DAkkS Deutsche Akkreditierungsstelle D-PL-21375-01-03

INGENIEURBÜRO LENHARDT

Bundesnetzagentur

BNetzA-CAB-21/21-21

Test Report

Test report no.: 20054147-18456-1
Date of issue: 2021-03-12

Test result: The test item **- passed - and complies** with below listed standards.

Applicant
Veoneer US, Inc.

Manufacturer
Veoneer US, Inc.

Test Item
NB24G20V0

RF-Spectrum Testing according to:

FCC 47 CFR Part 15
Radio Frequency Devices, Subpart C -
§15.249 Operation within the bands 902-928 MHz, 2400-2483.5 MHz, 5725-5875 MHZ, and 24.0-24.25 GHz

Tested by (name, function, signature)	*Karsten Geraldy* *Head of Laboratory RF*	signature
Approved by (name, function, signature)	*Dr.-Ing. Harald Ansorge* *Managing Director*	signature

Applicant and Test item details	
Applicant	Veoneer US, Inc. 26360 American Drive Southfield, MI 48034, USA
Manufacturer	Veoneer US, Inc. 26360 American Drive Southfield, MI 48034, USA
Test item description	24 GHz NB automotive radar
Model/Type reference	NB24G20V0
FCC ID	WU8NB24G20V0
Frequency	24.05 GHz – 24.25 GHz
Antenna	Integrated planar patch antenna
Power supply	8.0 V – 16.0 V DC
Temperature range	-40 °C – +85 °C

Disclaimer and Notes

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Within this test report, a ☒ point / ☐ comma is used as a decimal separator.
If otherwise, a detailed note is added adjected to its use.

Decision rule: Binary Statement for Simple Acceptance Rule according ILAC-G8:09/2019

IBL-Lab GmbH does not take test samples. The EUT used for testing is provided by the applicant.

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2 GENERAL INFORMATION

2.1 Administrative details

Testing laboratory	**IBL-Lab GmbH** Heinrich-Hertz-Allee 7 66386 Sankt Ingbert / Germany Fon: +49 6894 38938-0 Fax: +49 6894 38938-99 URL: www.ib-lenhardt.de E-Mail: info@ib-lenhardt.de
Accreditation	The testing laboratory is accredited by Deutsche Akkreditierungsstelle GmbH (DAkkS) in compliance with DIN EN ISO/IEC 17025:2018. Scope of testing and registration number: • Electromagnetic Compatibility and Telecommunication (FCC requirements) D-PL-21375-01-03 Website DAkkS: https://www.dakks.de/ The Deutsche Akkreditierungsstelle GmbH (DAkkS) is also a signatory to ILAC Mutual Recognition Arrangement
Testing location	**IBL-Lab GmbH** Heinrich-Hertz-Allee 7 66386 St. Ingbert / Germany
Date of receipt of test samples	2021-02-09
Start – End of tests	2021-02-09 – 2021-02-17

2.2 Possible test case verdicts

Test sample meets the requirements	P (PASS)
Test sample does not meet the requirements	F (FAIL)
Test case does not apply to the test sample	N/A (Not applicable)
Test case not performed	N/P (Not performed)

2.3 Observations

No additional observations other than the reported observations within this test report have been made.

2.4 Opinions and interpretations

No appropriate opinions or interpretations according ISO/IEC 17025:2017 clause 7.8.7 are within this test report.

2.5 Revision History

-1 Initial Version

2.6 Further documents

List of further applicable documents belonging to the present test report:

External EUT photographs:	20054147-18456_AnnexA
Internal EUT photographs:	20054147-18456_AnnexB
Test setup photographs:	20054147-18456_AnnexC

3 ENVIRONMENTAL & TEST CONDITIONS

3.1 Environmental conditions

Temperature	20°C ± 5°C
Relative humidity	25-75% r.H.
Barometric Pressure	860-1060 mbar
Power supply	230 V AC ± 5%

3.2 Normal and extreme test conditions

	minimum	nominal	maximum
Temperature	-40 °C	+22 °C	+85 °C
Relative humidity	-/-	45 % r.h.	-/-
Power supply	8.0 V DC	13 V DC	16.0 V DC

4 TEST STANDARDS AND REFERENCES

Test standard (accredited)	Description
FCC 47 CFR Part 15	Radio Frequency Devices, Subpart C - §15.249 Operation within the bands 902-928 MHz, 2400-2483.5 MHz, 5725-5875 MHZ, and 24.0-24.25 GHz

Reference	Description
ANSI C63.4-2014	American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz
ANSI C63.10-2013	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices

5 EQUIPMENT UNDER TEST (EUT)

5.1 Product description

24 GHz NB automotive radar

5.2 Description of test item

Model name*	NB24G20V0
Serial number*	NON-FIP: 832108200366 FIP: 832209200602
PCB identifier*	680414500F
Hardware status*	Rev E
Software status*	CFG 369

*: as declared by applicant

5.3 Technical data of test item

Operational carrier frequency*	24.05 GHz – 24.25 GHz
Operational frequency band*	24.00 GHz – 24.25 GHz
Type of radio transmission*	Modulated carrier
Modulation type*	Pulsed, FSK, Stepped FM
Number of channels*	1
Channel bandwidth*	<200 MHz
Channel spacing*	n.a.
Receiver category*	n.a.
Receiver bandwidth*	n.a.
Duty cycle*	n.a.
Antenna*	Integrated planar patch antenna
Rated RF output power*	13.26 dBm
Power supply*	8.0 V – 16.0 V DC
Temperature range*	-40 °C – +85 °C
Emission designator*	200MP0N

*: as declared by applicant

5.4 Additional information

Model differences	The sensor has two possible housings, a housing with a form in place (FIP) gasket and one without. The sensor function between the two housing variants does not change. The housing with the FIP gasket is used to control radiated emissions. Radome, RF Shield & PCBA are the same for NB2.0 Radar for both with and without FIP gasket variants.
Ancillaries tested with	n.a.
Additional equipment used for testing	Notebook with CAN-adapter and special test software was used to stop FMCW and set low/mid/high carrier acc. to §15.31(c)

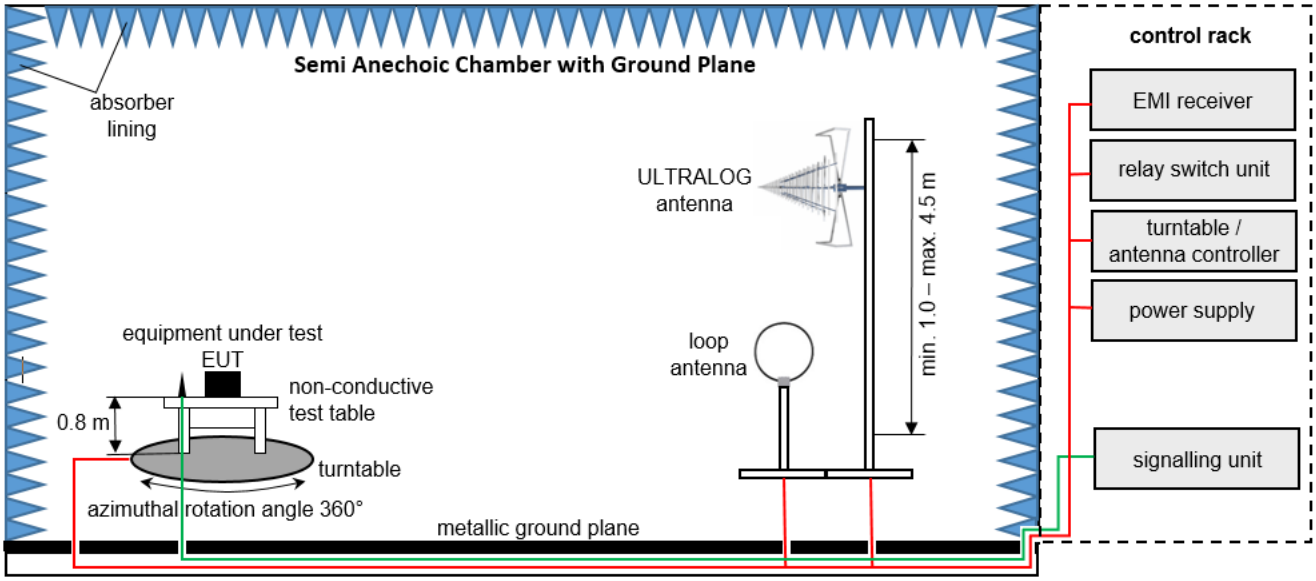
6 Test Setup Description

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

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

6.1 Semi Anechoic Chamber with Ground Plane

Radiated measurements are performed in vertical and horizontal plane in the frequency range 30 MHz to 1 GHz in a Semi Anechoic Chamber with a metallic ground plane. The EUT is positioned on a non-conductive test table with a height of 0.80 m above the metallic ground plane that covers the whole chamber. The receiving antennas conform to specification ANSI C63.10-2013, American National Standard for Testing Unlicensed Wireless Devices. These antennas can be moved over the height range between 1.0 m and 4.5 m in order to search for maximum field strength emitted from the EUT. The measurement distances between EUT and receiving antennas are indicated in the test setups for the various frequency ranges. For each measurement, the EUT is rotated in all three axes until the maximum field strength is received. The wanted and unwanted emissions are received by a spectrum analyzer where the detector modes and resolution bandwidths over various frequency ranges are set according to requirement ANSI C63.



Measurement distance: ULTRALOG antenna 3 m; loop antenna 3 m
EMC32 software version: 11.10.00

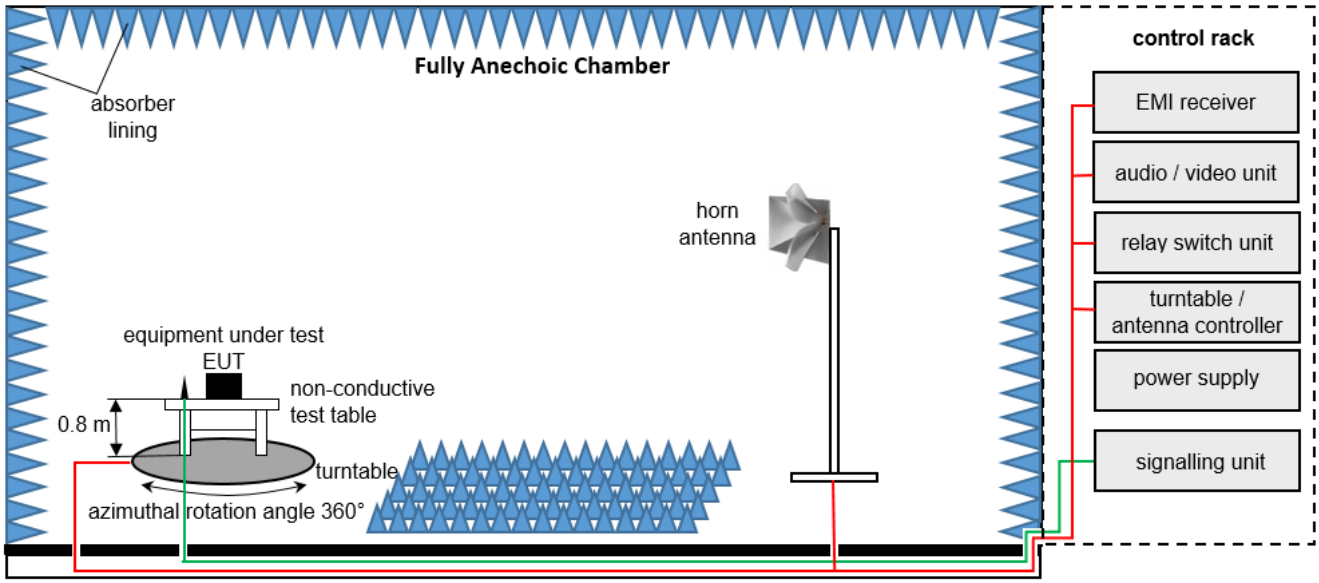
FS = UR + CL + AF
(FS-field strength; UR-voltage at the receiver; CL-loss of the cable; AF-antenna factor)

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

List of test equipment used:

