1 Mbps
2402	1.665	-	-	2 Mbps
2442	1.813	-	-	2 Mbps
2480	1.780	-	-	2 Mbps

Remark:

- Please see the measurement plots.

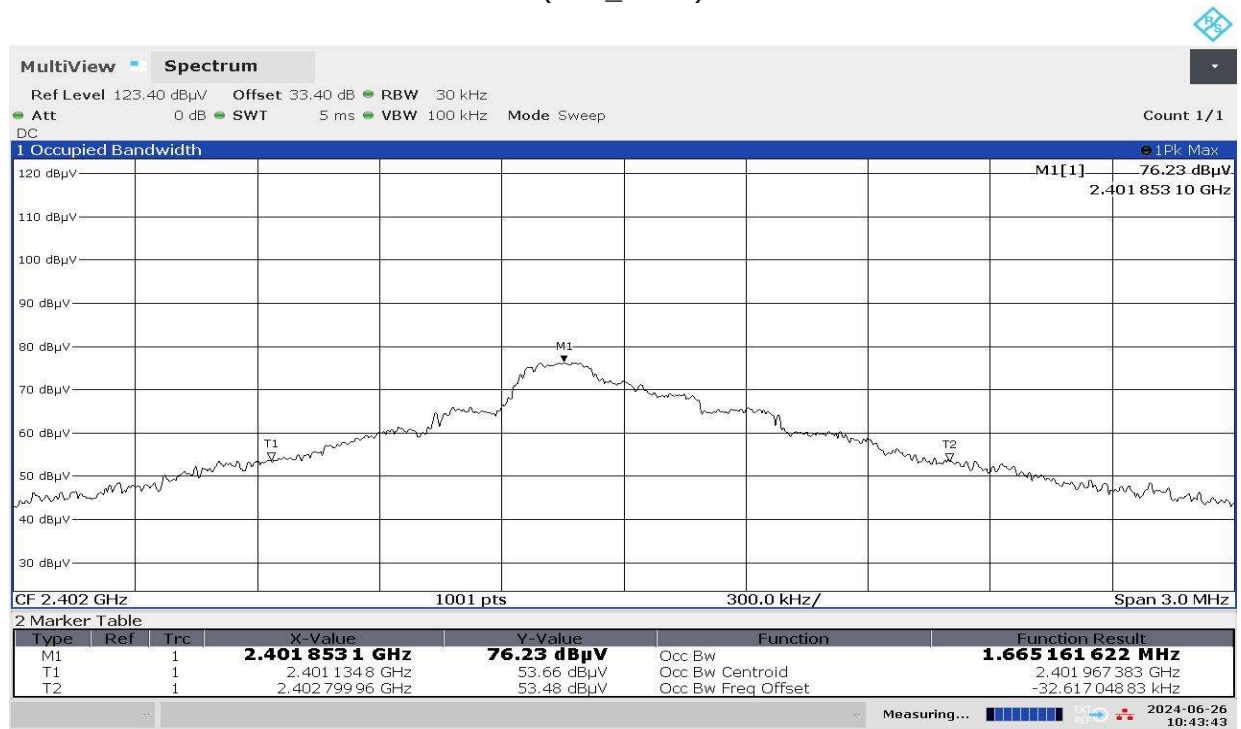
5.3.4. MEASUREMENT PLOTS

Radio Technology = BTLE, Operating Frequency = Low, 1 Mbps
(S01_AB01)



10:49:04 AM 06/26/2024

Radio Technology = BTLE, Operating Frequency = Low, 2 Mbps
(S01_AB01)



10:43:43 AM 06/26/2024

Radio Technology = BTLE, Operating Frequency = Mid, 1 Mbps
(S01_AB01)



Radio Technology = BTLE, Operating Frequency = Mid, 2 Mbps
(S01_AB01)



Radio Technology = BTLE, Operating Frequency = High; 1 Mbps
(S01_AB01)



11:20:07 AM 06/26/2024

Radio Technology = BTLE, Operating Frequency = High; 2 Mbps
(S01_AB01)