No.	Equipment	Manufacturer	Type	Serial No.	IBL No.	Kind of Calibration	Last / Next Calibration
1	Power Supply	Elektro-Automatik GmbH & Co. KG	EA-PSI 9080-40 T	2000230001	LAB000313	NE	–
2	Test table	innco systems GmbH	PT1208-080-RH	-	LAB000306	NE	–
3	Positioner	maturo GmbH	TD 1.5-10KG		LAB000258	NE	–
4	Compressed Air	Implotex	1-850-30	-	LAB000256	NE	–
5	EMI Test Receiver	Rohde & Schwarz	ESW26	101481	LAB000236	K	2020-06-03 → 12M → 2021-06-03
6	Semi-Anechoic Chamber (SAC)	Albatross Projects GmbH	SAC 5 (Babylon 5)	20168.PRB	LAB000235	ZW	2020-08-24 → 12M → 2021-08-24
7	Measurement Software	Rohde & Schwarz	EMC32 V11.00.10		LAB000226	NE	–
8	Turntable	maturo GmbH	TT2.0-2t	TT2.0-2t/921	LAB000225	NE	–
9	Antenna Mast	maturo GmbH	CAM4.0-P	CAM4.0-P/316	LAB000224	NE	–
10	Antenna Mast	maturo GmbH	BAM4.5-P	BAM4.5-P/272	LAB000223	NE	–
11	Controller	maturo GmbH	FCU 3.0	10082	LAB000222	NE	–
12	Power Supply	Elektro-Automatik GmbH & Co. KG	PS 2042-10 B	2878350292	LAB000191	NE	–
13	Open Switch and Control Platform	Rohde & Schwarz	OSP200 Base Unit 2HU	101748	LAB000149	ZW	2020-07-07 → 12M → 2021-07-07
14	Antenna	Rohde & Schwarz	HF907	102898	LAB000124	K	2020-04-23 → 36M → 2021-04-23
15	Antenna	Rohde & Schwarz	HL562E	102001	LAB000123	K	2020-07-05 → 36M → 2021-07-05
16	Antenna	Rohde & Schwarz	HFH2-Z2E - Active Loop Antenna	100954	LAB000108	K	2020-03-25 → 36M → 2021-03-25
17	Pre-Amplifier	Schwarzbeck Mess-Elektronik OHG	BBV 9718 C	84	LAB000169	NE	–

6.2 Fully Anechoic Chamber



Measurement distance: horn antenna 3 m
EMC32 software version: 11.10.00

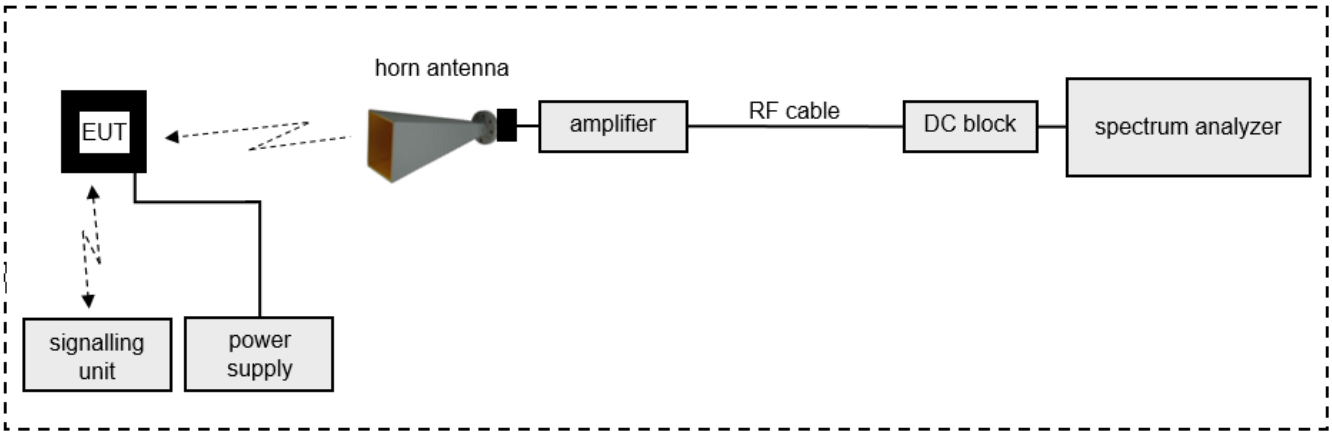
FS = UR + CA + AF
(FS-field strength; UR-voltage at the receiver; CA-loss of the signal path; AF-antenna factor)

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

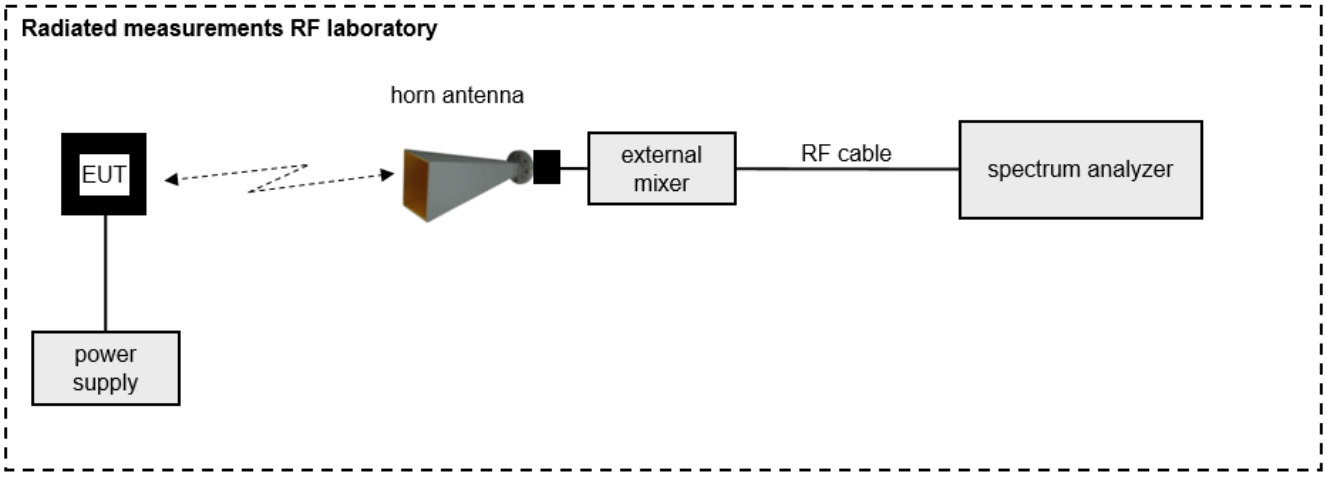
List of test equipment used:

No.	Equipment	Manufacturer	Type	Serial No.	IBL No.	Kind of Calibration	Last / Next Calibration
1	Power Supply	Elektro-Automatik GmbH & Co. KG	EA-PSI 9080-40 T	2000230001	LAB000313	NE	–
2	Test table	innco systems GmbH	PT1208-080-RH	-	LAB000306	NE	–
3	Positioner	maturo GmbH	TD 1.5-10KG		LAB000258	NE	–
4	Compressed Air	Implotex	1-850-30	-	LAB000256	NE	–
5	EMI Test Receiver	Rohde & Schwarz	ESW26	101481	LAB000236	K	2020-06-03 → 12M → 2021-06-03
6	Semi-Anechoic Chamber (SAC)	Albatross Projects GmbH	SAC 5 (Babylon 5)	20168.PRB	LAB000235	ZW	2020-08-24 → 12M → 2021-08-24
7	Measurement Software	Rohde & Schwarz	EMC32 V11.00.10		LAB000226	NE	–
8	Turntable	maturo GmbH	TT2.0-2t	TT2.0-2t/921	LAB000225	NE	–
9	Antenna Mast	maturo GmbH	CAM4.0-P	CAM4.0-P/316	LAB000224	NE	–
10	Antenna Mast	maturo GmbH	BAM4.5-P	BAM4.5-P/272	LAB000223	NE	–
11	Controller	maturo GmbH	FCU 3.0	10082	LAB000222	NE	–
12	Power Supply	Elektro-Automatik GmbH & Co. KG	PS 2042-10 B	2878350292	LAB000191	NE	–
13	Open Switch and Control Platform	Rohde & Schwarz	OSP200 Base Unit 2HU	101748	LAB000149	ZW	2020-07-07 → 12M → 2021-07-07
14	Antenna	Rohde & Schwarz	HF907	102898	LAB000124	K	2020-04-23 → 36M → 2021-04-23
15	Antenna	Rohde & Schwarz	HL562E	102001	LAB000123	K	2020-07-05 → 36M → 2021-07-05
16	Antenna	Rohde & Schwarz	HFH2-Z2E - Active Loop Antenna	100954	LAB000108	K	2020-03-25 → 36M → 2021-03-25
17	Pre-Amplifier	Schwarzbeck Mess-Elektronik OHG	BBV 9718 C	84	LAB000169	NE	–

6.3 Radiated measurements > 18 GHz



6.4 Radiated measurements > 50 GHz



Measurement distance: horn antenna e.g. 50 cm

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

Example calculation:
FS [dBµV/m] = 40.0 [dBµV/m] + (-60.1) [dB] + 36.74 [dB/m] = 16.64 [dBµV/m] (6.79 µV/m)

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

List of test equipment used:

No.	Equipment	Manufacturer	Type	Serial No.	IBL No.	Kind of Calibration	Last / Next Calibration
1	Test table	innco systems GmbH	PT0707-RH light	–	LAB000303	–	–
2	Spectrum Analyser	Rohde & Schwarz	FSW43	101391	LAB000289	NE	–
3	Power Supply	Elektro-Automatik GmbH & Co. KG	PS 2042-10 B	2878350263	LAB000190	NE	–
4	WG-Coax-Adapter	Flann Microwave Ltd	23373-TF30 UG383/U	273385	LAB000185	ZW	2020-07-01 → 12M → 2021-07-01
5	WG-Coax-Adapter	Flann Microwave Ltd	22093-TF30 UG599/U	273263	LAB000183	ZW	2020-07-01 → 12M → 2021-07-01
6	WG-Coax-Adapter	Flann Microwave Ltd	20093-TF30 UBR220	273374	LAB000181	ZW	2020-07-01 → 12M → 2021-07-01
7	Coaxial Cable	Huber & Suhner	SF101/1.0m	503989/1	LAB000163	ZW	2020-06-05 → 12M → 2021-06-05
8	Coaxial Cable	Huber & Suhner	SF101/0.5m	504118/1	LAB000162	ZW	2020-06-05 → 12M → 2021-06-05
9	Coaxial Cable	Huber & Suhner	ST18/48"	2276454-01	LAB000157	ZW	2020-07-03 → 12M → 2021-07-03
10	Coaxial Cable	Rosenberger	LU7-022-1000	34	LAB000154	NE	–
11	Coaxial Cable	Rosenberger	LU7-022-1000	33	LAB000153	NE	–
12	Antenna	Flann Microwave Ltd	27240-20	273367	LAB000137	ZW	2020-08-01 → 12M → 2021-08-01
13	Antenna	Flann Microwave Ltd	25240-20	272860	LAB000133	ZW	2020-07-01 → 12M → 2021-07-01
14	Antenna	Flann Microwave Ltd	23240-20	273430	LAB000132	ZW	2020-07-01 → 12M → 2021-07-01
15	Antenna	Flann Microwave Ltd	22240-20	270448	LAB000130	K	2020-06-29 → 36M → 2021-06-29
16	Antenna	Flann Microwave Ltd	20240-20	266403	LAB000128	K	2020-06-29 → 36M → 2021-06-29
17	Harmonic Mixer	Rohde & Schwarz	FS-Z110	102000	LAB000114	K	2020-03-26 → 12M → 2021-03-26
18	Harmonic Mixer	Rohde & Schwarz	FS-Z75	102015	LAB000112	K	2020-03-26 → 12M → 2021-03-26
19	Spectrum Analyser	Rohde & Schwarz	FSW50	101450	LAB000111	K	2020-05-05 → 12M → 2021-05-05
20	Antenna Mast	Schwarzbeck Mess-Elektronik OHG	AM 9104	99	LAB000109	NE	–
21	Climatic Chamber	CTS GmbH	T-65/50	204002	LAB000110	ZW	2020-06-01 → 12M → 2021-06-01

7 Measurement procedures

7.1 Radiated spurious emissions from 9 kHz to 30 MHz

Test setup

- The EUT is set up according to its intended use, as described in the user manual or as defined by the manufacturer.
- In case of floor standing equipment, it is placed in the middle of the turn table.
  In case of tabletop equipment it is placed on a non-conductive table with a height of 80 cm.
- Additional equipment, cables, … necessary for testing, are positioned like under normal operation.
- Interface cables, e.g. power supply, network, … are connected to the connection box in the turn table.
- EUT is powered on and set into operation.

Pre-scan

- Turntable performs an azimuthal rotation from 0° to 315° in 45° steps.
- For each turntable step the EMI-receiver/spectrum analyser performs a positive-peak/max-hold sweep (=worst-case). Data is transferred to EMI-software and recorded. EMI-software will show the maximum level of all single sweeps as the final result for the pre-scan.

Final measurement

- Significant emissions found during the pre-scan will be maximized by the EMI-software by rotating the turntable from 0° to 360°.
- Loop antenna is rotated with special 3D adapter set to find maximum level of emissions.
- Plot of the pre-scan with frequencies of identified emissions including levels, correction factors, turn table position and settings of measuring equipment is recorded.