11:26:01 AM 06/26/2024

5.3.5. TEST EQUIPMENT USED

- Radiated Emissions FAR 2.4 GHz FCC

6. TEST EQUIPMENT

6.1. TEST EQUIPMENT HARDWARE

- 1 Radiated Emissions FAR 2.4 GHz FCC
Radiated emission tests for 2.4 GHz ISM devices in a fully anechoic room

Ref.No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
1.1	Opus10 TPR (8253.00)	T/P Logger 13	Lufft Mess- und Regeltechnik GmbH	13936	2023-12	2025-12
1.2	Innco Systems CO3000	Controller for bore sight mast FAC	innco systems GmbH	CO3000/1460/54740522/P	N/A	N/A
1.3	AMF-7D00101800-30-10P-R	Broadband Amplifier 100 MHz - 18 GHz	Miteq		N/A	N/A
1.4	Anechoic Chamber 03	FAR, 8.80m x 4.60m x 4.05m (l x w x h)	Albatross Projects	P26971-647-001-PRB	N/A	N/A
1.5	Fluke 177	Digital Multimeter 03 (Multimeter)	Fluke Europe B.V.	86670383	2023-08	2025-08
1.6	JS4-18002600-32-5P	Broadband Amplifier 18 GHz - 26 GHz	Miteq	849785	N/A	N/A
1.7	FSW43	Spectrum Analyzer	Rohde & Schwarz GmbH & Co. KG	103779	2023-04	2025-04
1.8	EP 1200/B, NA/B1	AC Source, Amplifier with integrated variable Oscillator	Spitzenberger & Spies GmbH & Co. KG	B6278	N/A	N/A
1.9	3160-09	Standard Gain / Pyramidal Horn Antenna 26.5 GHz	EMCO Elektronik GmbH	00083069	N/A	N/A
1.10	WHKX 7.0/18G-8SS	High Pass Filter	Wainwright Instruments GmbH	09	N/A	N/A
1.11	MA3000/0800-XP-ET-compact	Bore Sight Antenna Mast	innco systems GmbH	9210522	N/A	N/A
1.12	TT 1.5 WI	Turn Table	Maturo GmbH	-	N/A	N/A
1.13	5HC3500/18000-1.2-KK	High Pass Filter	Trilithic	200035008	N/A	N/A
1.14	Opus 20 THI (8120.00)	ThermoHygro Datalogger	Lufft Mess- und Regeltechnik GmbH	115.0318.0802.033	2023-08	2025-08
1.15	TD1.5-10kg	EUT Tilt Device (Rohacell)	Maturo GmbH	TD1.5-10kg/024/3790709	N/A	N/A
1.16	AFS42-00101800-25-S-42	Broadband Amplifier 25 MHz - 18 GHz	Miteq	2035324	N/A	N/A
1.17	HF 907	Double-ridged horn	Rohde & Schwarz	102444	2021-09	2024-09

2 Radiated Emissions SAC H-Field
Radiated emission tests in the H-Field in a semi anechoic room

Ref.No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
2.1	N5000/NP	Filter for EUT, 2 Lines, 250 V, 16 A	ETS-LINDGREN	241515	N/A	N/A
2.2	Opus10 TPR (8253.00)	T/P Logger 13	Lufft Mess- und Regeltechnik GmbH	13936	2023-12	2025-12
2.3	ESW44	EMI Receiver / Spectrum Analyzer	Rohde & Schwarz GmbH & Co. KG	101603	2024-03	2026-03
2.4	Anechoic Chamber 01	SAC/FAR, 10.58 m x 6.38 m x 6.00 m	Frankonia Germany EMC Solution GmbH	none	N/A	N/A
2.5	Fluke 177	Digital Multimeter 03 (Multimeter)	Fluke Europe B.V.	86670383	2023-08	2025-08
2.6	Opus10 THI (8152.00)	T/H Logger 10	Lufft Mess- und Regeltechnik GmbH	12488	2023-12	2025-12
2.7	EP 1200/B, NA/B1	AC Source, Amplifier with integrated variable Oscillator	Spitzenberger & Spies GmbH & Co. KG	B6278	N/A	N/A
2.8	DS 420S	Turn Table 2 m diameter	HD GmbH	420/573/99	N/A	N/A
2.9	HFH2-Z2	Loop Antenna + 3 Axis Tripod	Rohde & Schwarz GmbH & Co. KG	829324/006	2024-04	2027-04
2.10	CS-RUB6	Rubidium Frequency Standard	Rohde & Schwarz GmbH & Co. KG	100321	2023-10	2024-10