Detailed requirements can be found in e.g. ANSI C63.4 / C63.10

7.2 Radiated spurious emissions from 30 MHz to 1 GHz

Test setup

- The EUT is set up according to its intended use, as described in the user manual or as defined by the manufacturer.
- In case of floor standing equipment, it is placed in the middle of the turn table.
  In case of tabletop equipment it is placed on a non-conductive table with a height of 80 cm.
- Additional equipment, cables, … necessary for testing, are positioned like under normal operation.
- Interface cables, e.g. power supply, network, … are connected to the connection box in the turn table.
- EUT is powered on and set into operation.

Pre-scan

- Turntable performs an azimuthal rotation from 0° to 315° in 45° steps.
- Antenna polarisation is changed (H-V / V-H) and antenna height is changed from 1 meter to 4 meters.
- For each turntable step / antenna polarisation / antenna height the EMI-receiver/spectrum analyser performs a positive-peak/max-hold sweep (=worst-case). Data is transferred to EMI-software and recorded. EMI-software will show the maximum level of all single sweeps as the final result for the pre-scan.

Final measurement

- Significant emissions found during the pre-scan will be maximized by the EMI-software based on evaluated data during the pre-scan by rotating the turntable and changing antenna height and polarisation.
- Final measurement will be performed with measuring equipment settings as defined in the applicable test standards (e.g. ANSI C6.4).
- Plot of the pre-scan with frequencies of identified emissions including levels, correction factors, turn table position, antenna polarisation and settings of measuring equipment is recorded.

Detailed requirements can be found in e.g. ANSI C63.4 / C63.10

7.3 Radiated spurious emissions from 1 GHz to 18 GHz

Test setup

- The EUT is set up according to its intended use, as described in the user manual or as defined by the manufacturer.
- In case of floor standing equipment, it is placed in the middle of the turn table.
  In case of tabletop equipment it is placed on a non-conductive table with a height of 80 cm.
- Additional equipment, cables, … necessary for testing, are positioned like under normal operation.
- Interface cables, e.g. power supply, network, … are connected to the connection box in the turn table.
- EUT is powered on and set into operation.

Pre-scan

- Turntable performs an azimuthal rotation from 0° to 315° in 45° steps.
- Antenna polarisation is changed (H-V / V-H) and antenna height is changed from 1 meter to 4 meters.
- For each turntable step / antenna polarisation / antenna height the EMI-receiver/spectrum analyser performs a positive-peak/max-hold sweep (=worst-case). Data is transferred to EMI-software and recorded. EMI-software will show the maximum level of all single sweeps as the final result for the pre-scan.

Final measurement

- Significant emissions found during the pre-scan will be maximized by the EMI-software based on evaluated data during the pre-scan by rotating the turntable and changing antenna height and polarisation.
- Final measurement will be performed with measuring equipment settings as defined in the applicable test standards (e.g. ANSI C6.4).
- Plot of the pre-scan with frequencies of identified emissions including levels, correction factors, turn table position, antenna polarisation and settings of measuring equipment is recorded.

Detailed requirements can be found in e.g. ANSI C63.4 / C63.10

7.4 Radiated spurious emissions above 18 GHz

Test setup

- The EUT is set up according to its intended use, as described in the user manual or as defined by the manufacturer.
- Additional equipment, cables, … necessary for testing, are positioned like under normal operation.
- EUT is powered on and set into operation.
- Test distance depends on EUT size and test antenna size (farfield conditions shall be met).

Pre-scan

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

Final measurement

- Significant emissions found during the pre-scan will be maximized, i.e. position and antenna orientation causing the highest emissions with Peak and RMS detector
- Final measurement will be performed with measuring equipment settings as defined in the applicable test standards (e.g. ANSI C63.4 / C63.10).
- Final plot showing measurement data, levels, frequency, measuring time, bandwidth, correction factor, margin to the limit and limit is recorded.

Note

- In case of measurements with external harmonic mixers (e.g. above 50 GHz) special care is taken to avoid possible overloading of the external mixer's input.
- As external harmonic mixers may generate false images, care is taken to ensure that any emission measured by the spectrum analyzer is indeed radiated from the EUT and not internally generated by the external harmonic mixer. Signal identification feature of spectrum analyzer is used to eliminate/reduce images of the external harmonic mixer.

Detailed requirements can be found in e.g. ANSI C63.4 / C63.10

8 SUMMARY OF TEST RESULTS

Test specification
FCC 47 CFR Part 15.249

Clause	Requirement / Test case	Test Conditions	Result / Remark	Verdict
§2.1049	Occupied bandwidth (99% bandwidth)	Normal		P
§12.215(c)	Transmitter frequency stability	Extreme		P
§15.249(a)	Field strength of emissions (wanted signal)	Normal		P
§15.249(d) §15.209(a)	Field strength of emissions (spurious & harmonics)	Normal		P

Notes
FCC's Millimeter Wave Test Procedures: I. A radiated method of measurements in order to demonstrate compliance with the various regulatory requirements has been chosen in consideration of test equipment availability and the limitations of many external harmonic mixers. A conducted method of measurement could be employed if EUT and mixer waveguides both are accessible and of the same type (WG number) and if waveguide sections and transitions can be found. Another potential problem is that the peak power output may exceed the +20 dBm input power limit of many commercially available mixers. For these reasons a radiated method is preferred.

Comments and observations
none

9 TEST RESULTS

9.1 Occupied bandwidth

Description

§2.1049 Measurements required: Occupied bandwidth.

The occupied bandwidth, that is the frequency bandwidth such that, below its lower and above its upper frequency limits, the mean powers radiated are each equal to 0.5 percent of the total mean power radiated by a given emission shall be measured.

Limits

The radar device's occupied bandwidth (i.e. 99% emission bandwidth) shall be contained in the frequency band.

Test procedure

ANSI C63.10, 6.9.3

The occupied bandwidth is the frequency bandwidth such that, below its lower and above its upper frequency limits, the mean powers are each equal to 0.5% of the total mean power of the given emission.

The following procedure shall be used for measuring 99% power bandwidth:

a) The instrument center frequency is set to the nominal EUT channel center frequency. The frequency span for the spectrum analyzer shall be between 1.5 times and 5.0 times the OBW.

b) The nominal IF filter bandwidth (3 dB RBW) shall be in the range of 1% to 5% of the OBW, and VBW shall be approximately three times the RBW, unless otherwise specified by the applicable requirement.

c) Set the reference level of the instrument as required, keeping the signal from exceeding the maximum input mixer level for linear operation. In general, the peak of the spectral envelope shall be more than [10 log (OBW/RBW)] below the reference level. Specific guidance is given in 4.1.5.2.

d) Step a) through step c) might require iteration to adjust within the specified range.

e) Video averaging is not permitted. Where practical, a sample detection and single sweep mode shall be used. Otherwise, peak detection and max hold mode (until the trace stabilizes) shall be used.

f) Use the 99% power bandwidth function of the instrument (if available) and report the measured bandwidth.

g) If the instrument does not have a 99% power bandwidth function, then the trace data points are recovered and directly summed in linear power terms. The recovered amplitude data points, beginning at the lowest frequency, are placed in a running sum until 0.5% of the total is reached; that frequency is recorded as the lower frequency. The process is repeated until 99.5% of the total is reached; that frequency is recorded as the upper frequency. The 99% power bandwidth is the difference between these two frequencies.

h) The occupied bandwidth shall be reported by providing plot(s) of the measuring instrument display; the plot axes and the scale units per division shall be clearly labeled. Tabular data may be reported in addition to the plot(s).

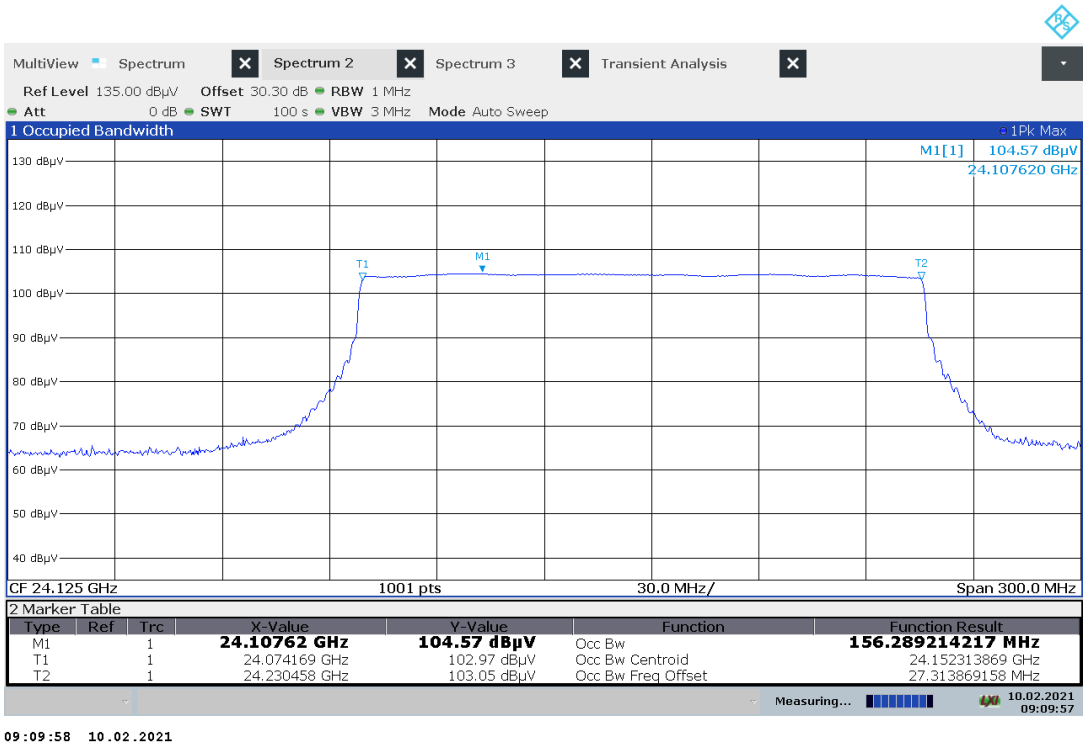
Note

Measurements with the peak detector are also suitable to demonstrate compliance of an EUT, as long as the required resolution bandwidth is used, because peak detection will yield amplitudes equal to or greater than amplitudes measured with RMS detector. The measurement data from a spectrum analyser peak detector will represent the worst-case results (see ANSI C63.10).

Test results

EUT mode	Test distance	f_L [GHz]	f_H [GHz]	99% OBW [MHz]
NON-FIP	1 m	24.074169	24.230458	156.289
FIP	1 m	24.074120	24.230395	156.275

Plot no. 1: 99% OBW, Peak detector, NON-FIP EUT



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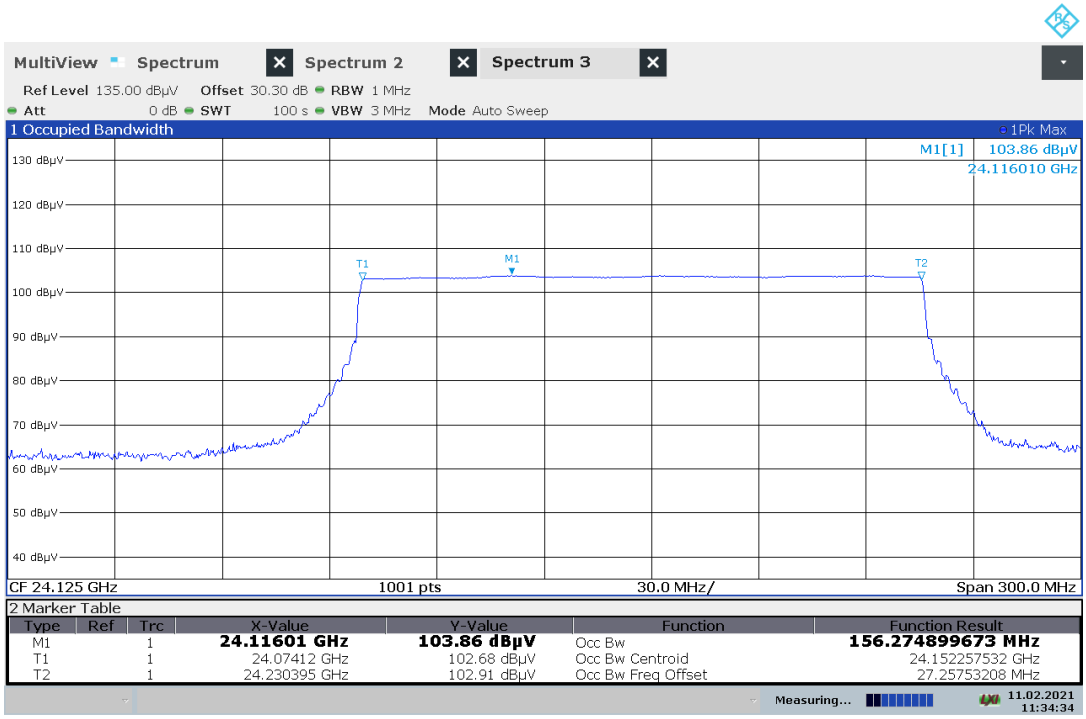
Plot no. 2: 99% OBW, Peak detector, FIP EUT



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9.2 Transmitter frequency stability

Description

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

Limits

The radar device's occupied bandwidth (i.e. 99% emission bandwidth) shall be contained in the frequency band.