3 Radiated Emissions SAC up to 1 GHz
Radiated emission tests up to 1 GHz in a semi anechoic room

Ref.No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
3.1	N5000/NP	Filter for EUT, 2 Lines, 250 V, 16 A	ETS-LINDGREN	241515	N/A	N/A
3.2	Opus10 TPR (8253.00)	T/P Logger 13	Lufft Mess- und Regeltechnik GmbH	13936	2023-12	2025-12
3.3	ESW44	EMI Receiver / Spectrum Analyzer	Rohde & Schwarz GmbH & Co. KG	101603	2024-03	2026-03
3.4	Anechoic Chamber 01	SAC/FAR, 10.58 m x 6.38 m x 6.00 m	Frankonia Germany EMC Solution GmbH	none	N/A	N/A
3.5	HL 562 ULTRALOG	Biconical-log-per antenna (30 MHz - 3 GHz) with HL 562E biconicals	Rohde & Schwarz GmbH & Co. KG	830547/003	2021-09	2024-09
3.6	Fluke 177	Digital Multimeter 03 (Multimeter)	Fluke Europe B.V.	86670383	2023-08	2025-08
3.7	Opus10 THI (8152.00)	T/H Logger 10	Lufft Mess- und Regeltechnik GmbH	12488	2023-12	2025-12
3.8	EP 1200/B, NA/B1	AC Source, Amplifier with integrated variable Oscillator	Spitzenberger & Spies GmbH & Co. KG	B6278	N/A	N/A
3.9	DS 420S	Turn Table 2 m diameter	HD GmbH	420/573/99	N/A	N/A
3.10	CS-RUB6	Rubidium Frequency Standard	Rohde & Schwarz GmbH & Co. KG	100321	2023-10	2024-10
3.11	AM 4.0	Antenna Mast 4 m	Maturo GmbH	AM4.0/180/1192 0513	N/A	N/A

The calibration interval is the time interval between “Last Calibration” and “Calibration Due”

6.2. TEST EQUIPMENT SOFTWARE

Semi-Anechoic Chamber:	
Software	Version
EMC32 Measurement Software	10.60.10
INNCO Mast Controller	1.02.62
INNCO Mast Height	34.10
INNCO Mast Elevation	36.11
MATURO Controller	1.24
MATURO Mast	12.19
MATURO Turn-Table	30.10
Fully-Anechoic Chamber:	
Software	Version
EMC32 Measurement Software	10.60.10
MATURO Controller	1.30
MATURO Turn-Unit	11.10
MATURO Mast	12.10
MATURO Turntable	12.11
INNCO Controller	1.03.02
INNCO Mast Height	34.10
INNCO Mast Elevation	36.11
TS 8997	
WMS32 Measurement Software	11.60.00 (till 2024-03-19), 11.70.00 + Hotfix 01
Conducted AC Emissions:	
Software	Version
EMC32 Measurement Software	10.60.20

7. ANTENNA FACTORS, CABLE LOSS AND SAMPLE CALCULATIONS

This chapter contains the antenna factors with their corresponding path loss of the used measurement path for all antennas as well as the insertion loss of the LISN.

7.1. LISN R&S ESH3-Z5 (150 KHZ – 30 MHZ)

Frequency MHz	Corr. dB	LISN insertion loss ESH3- Z5 dB	cable loss (incl. 10 dB atten- uator) dB
0.15	10.1	0.1	10.0
5	10.3	0.1	10.2
7	10.5	0.2	10.3
10	10.5	0.2	10.3
12	10.7	0.3	10.4
14	10.7	0.3	10.4
16	10.8	0.4	10.4
18	10.9	0.4	10.5
20	10.9	0.4	10.5
22	11.1	0.5	10.6
24	11.1	0.5	10.6
26	11.2	0.5	10.7
28	11.2	0.5	10.7
30	11.3	0.5	10.8

Sample calculation

$$U_{\text{LISN}} (\text{dB } \mu\text{V}) = U (\text{dB } \mu\text{V}) + \text{Corr. (dB)}$$

U = Receiver reading

LISN Insertion loss = Voltage Division Factor of LISN

Corr. = sum of single correction factors of used LISN, cables, switch units (if used)

Linear interpolation will be used for frequencies in between the values in the table.

7.2. ANTENNA R&S HFH2-Z2 (9 KHZ – 30 MHZ)

Frequency	AF HFH-Z2)	Corr.	cable loss 1 (inside chamber)	cable loss 2 (outside chamber)	cable loss 3 (switch unit)	cable loss 4 (to receiver)	distance corr. (-40 dB/ decade)	d _{Limit} (meas. distance (limit))	d _{used} (meas. distance (used))
MHz	dB (1/m)	dB	dB	dB	dB	dB	dB	m	m
0.009	20.50	-79.6	0.1	0.1	0.1	0.1	-80	300	3
0.01	20.45	-79.6	0.1	0.1	0.1	0.1	-80	300	3
0.015	20.37	-79.6	0.1	0.1	0.1	0.1	-80	300	3
0.02	20.36	-79.6	0.1	0.1	0.1	0.1	-80	300	3
0.025	20.38	-79.6	0.1	0.1	0.1	0.1	-80	300	3
0.03	20.32	-79.6	0.1	0.1	0.1	0.1	-80	300	3
0.05	20.35	-79.6	0.1	0.1	0.1	0.1	-80	300	3
0.08	20.30	-79.6	0.1	0.1	0.1	0.1	-80	300	3
0.1	20.20	-79.6	0.1	0.1	0.1	0.1	-80	300	3
0.2	20.17	-79.6	0.1	0.1	0.1	0.1	-80	300	3
0.3	20.14	-79.6	0.1	0.1	0.1	0.1	-80	300	3
0.49	20.12	-79.6	0.1	0.1	0.1	0.1	-80	300	3
0.490001	20.12	-39.6	0.1	0.1	0.1	0.1	-40	30	3
0.5	20.11	-39.6	0.1	0.1	0.1	0.1	-40	30	3
0.8	20.10	-39.6	0.1	0.1	0.1	0.1	-40	30	3
1	20.09	-39.6	0.1	0.1	0.1	0.1	-40	30	3
2	20.08	-39.6	0.1	0.1	0.1	0.1	-40	30	3
3	20.06	-39.6	0.1	0.1	0.1	0.1	-40	30	3
4	20.05	-39.5	0.2	0.1	0.1	0.1	-40	30	3
5	20.05	-39.5	0.2	0.1	0.1	0.1	-40	30	3
6	20.02	-39.5	0.2	0.1	0.1	0.1	-40	30	3
8	19.95	-39.5	0.2	0.1	0.1	0.1	-40	30	3
10	19.83	-39.4	0.2	0.1	0.2	0.1	-40	30	3
12	19.71	-39.4	0.2	0.1	0.2	0.1	-40	30	3
14	19.54	-39.4	0.2	0.1	0.2	0.1	-40	30	3
16	19.53	-39.3	0.3	0.1	0.2	0.1	-40	30	3
18	19.50	-39.3	0.3	0.1	0.2	0.1	-40	30	3
20	19.57	-39.3	0.3	0.1	0.2	0.1	-40	30	3
22	19.61	-39.3	0.3	0.1	0.2	0.1	-40	30	3
24	19.61	-39.3	0.3	0.1	0.2	0.1	-40	30	3
26	19.54	-39.3	0.3	0.1	0.2	0.1	-40	30	3
28	19.46	-39.2	0.3	0.1	0.3	0.1	-40	30	3
30	19.73	-39.1	0.4	0.1	0.3	0.1	-40	30	3

Sample calculation

$E \text{ (dB } \mu\text{V/m)} = U \text{ (dB } \mu\text{V)} + AF \text{ (dB 1/m)} + Corr. \text{ (dB)}$

U = Receiver reading

AF = Antenna factor

Corr. = sum of single correction factors of used cables, switch unit, distance correction, amplifier (if applicable)

distance correction = $-40 * \text{LOG} (d_{\text{Limit}} / d_{\text{used}})$

Linear interpolation will be used for frequencies in between the values in the table.