Test procedure

ANSI C63.10, 6.9.3

The occupied bandwidth is the frequency bandwidth such that, below its lower and above its upper frequency limits, the mean powers are each equal to 0.5% of the total mean power of the given emission.

The following procedure shall be used for measuring 99% power bandwidth:

a) The instrument center frequency is set to the nominal EUT channel center frequency. The frequency span for the spectrum analyzer shall be between 1.5 times and 5.0 times the OBW.

b) The nominal IF filter bandwidth (3 dB RBW) shall be in the range of 1% to 5% of the OBW, and VBW shall be approximately three times the RBW, unless otherwise specified by the applicable requirement.

c) Set the reference level of the instrument as required, keeping the signal from exceeding the maximum input mixer level for linear operation. In general, the peak of the spectral envelope shall be more than [10 log (OBW/RBW)] below the reference level. Specific guidance is given in 4.1.5.2.

d) Step a) through step c) might require iteration to adjust within the specified range.

e) Video averaging is not permitted. Where practical, a sample detection and single sweep mode shall be used. Otherwise, peak detection and max hold mode (until the trace stabilizes) shall be used.

f) Use the 99% power bandwidth function of the instrument (if available) and report the measured bandwidth.

g) If the instrument does not have a 99% power bandwidth function, then the trace data points are recovered and directly summed in linear power terms. The recovered amplitude data points, beginning at the lowest frequency, are placed in a running sum until 0.5% of the total is reached; that frequency is recorded as the lower frequency. The process is repeated until 99.5% of the total is reached; that frequency is recorded as the upper frequency. The 99% power bandwidth is the difference between these two frequencies.

h) The occupied bandwidth shall be reported by providing plot(s) of the measuring instrument display; the plot axes and the scale units per division shall be clearly labeled. Tabular data may be reported in addition to the plot(s).

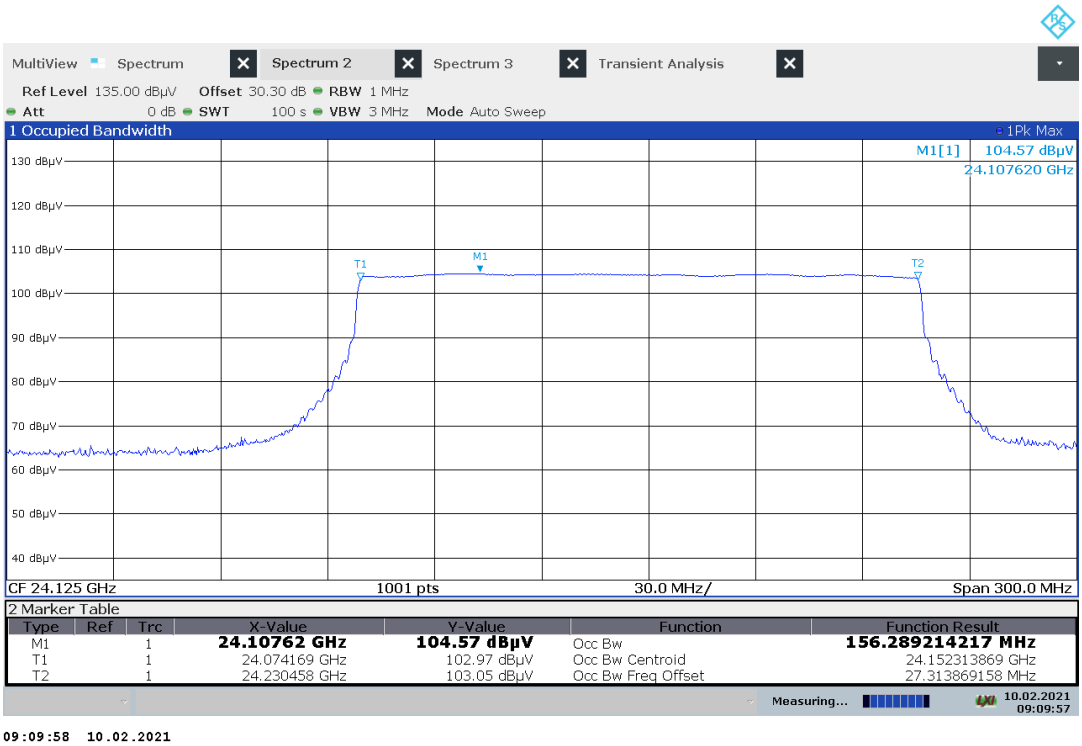
Note

Measurements with the peak detector are also suitable to demonstrate compliance of an EUT, as long as the required resolution bandwidth is used, because peak detection will yield amplitudes equal to or greater than amplitudes measured with RMS detector. The measurement data from a spectrum analyser peak detector will represent the worst-case results (see ANSI C63.10).

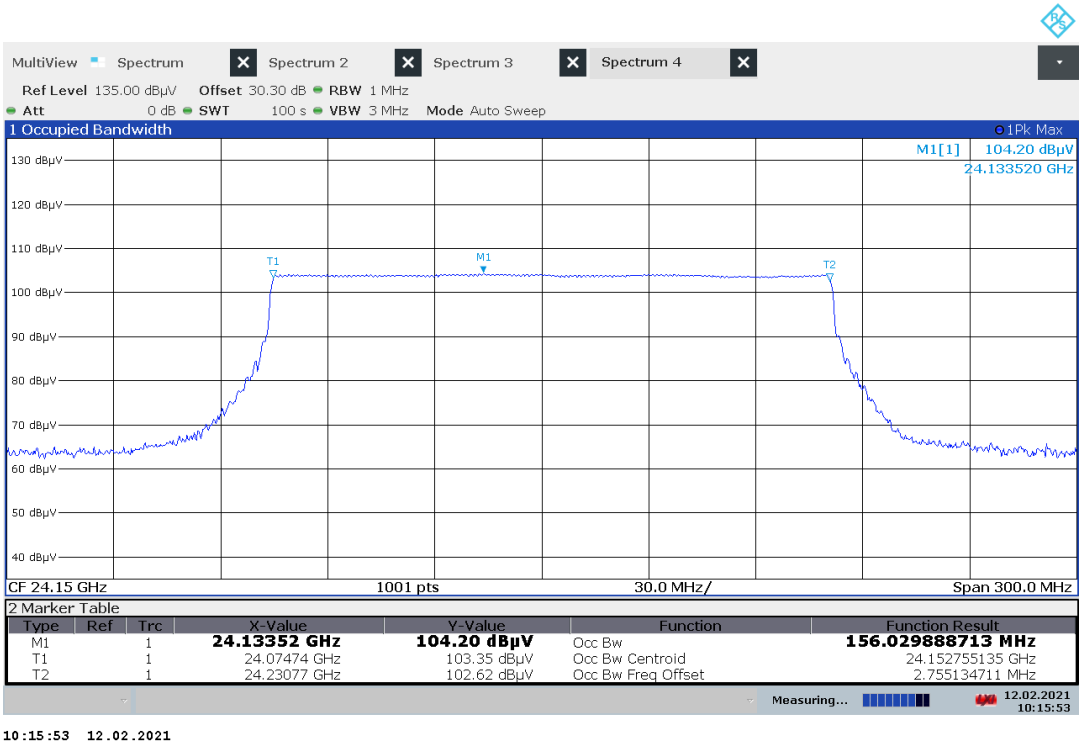
Test results

EUT mode	Temperature / Voltage	f_L [GHz]	f_H [GHz]	99% OBW [MHz]
NON-FIP	T_{max} / V_{nom}	24.076443	24.232539	156.097
NON-FIP	T_{nom} / V_{min}/V_{max}	24.074169	24.230458	156.289
NON-FIP	T_{min} / V_{nom}	24.07474	24.23077	156.030

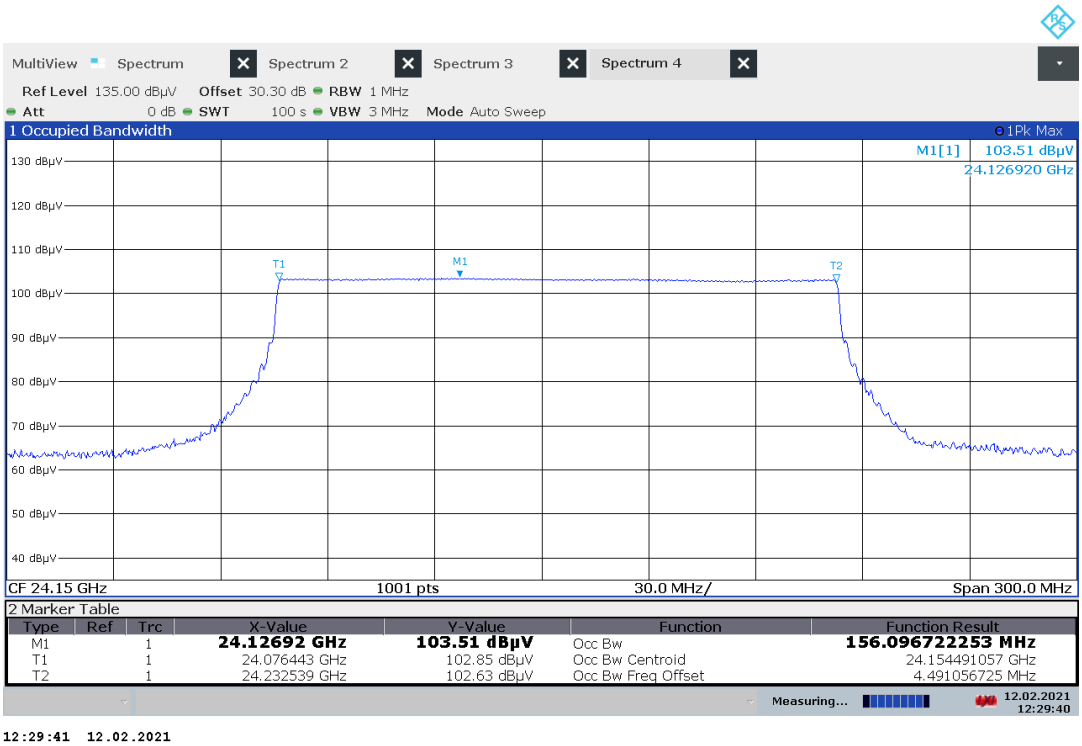
Plot no. 3: 99% OBW, Peak detector, T_{nom}



Plot no. 4: 99% OBW, Peak detector, T_{min}



Plot no. 5: 99% OBW, Peak detector, T_{max}



9.3 Field strength of emissions (wanted signal)

Description / Limits

§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	Field strength of harmonics
902 – 928 MHz	50 mV/m (94 dBµV/m)	500 µV/m (54 dBµV/m)
2400 – 2483.5 MHz	50 mV/m (94 dBµV/m)	500 µV/m (54 dBµV/m)
5725 – 5875 MHz	50 mV/m (94 dBµV/m)	500 µV/m (54 dBµV/m)
24.00 – 24.25 GHz	250 mV/m (108 dBµV/m)	2500 µV/m (68 dBµV/m)

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

Test procedure

§15.31 (c) Except as otherwise indicated in §15.256, for swept frequency equipment, measurements shall be made with the frequency sweep stopped at those frequencies chosen for the measurements to be reported.

§15.31 (m) Measurements on intentional radiators or receivers, other than TV broadcast receivers, shall be performed and, if required, reported for each band in which the device can be operated with the device operating at the number of frequencies in each band specified in the following table:

Frequency range	Number of frequencies	Location
< 1MHz bandwidth	1	middle
1 – 10 MHz bandwidth	2	1 near bottom and 1 near top
> 10 MHz bandwidth	3	1 near bottom / middle / top

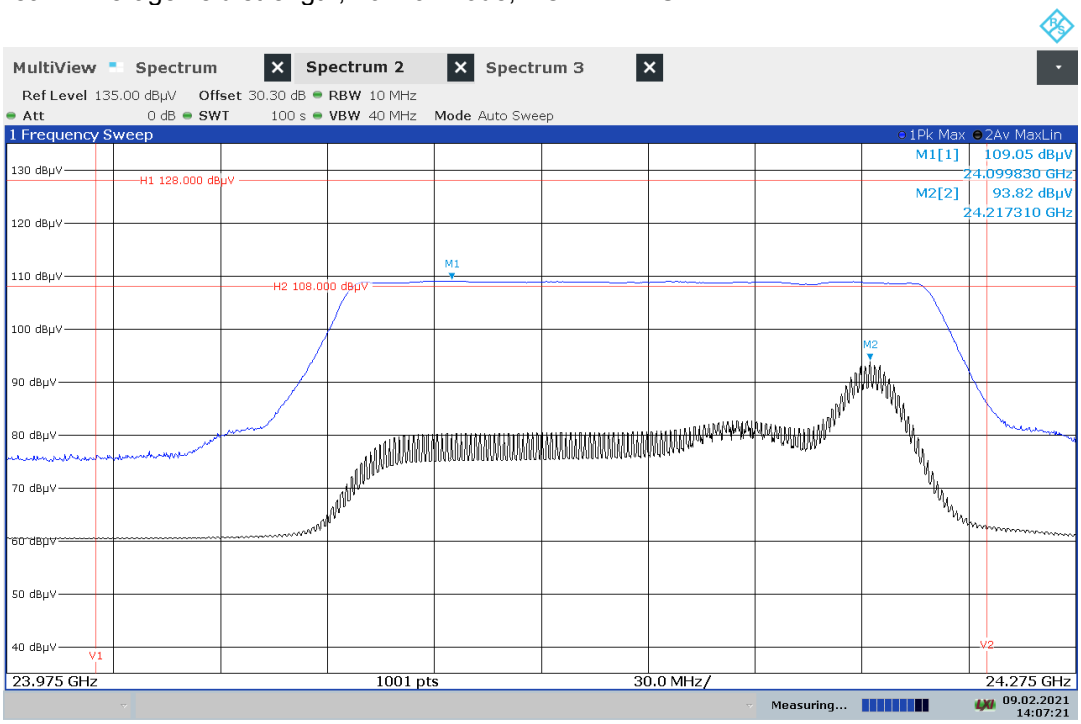
§15.35 (b) Unless otherwise specified, on any frequency or frequencies above 1000 MHz, the radiated emission limits are based on the use of measurement instrumentation employing an average detector function. Unless otherwise specified, measurements above 1000 MHz shall be performed using a minimum resolution bandwidth of 1 MHz. When average radiated emission measurements are specified in this part, including average emission measurements below 1000 MHz, there also is a limit on the peak level of the radio frequency emissions. Unless otherwise specified, e.g.,see §§15.250, 15.252, 15.253(d), 15.255, 15.256, and 15.509 through 15.519, the limit on peak radio frequency emissions is 20 dB above the maximum permitted average emission limit applicable to the equipment under test. This peak limit applies to the total peak emission level radiated by the device, e.g., the total peak power level. Note that the use of a pulse desensitization correction factor may be needed to determine the total peak emission level. The instruction manual or application note for the measurement instrument should be consulted for determining pulse desensitization factors, as necessary.

§15.35 (c) Unless otherwise specified, e.g., §§15.255(b), and 15.256(l)(5), 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 with any application for certification or shall be retained in the measurement data file for equipment subject to Supplier's Declaration of Conformity.

Test results

EUT mode	EUT	Test distance	AVG field strength [dBµV/m]	PK field strength [dBµV/m]
Normal	NON-FIP	1 m	93.8	109.1
Normal	FIP	1 m	93.2	108.8
B / M / T	NON-FIP	1 m	110.7	110.8

Plot no. 6: Peak / Average field strength, normal mode, NON-FIP EUT



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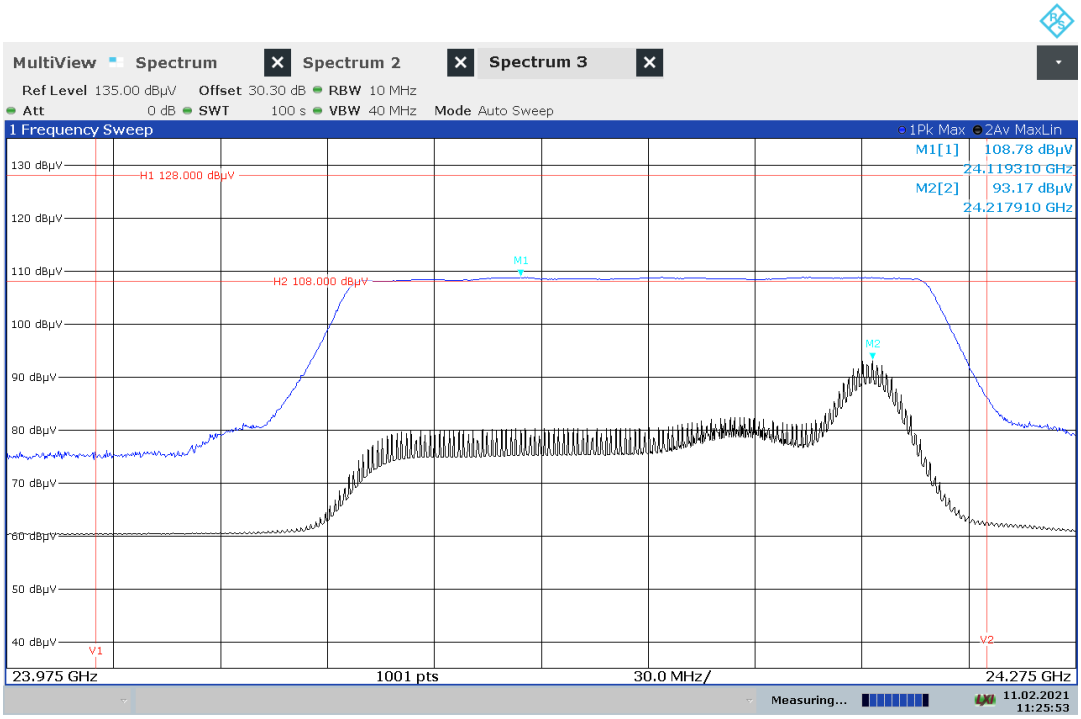
Plot no. 7: Peak / Average field strength, normal mode, FIP EUT



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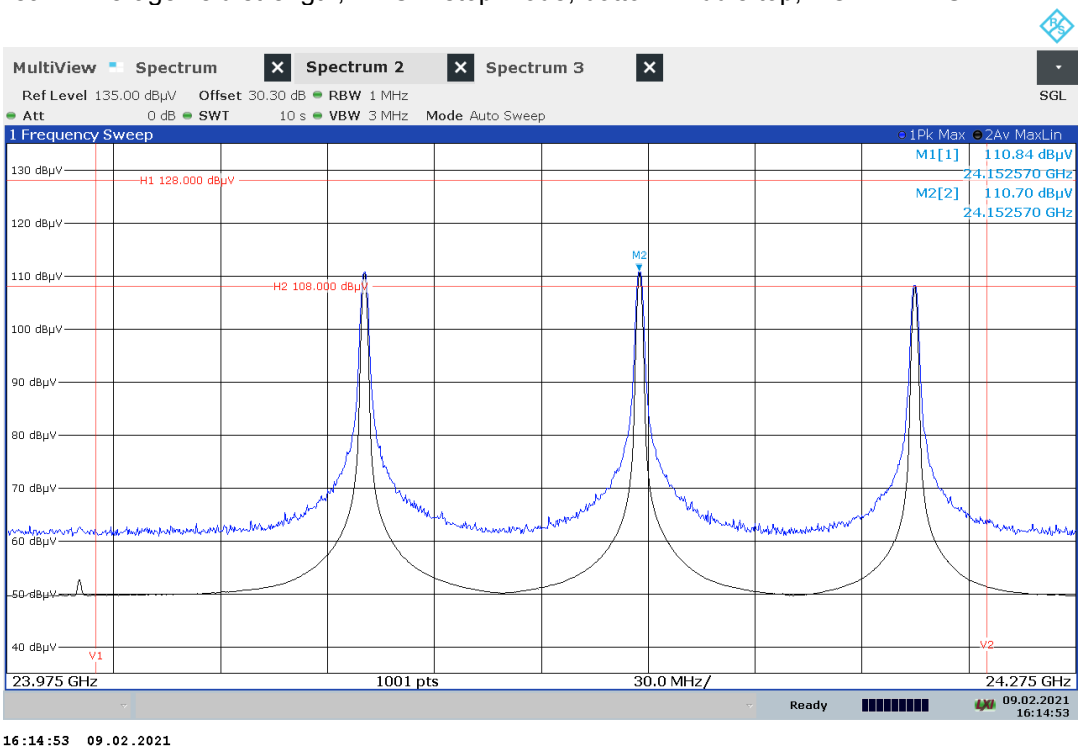
Plot no. 8: Peak / Average field strength, FMCW stop mode, bottom/middle/top, NON-FIP EUT



Note: CW-mode (B/M/T) with duty cycle of 100%, duty cycle of normal mode needs to be considered!

9.4 Field strength of emissions (spurious and harmonics)

Description / Limits

§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	Field strength of harmonics
902 – 928 MHz	50 mV/m (94 dBµV/m)	500 µV/m (54 dBµV/m)
2400 – 2483.5 MHz	50 mV/m (94 dBµV/m)	500 µV/m (54 dBµV/m)
5725 – 5875 MHz	50 mV/m (94 dBµV/m)	500 µV/m (54 dBµV/m)
24.00 – 24.25 GHz	250 mV/m (108 dBµV/m)	2500 µV/m (68 dBµV/m)

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

§15.249 (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:

Frequency	Field Strength	Measurement distance
0.009 – 0.490 MHz	2400/F[kHz] µV/m	300 m
0.490 – 1.705 MHz	24000/F[kHz] µV/m	30 m
1.705 – 30.0 MHz	30.0 µV/m / 29.5 dBµV/m	30 m
30 – 88 MHz	100 µV/m / 40.0 dBµV/m	3 m
88 – 216 MHz	150 µV/m / 43.5 dBµV/m	3 m
216 – 960 MHz	200 µV/m / 46.0 dBµV/m	3 m
960 – 100 000 MHz	500 µV/m / 54.0 dBµV/m	3 m

§15.249 (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.

Test procedure

§15.31 (c) Except as otherwise indicated in §15.256, for swept frequency equipment, measurements shall be made with the frequency sweep stopped at those frequencies chosen for the measurements to be reported.

§15.31 (m) Measurements on intentional radiators or receivers, other than TV broadcast receivers, shall be performed and, if required, reported for each band in which the device can be operated with the device operating at the number of frequencies in each band specified in the following table:

Frequency range	Number of frequencies	Location
< 1MHz bandwidth	1	middle
1 – 10 MHz bandwidth	2	1 near bottom and 1 near top
> 10 MHz bandwidth	3	1 near bottom / middle / top

§15.35 (b) Unless otherwise specified, on any frequency or frequencies above 1000 MHz, the radiated emission limits are based on the use of measurement instrumentation employing an average detector function. Unless otherwise specified, measurements above 1000 MHz shall be performed using a minimum resolution bandwidth of 1 MHz. When average radiated emission measurements are specified in this part, including average emission measurements below 1000 MHz, there also is a limit on the peak level of the radio frequency emissions. Unless otherwise specified, e.g.,see §§15.250, 15.252, 15.253(d), 15.255, 15.256, and 15.509 through 15.519, the limit on peak radio frequency emissions is 20 dB above the maximum permitted average emission limit applicable to the equipment under test. This peak limit applies to the total peak emission level radiated by the device, e.g., the total peak power level. Note that the use of a pulse desensitization correction factor may be needed to determine the total peak emission level. The instruction manual or application note for the measurement instrument should be consulted for determining pulse desensitization factors, as necessary.