Table shows an extract of values

7.3. ANTENNA R&S HL562 (30 MHZ – 1 GHZ)

($d_{\text{Limit}} = 3 \text{ m}$)

Frequency MHz	AF R&S HL562 dB (1/m)	Corr. dB
30	18.6	0.6
50	6.0	0.9
100	9.7	1.2
150	7.9	1.6
200	7.6	1.9
250	9.5	2.1
300	11.0	2.3
350	12.4	2.6
400	13.6	2.9
450	14.7	3.1
500	15.6	3.2
550	16.3	3.5
600	17.2	3.5
650	18.1	3.6
700	18.5	3.6
750	19.1	4.1
800	19.6	4.1
850	20.1	4.4
900	20.8	4.7
950	21.1	4.8
1000	21.6	4.9

cable loss 1 (inside chamber) dB	cable loss 2 (outside chamber) dB	cable loss 3 (switch unit) dB	cable loss 4 (to receiver) dB	distance corr. (-20 dB/ decade) dB	d_{Limit} (meas. distance (limit)) m	d_{used} (meas. distance (used)) m
0.29	0.04	0.23	0.02	0.0	3	3
0.39	0.09	0.32	0.08	0.0	3	3
0.56	0.14	0.47	0.08	0.0	3	3
0.73	0.20	0.59	0.12	0.0	3	3
0.84	0.21	0.70	0.11	0.0	3	3
0.98	0.24	0.80	0.13	0.0	3	3
1.04	0.26	0.89	0.15	0.0	3	3
1.18	0.31	0.96	0.13	0.0	3	3
1.28	0.35	1.03	0.19	0.0	3	3
1.39	0.38	1.11	0.22	0.0	3	3
1.44	0.39	1.20	0.19	0.0	3	3
1.55	0.46	1.24	0.23	0.0	3	3
1.59	0.43	1.29	0.23	0.0	3	3
1.67	0.34	1.35	0.22	0.0	3	3
1.67	0.42	1.41	0.15	0.0	3	3
1.87	0.54	1.46	0.25	0.0	3	3
1.90	0.46	1.51	0.25	0.0	3	3
1.99	0.60	1.56	0.27	0.0	3	3
2.14	0.60	1.63	0.29	0.0	3	3
2.22	0.60	1.66	0.33	0.0	3	3
2.23	0.61	1.71	0.30	0.0	3	3

($d_{\text{Limit}} = 10 \text{ m}$)

30	18.6	-9.9
50	6.0	-9.6
100	9.7	-9.2
150	7.9	-8.8
200	7.6	-8.6
250	9.5	-8.3
300	11.0	-8.1
350	12.4	-7.9
400	13.6	-7.6
450	14.7	-7.4
500	15.6	-7.2
550	16.3	-7.0
600	17.2	-6.9
650	18.1	-6.9
700	18.5	-6.8
750	19.1	-6.3
800	19.6	-6.3
850	20.1	-6.0
900	20.8	-5.8
950	21.1	-5.6
1000	21.6	-5.6

0.29	0.04	0.23	0.02	-10.5	10	3
0.39	0.09	0.32	0.08	-10.5	10	3
0.56	0.14	0.47	0.08	-10.5	10	3
0.73	0.20	0.59	0.12	-10.5	10	3
0.84	0.21	0.70	0.11	-10.5	10	3
0.98	0.24	0.80	0.13	-10.5	10	3
1.04	0.26	0.89	0.15	-10.5	10	3
1.18	0.31	0.96	0.13	-10.5	10	3
1.28	0.35	1.03	0.19	-10.5	10	3
1.39	0.38	1.11	0.22	-10.5	10	3
1.44	0.39	1.20	0.19	-10.5	10	3
1.55	0.46	1.24	0.23	-10.5	10	3
1.59	0.43	1.29	0.23	-10.5	10	3
1.67	0.34	1.35	0.22	-10.5	10	3
1.67	0.42	1.41	0.15	-10.5	10	3
1.87	0.54	1.46	0.25	-10.5	10	3
1.90	0.46	1.51	0.25	-10.5	10	3
1.99	0.60	1.56	0.27	-10.5	10	3
2.14	0.60	1.63	0.29	-10.5	10	3
2.22	0.60	1.66	0.33	-10.5	10	3
2.23	0.61	1.71	0.30	-10.5	10	3