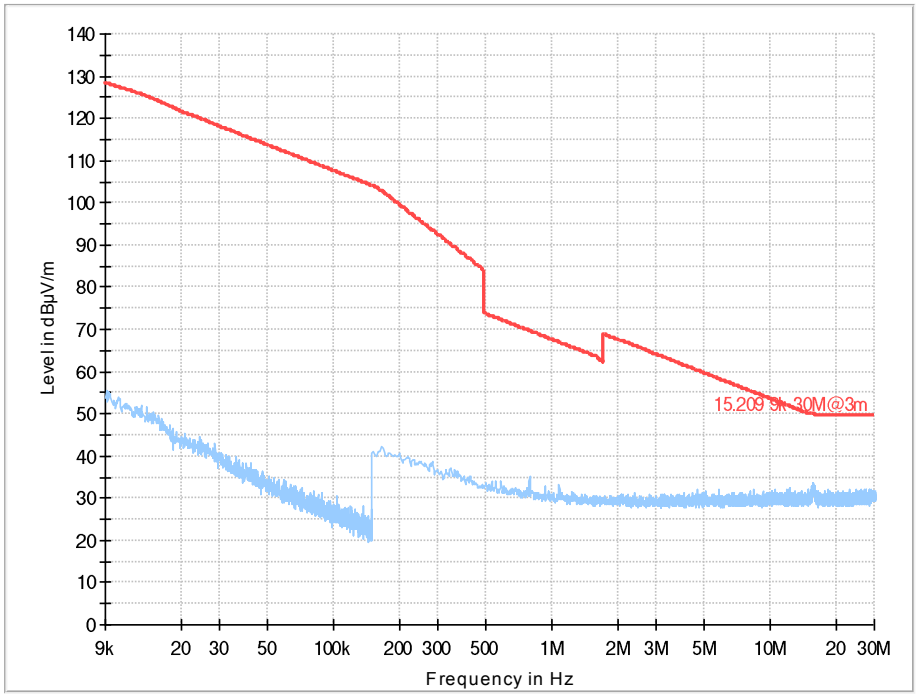
§15.35 (c) Unless otherwise specified, e.g., §§15.255(b), and 15.256(l)(5), when the radiated emission limits are expressed in terms of the average value of the emission, and pulsed operation is employed, the measurement field strength shall be determined by averaging over one complete pulse train, including 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 with any application for certification or shall be retained in the measurement data file for equipment subject to Supplier's Declaration of Conformity.

Typical test distances

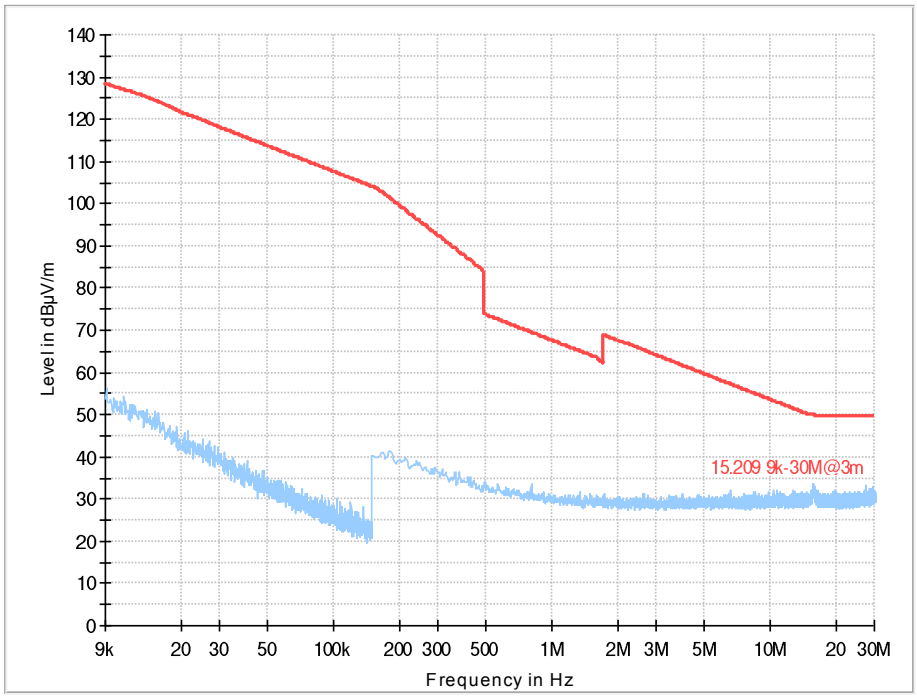
Up to 18 GHz: 3.00 m
18 – 50 GHz: 0.50 m
50 – 110 GHz: 0.25 m
110 – 245 GHz: 0.10 m
In-band / OOB: 1m

Channel / Mode	Frequency [GHz]	Detector	Test distance [m]	Level [dBµV/m]	Limit [dBµV/m]	Margin [dB]
NON-FIP	0.32	QP	3	33.8	46.0	12.2
NON-FIP	0.48	QP	3	36.2	46.0	9.8
NON-FIP	0.64	QP	3	45.0	46.0	1.0
NON-FIP	12.087	AVG	3	43.2	54.0	10.8
NON-FIP	48.435	AVG	0.5	52.9	68.0	15.1
NON-FIP	72.651	AVG	0.25	43.6	68.0	24.4
FIP	12.075	AVG	3	43.8	54.0	10.2
FIP	48.434	AVG	0.5	51.8	68.0	16.2

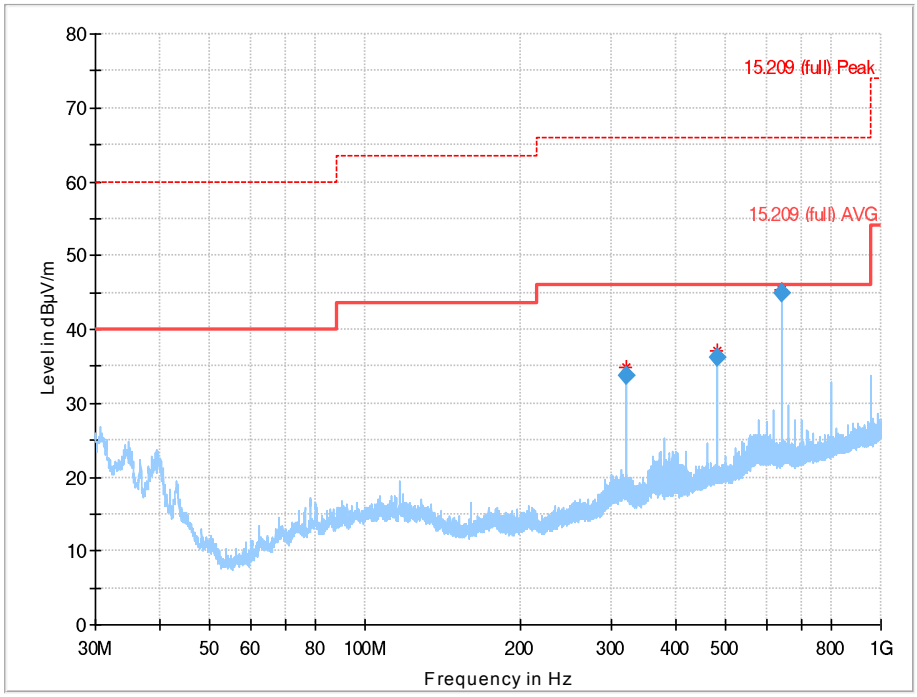
Plot no. 9: radiated emissions 9 kHz – 30 MHz, loop antenna, NON-FIP EUT



Plot no. 10: radiated emissions 9 kHz – 30 MHz, loop antenna, FIP-EUT



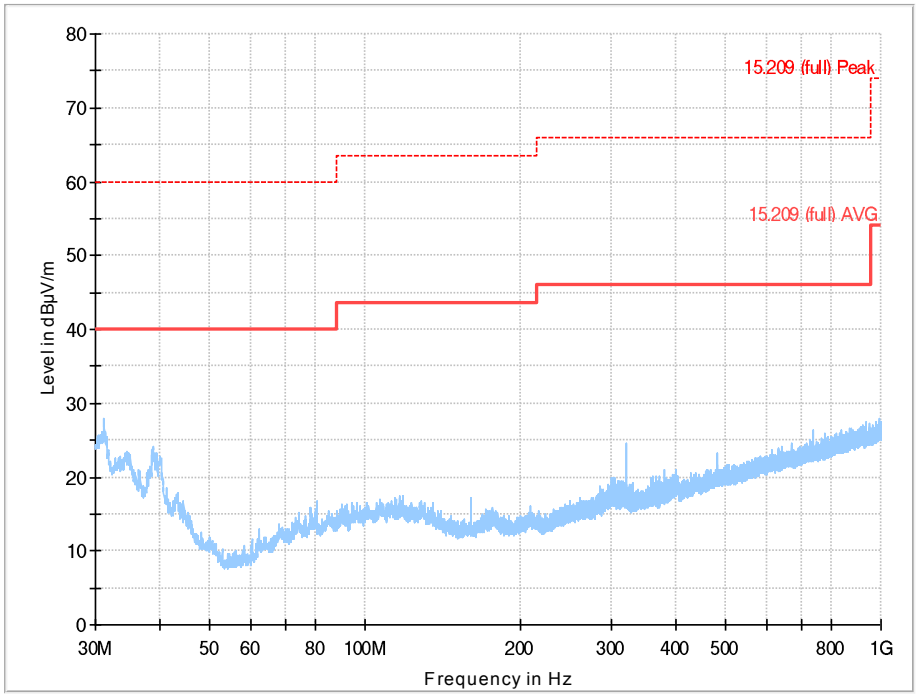
Plot no. 11: radiated emissions 30 MHz – 1 GHz, hor./vert. polarization, NON-FIP EUT



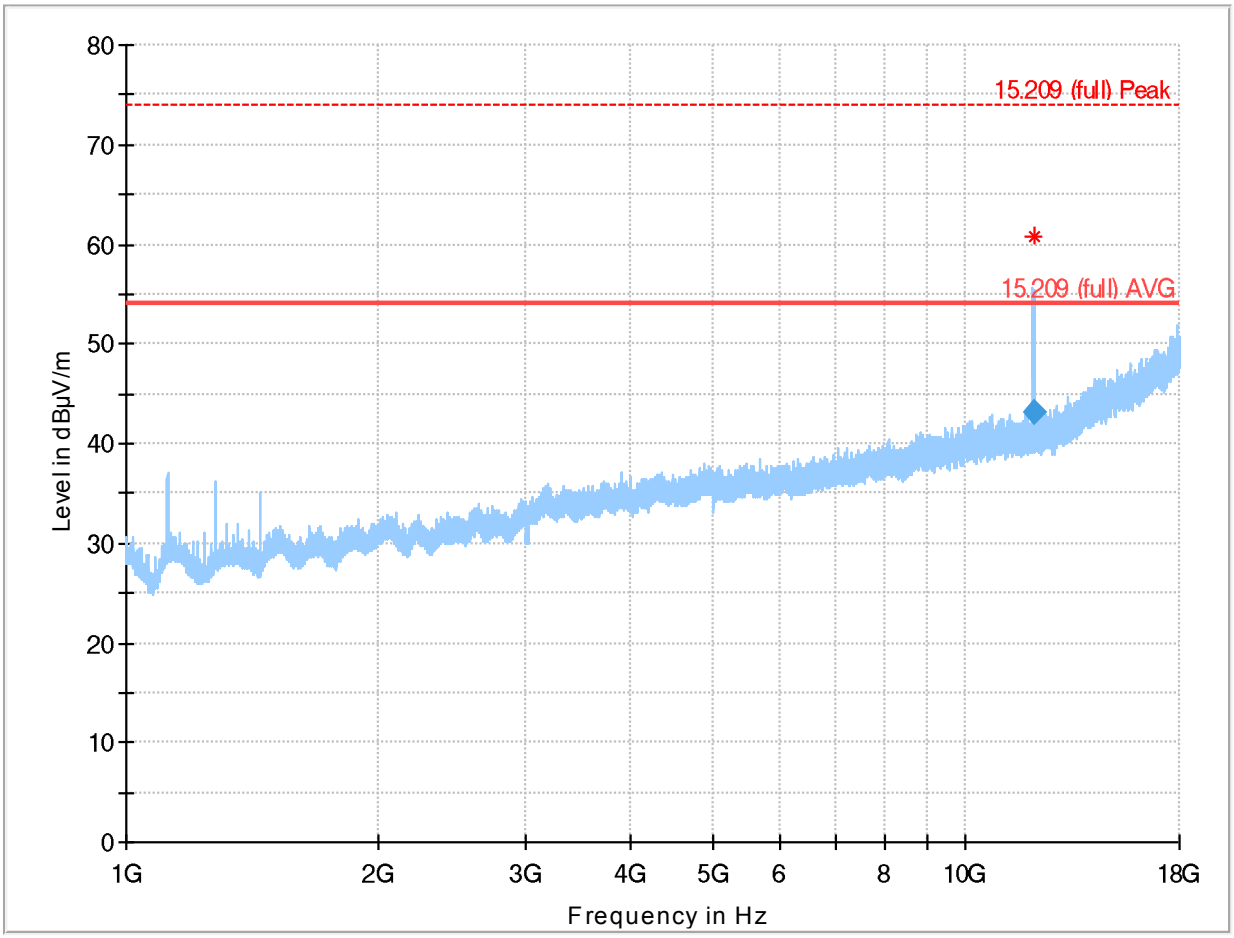
Final_Result

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)
320.000000	33.82	46.00	12.18	100.0	120.000	120.0	V	184.0
480.000000	36.17	46.00	9.83	100.0	120.000	138.0	V	246.0
640.000000	44.96	46.00	1.04	100.0	120.000	103.0	V	150.0