Sample calculation

$E \text{ (dB } \mu\text{V/m)} = U \text{ (dB } \mu\text{V)} + \text{AF (dB 1/m)} + \text{Corr. (dB)}$

U = Receiver reading

AF = Antenna factor

Corr. = sum of single correction factors of used cables, switch unit, distance correction, amplifier (if applicable)

distance correction = $-20 * \text{LOG} (d_{\text{Limit}} / d_{\text{used}})$

Linear interpolation will be used for frequencies in between the values in the table.

Tables show an extract of values.

7.4. ANTENNA R&S HF907 (1 GHZ – 18 GHZ)

Frequency	AF R&S HF907	Corr.
MHz	dB (1/m)	dB
1000	24.4	-19.4
2000	28.5	-17.4
3000	31.0	-16.1
4000	33.1	-14.7
5000	34.4	-13.7
6000	34.7	-12.7
7000	35.6	-11.0

cable loss 1 (relay + cable inside chamber)	cable loss 2 (outside chamber)	cable loss 3 (switch unit, atten- uator & pre-amp)	cable loss 4 (to receiver)		
dB	dB	dB	dB		
0.99	0.31	-21.51	0.79		
1.44	0.44	-20.63	1.38		
1.87	0.53	-19.85	1.33		
2.41	0.67	-19.13	1.31		
2.78	0.86	-18.71	1.40		
2.74	0.90	-17.83	1.47		
2.82	0.86	-16.19	1.46		

Frequency	AF R&S HF907	Corr.
MHz	dB (1/m)	dB
3000	31.0	-23.4
4000	33.1	-23.3
5000	34.4	-21.7
6000	34.7	-21.2
7000	35.6	-19.8

cable loss 1 (relay inside chamber)	cable loss 2 (inside chamber)	cable loss 3 (outside chamber)	cable loss 4 (switch unit, atten- uator & pre-amp)	cable loss 5 (to receiver)	used for FCC 15.247
dB	dB	dB	dB	dB	
0.47	1.87	0.53	-27.58	1.33	
0.56	2.41	0.67	-28.23	1.31	
0.61	2.78	0.86	-27.35	1.40	
0.58	2.74	0.90	-26.89	1.47	
0.66	2.82	0.86	-25.58	1.46	

Frequency	AF R&S HF907	Corr.
MHz	dB (1/m)	dB
7000	35.6	-57.3
8000	36.3	-56.3
9000	37.1	-55.3
10000	37.5	-56.2
11000	37.5	-55.3
12000	37.6	-53.7
13000	38.2	-53.5
14000	39.9	-56.3
15000	40.9	-54.1
16000	41.3	-54.1
17000	42.8	-54.4
18000	44.2	-54.7

cable loss 1 (relay inside chamber)	cable loss 2 (High Pass)	cable loss 3 (pre- amp)	cable loss 4 (inside chamber)	cable loss 5 (outside chamber)	cable loss 6 (to receiver)
dB	dB	dB	dB	dB	dB
0.56	1.28	-62.72	2.66	0.94	1.46
0.69	0.71	-61.49	2.84	1.00	1.53
0.68	0.65	-60.80	3.06	1.09	1.60
0.70	0.54	-61.91	3.28	1.20	1.67
0.80	0.61	-61.40	3.43	1.27	1.70
0.84	0.42	-59.70	3.53	1.26	1.73
0.83	0.44	-59.81	3.75	1.32	1.83
0.91	0.53	-63.03	3.91	1.40	1.77
0.98	0.54	-61.05	4.02	1.44	1.83
1.23	0.49	-61.51	4.17	1.51	1.85
1.36	0.76	-62.36	4.34	1.53	2.00
1.70	0.53	-62.88	4.41	1.55	1.91

Sample calculation

$E \text{ (dB } \mu\text{V/m)} = U \text{ (dB } \mu\text{V)} + AF \text{ (dB 1/m)} + \text{Corr. (dB)}$

U = Receiver reading

AF = Antenna factor

Corr. = sum of single correction factors of used cables, switch unit, distance correction, amplifier (if applicable)
Linear interpolation will be used for frequencies in between the values in the table.

Tables show an extract of values.

7.5. ANTENNA EMCO 3160-09 (18 GHZ – 26.5 GHZ)

Frequency	AF EMCO 3160-09	Corr.	cable loss 1 (inside chamber)	cable loss 2 (pre- amp)	cable loss 3 (inside chamber)	cable loss 4 (switch unit)	cable loss 5 (to receiver)
MHz	dB (1/m)	dB	dB	dB	dB	dB	dB
18000	40.2	-23.5	0.72	-35.85	6.20	2.81	2.65
18500	40.2	-23.2	0.69	-35.71	6.46	2.76	2.59
19000	40.2	-22.0	0.76	-35.44	6.69	3.15	2.79
19500	40.3	-21.3	0.74	-35.07	7.04	3.11	2.91
20000	40.3	-20.3	0.72	-34.49	7.30	3.07	3.05
20500	40.3	-19.9	0.78	-34.46	7.48	3.12	3.15
21000	40.3	-19.1	0.87	-34.07	7.61	3.20	3.33
21500	40.3	-19.1	0.90	-33.96	7.47	3.28	3.19
22000	40.3	-18.7	0.89	-33.57	7.34	3.35	3.28
22500	40.4	-19.0	0.87	-33.66	7.06	3.75	2.94
23000	40.4	-19.5	0.88	-33.75	6.92	3.77	2.70
23500	40.4	-19.3	0.90	-33.35	6.99	3.52	2.66
24000	40.4	-19.8	0.88	-33.99	6.88	3.88	2.58
24500	40.4	-19.5	0.91	-33.89	7.01	3.93	2.51
25000	40.4	-19.3	0.88	-33.00	6.72	3.96	2.14
25500	40.5	-20.4	0.89	-34.07	6.90	3.66	2.22
26000	40.5	-21.3	0.86	-35.11	7.02	3.69	2.28
26500	40.5	-21.1	0.90	-35.20	7.15	3.91	2.36

Sample calculation

$E \text{ (dB } \mu\text{V/m)} = U \text{ (dB } \mu\text{V)} + AF \text{ (dB 1/m)} + \text{Corr. (dB)}$

U = Receiver reading

AF = Antenna factor

Corr. = sum of single correction factors of used cables, switch unit, distance correction, amplifier (if applicable)

Linear interpolation will be used for frequencies in between the values in the table.

Table shows an extract of values.

7.6. ANTENNA EMCO 3160-10 (26.5 GHZ – 40 GHZ)

Frequency	AF EMCO 3160-10	Corr.	cable loss 1 (inside chamber)	cable loss 2 (outside chamber)	cable loss 3 (switch unit)	cable loss 4 (to receiver)	distance corr. (-20 dB/ decade)	d _{Limit} (meas. distance (limit))	d _{used} (meas. distance (used))
GHz	dB (1/m)	dB	dB	dB	dB	dB	dB	m	m
26.5	43.4	-11.2	4.4				-9.5	3	1.0
27.0	43.4	-11.2	4.4				-9.5	3	1.0
28.0	43.4	-11.1	4.5				-9.5	3	1.0
29.0	43.5	-11.0	4.6				-9.5	3	1.0
30.0	43.5	-10.9	4.7				-9.5	3	1.0
31.0	43.5	-10.8	4.7				-9.5	3	1.0
32.0	43.5	-10.7	4.8				-9.5	3	1.0
33.0	43.6	-10.7	4.9				-9.5	3	1.0
34.0	43.6	-10.6	5.0				-9.5	3	1.0
35.0	43.6	-10.5	5.1				-9.5	3	1.0
36.0	43.6	-10.4	5.1				-9.5	3	1.0
37.0	43.7	-10.3	5.2				-9.5	3	1.0
38.0	43.7	-10.2	5.3				-9.5	3	1.0
39.0	43.7	-10.2	5.4				-9.5	3	1.0
40.0	43.8	-10.1	5.5				-9.5	3	1.0