Plot no. 12: radiated emissions 30 MHz – 1 GHz, hor./vert. polarization, FIP EUT



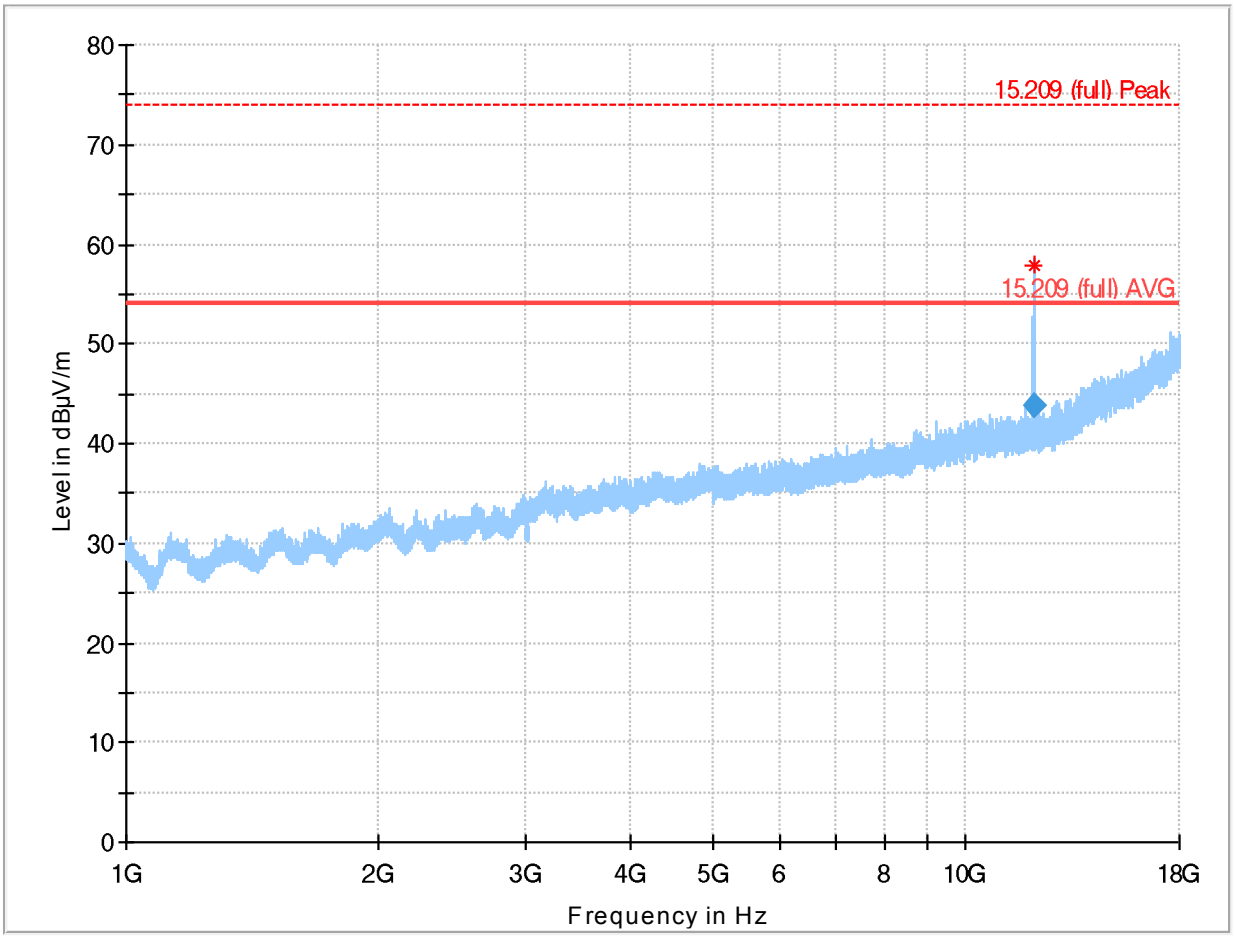
Plot no. 13: radiated emissions 1 GHz – 18 GHz, hor./vert. polarization, NON-FIP EUT



Final_Result

Frequency (MHz)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)
12087.225000	43.20	54.00	10.80	100.0	1000.000	150.0	H	73.0

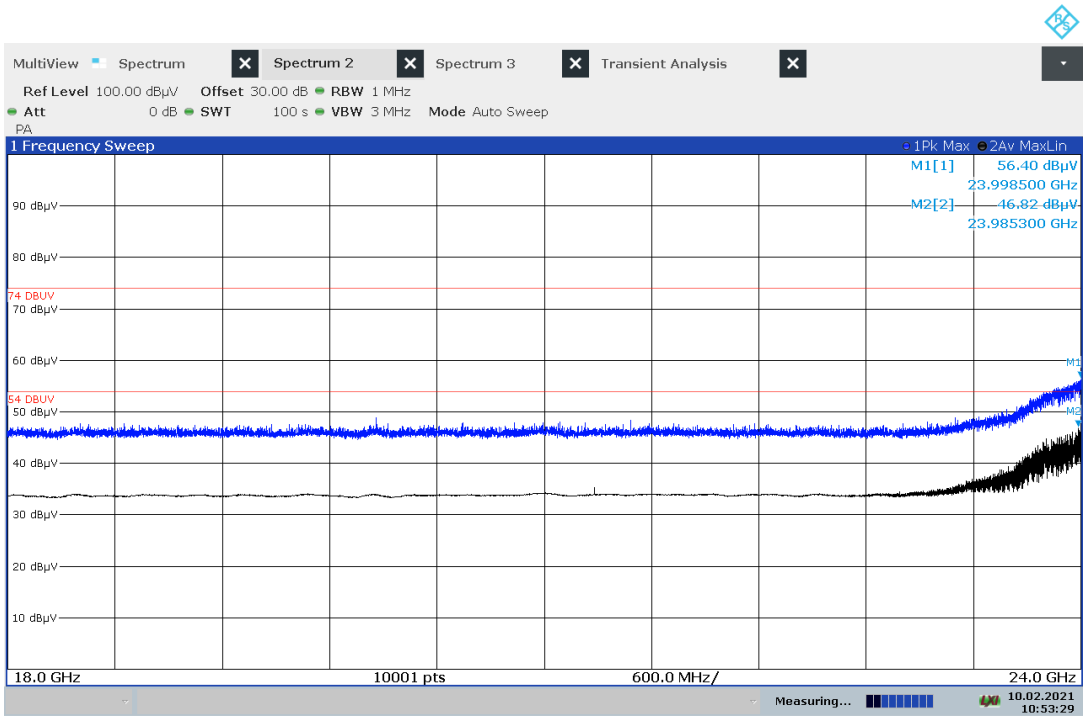
Plot no. 14: radiated emissions 1 GHz – 18 GHz, hor./vert. polarization, FIP EUT



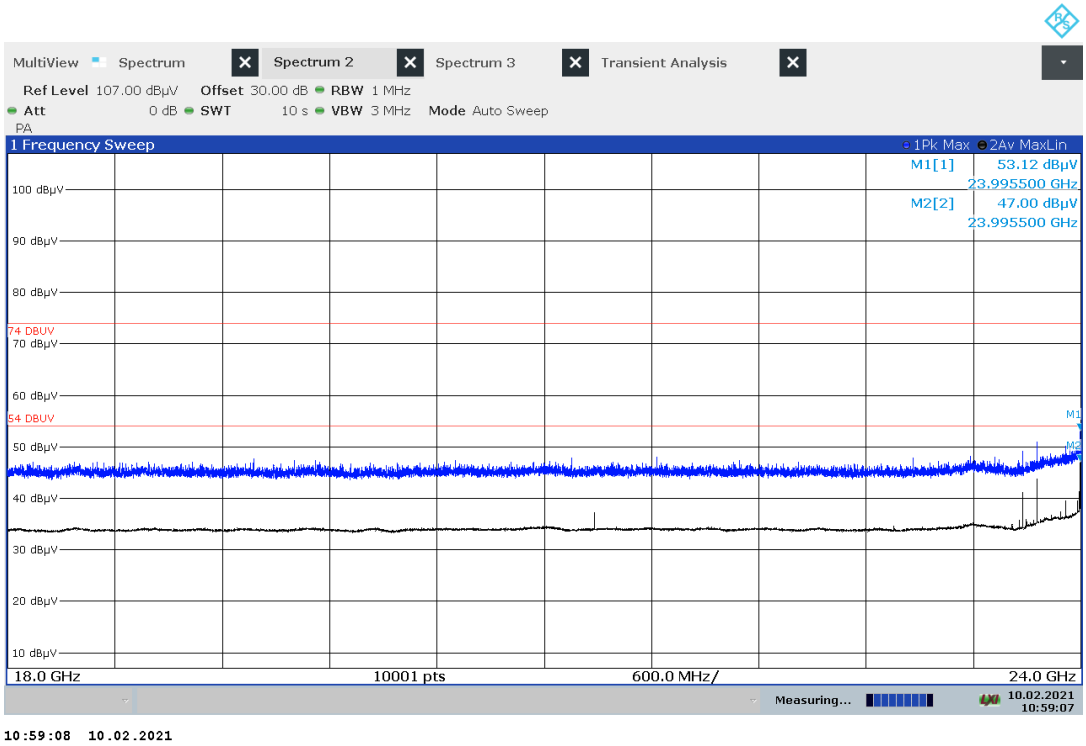
Final_Result

Frequency (MHz)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)
12074.850000	43.78	54.00	10.22	100.0	1000.000	150.0	H	82.0

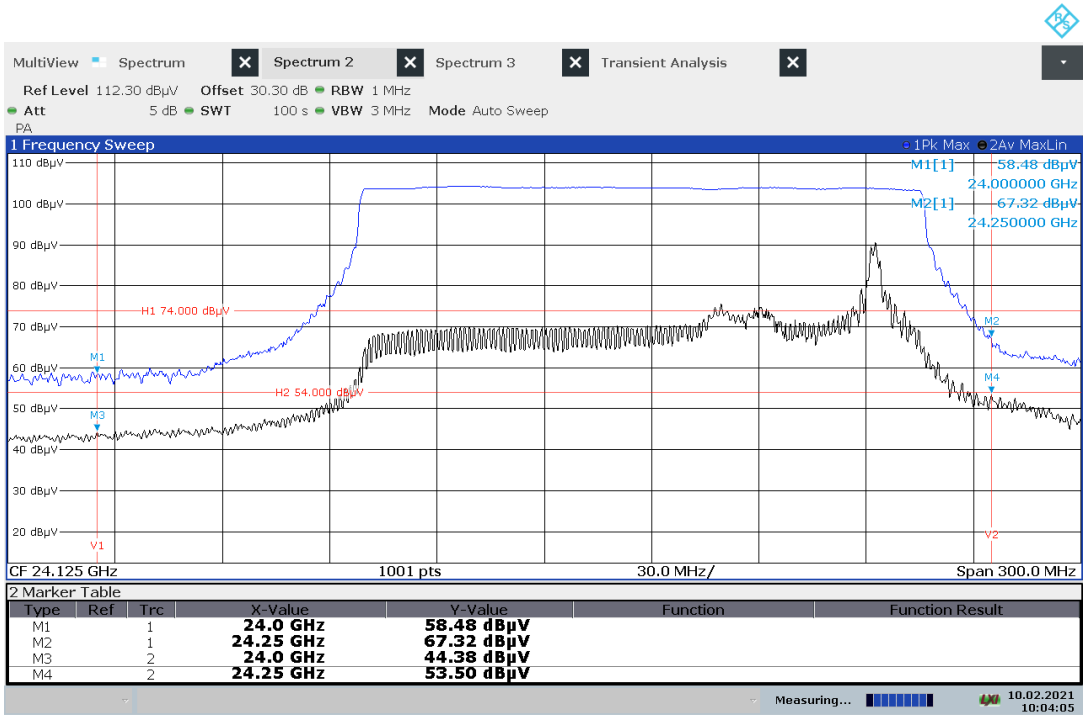
Plot no. 15: radiated emissions 18 GHz – 24 GHz, hor./vert. polarization, normal mode, NON-FIP EUT



Plot no. 16: radiated emissions 18 GHz – 24 GHz, hor./vert. polarization, FMCW stop mode, bottom, NON-FIP



Plot no. 17: band edge compliance 24 GHz – 24.25 GHz, hor./vert. polarization, normal mode, NON-FIP EUT