Sample calculation

$E \text{ (dB } \mu\text{V/m)} = U \text{ (dB } \mu\text{V)} + AF \text{ (dB 1/m)} + Corr. \text{ (dB)}$

U = Receiver reading

AF = Antenna factor

Corr. = sum of single correction factors of used cables, switch unit, distance correction, amplifier (if applicable)

Linear interpolation will be used for frequencies in between the values in the table.

distance correction = $-20 * \text{LOG} (d_{\text{Limit}} / d_{\text{used}})$

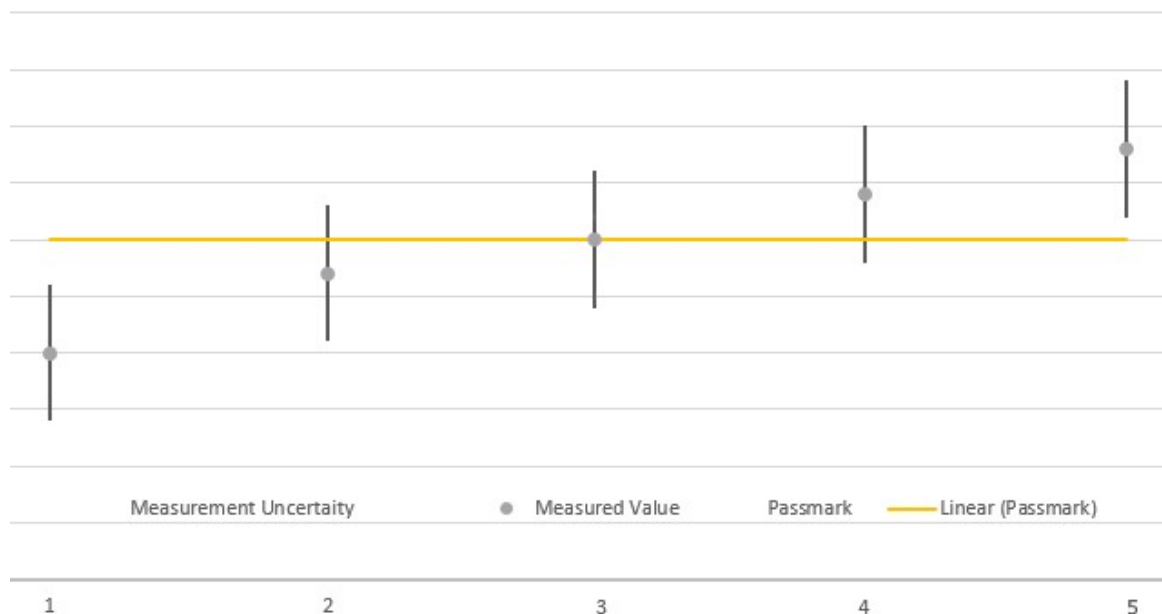
Linear interpolation will be used for frequencies in between the values in the table.

Table shows an extract of values.

8. MEASUREMENT UNCERTAINTIES

Test Case	Parameter	Uncertainty
AC Power Line	Power	± 3.4 dB
Field Strength of spurious radiation	Power	± 5.5 dB
6 dB / 26 dB / 99% Bandwidth	Power Frequency	± 2.9 dB ± 11.2 kHz
Conducted Output Power	Power	± 2.2 dB
Band Edge Compliance	Power Frequency	± 2.2 dB ± 11.2 kHz
Frequency Stability	Frequency	± 25 Hz
Power Spectral Density	Power	± 2.2 dB

The measurement uncertainties for all parameters are calculated with an expansion factor (coverage factor) $k = 1.96$. This means, that the true value is in the corresponding interval with a probability of 95 %.



The verdicts in this test report are given according the above diagram:

Case	Measured Value	Uncertainty Range	Verdict
1	below pass mark	below pass mark	Passed
2	below pass mark	within pass mark	Passed
3	on pass mark	within pass mark	Passed
4	above pass mark	within pass mark	Failed
5	above pass mark	above pass mark	Failed

That means, the laboratory applies, as decision rule (see ISO/IEC 17025:2017), the so-called shared risk principle.

9. PHOTO REPORT

Please see separate photo report.

*****END OF TEST REPORT*****