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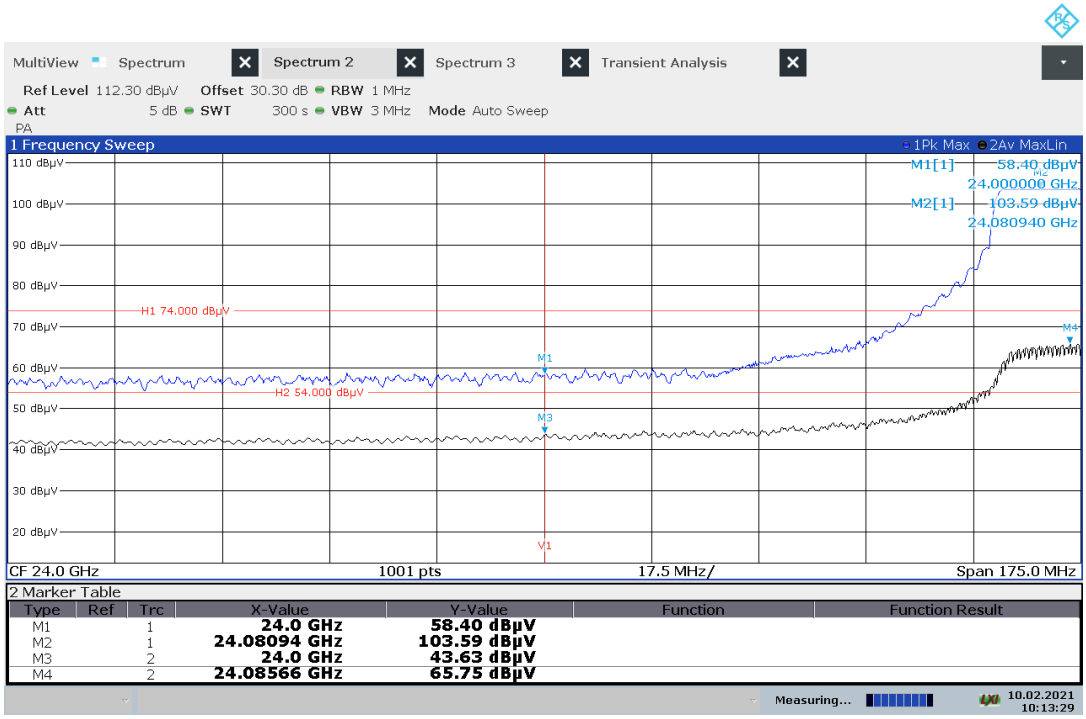
Plot no. 18: band edge compliance 24 GHz, hor./vert. polarization, normal mode, NON-FIP EUT



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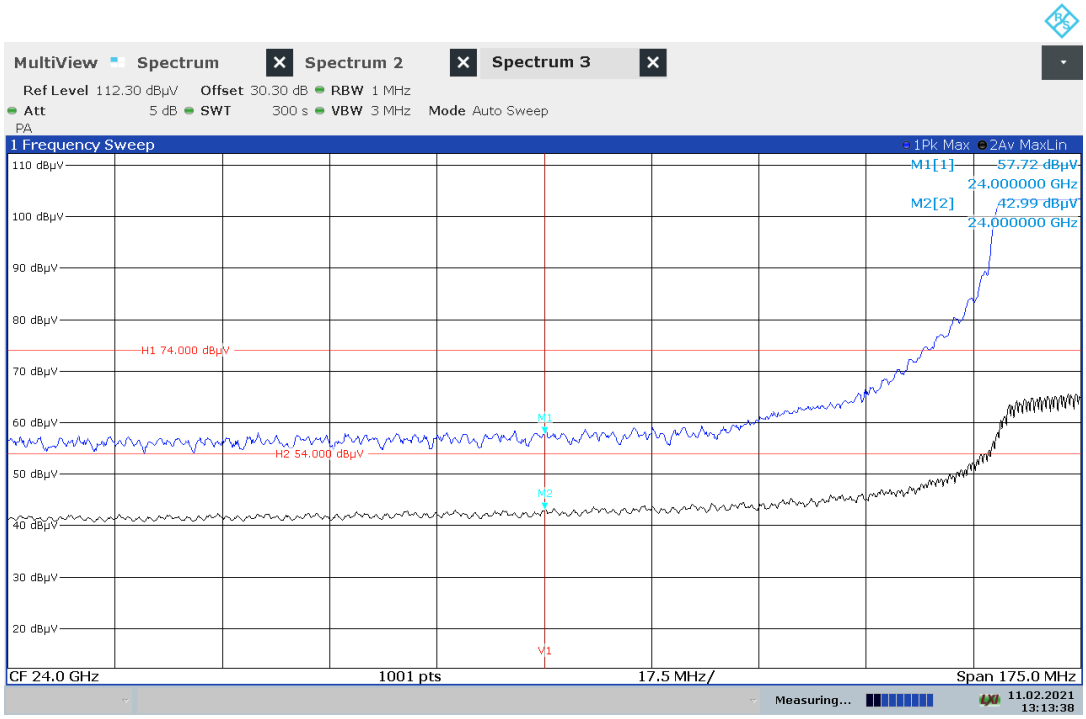
Plot no. 19: band edge compliance 24 GHz, hor./vert. polarization, FMCW stop mode, bottom, NON-FIP EUT

10:17:41 10.02.2021

Plot no. 20: band edge compliance 24 GHz, hor./vert. polarization, normal mode, FIP EUT



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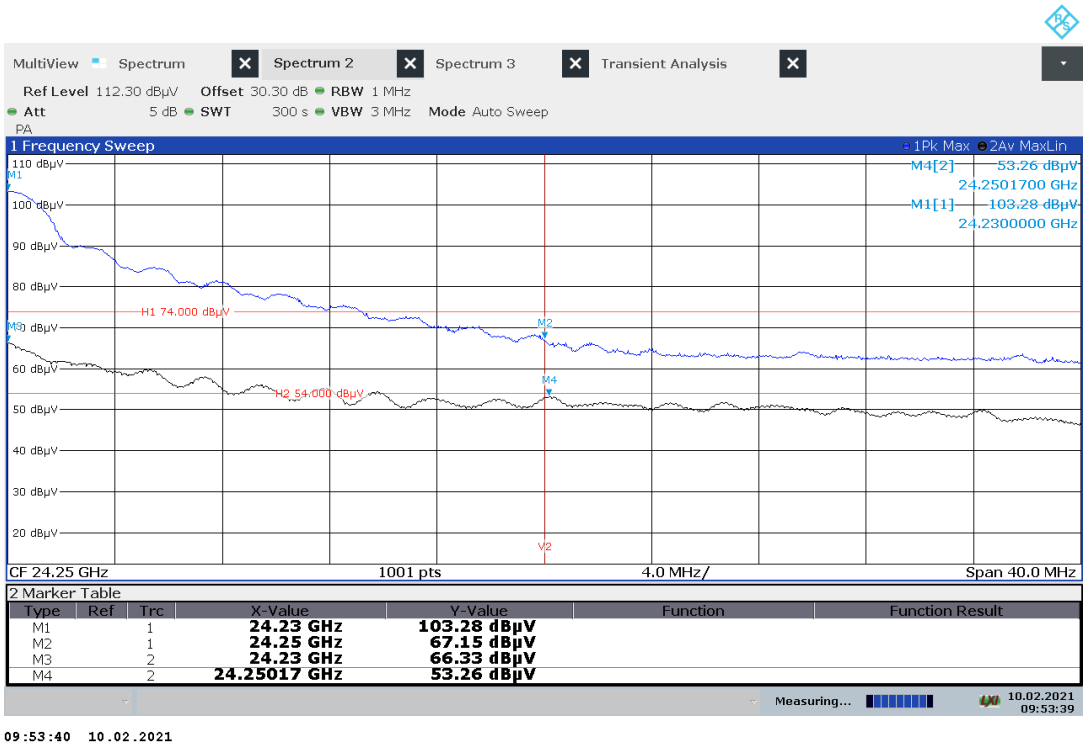
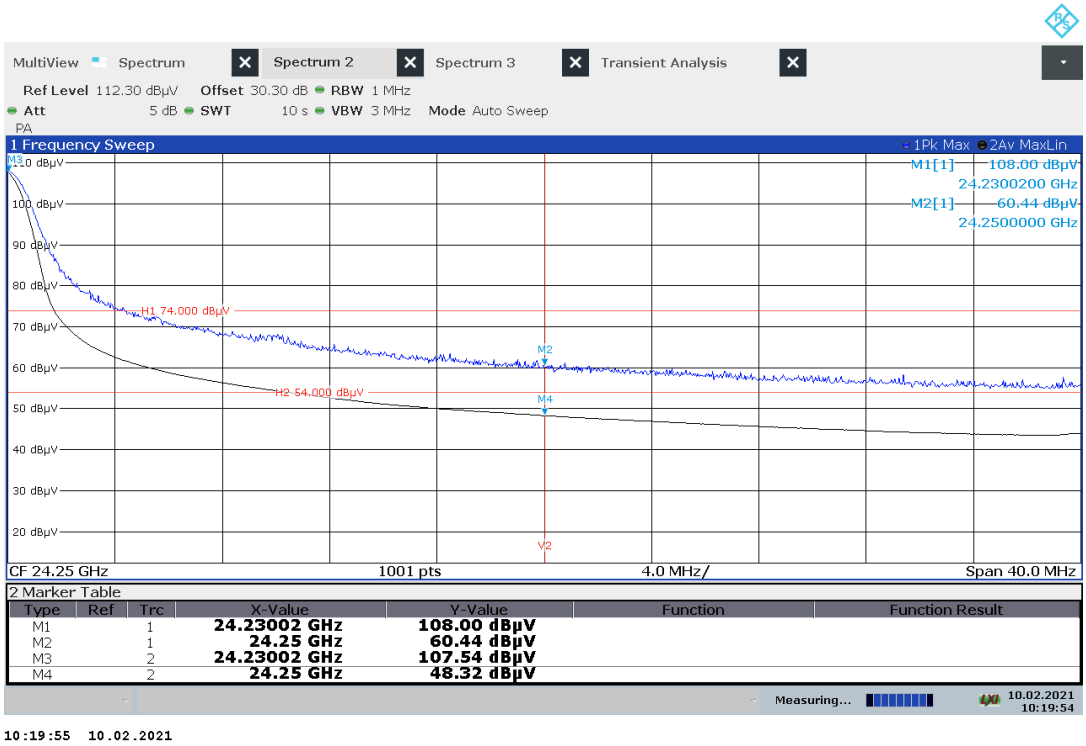
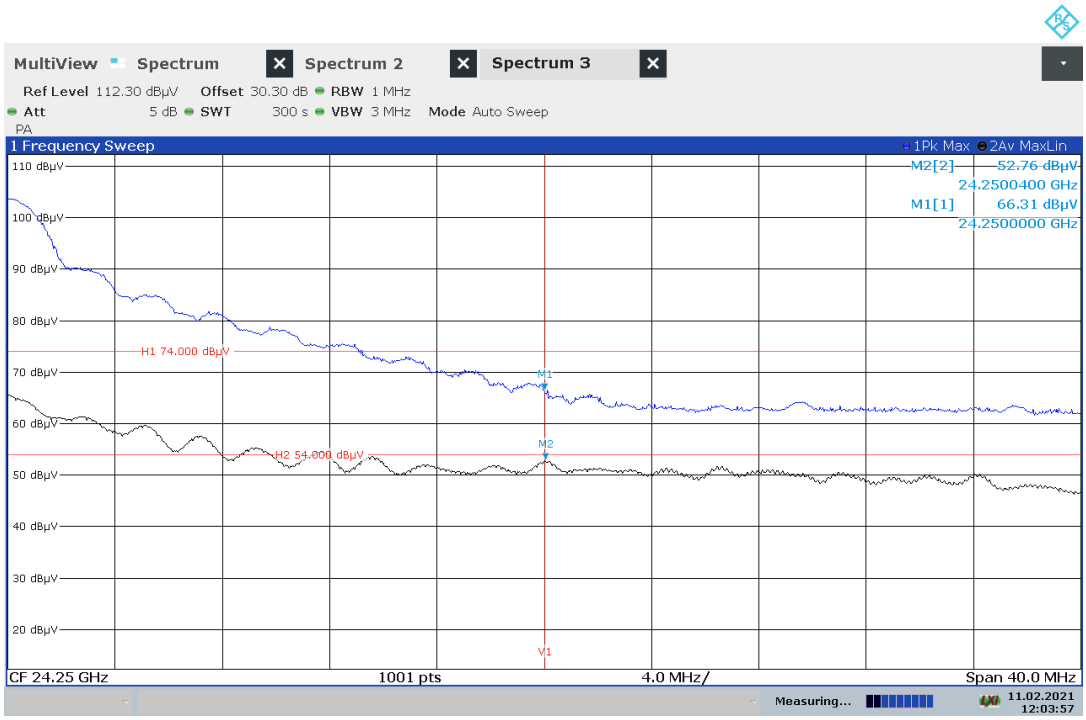
Plot no. 21: band edge compliance 24.25 GHz, hor./vert. polarization, normal mode, NON-FIP EUT



Plot no. 22: band edge compliance 24.25 GHz, hor./vert. polarization, FMCW stop mode, top, NON-FIP EUT

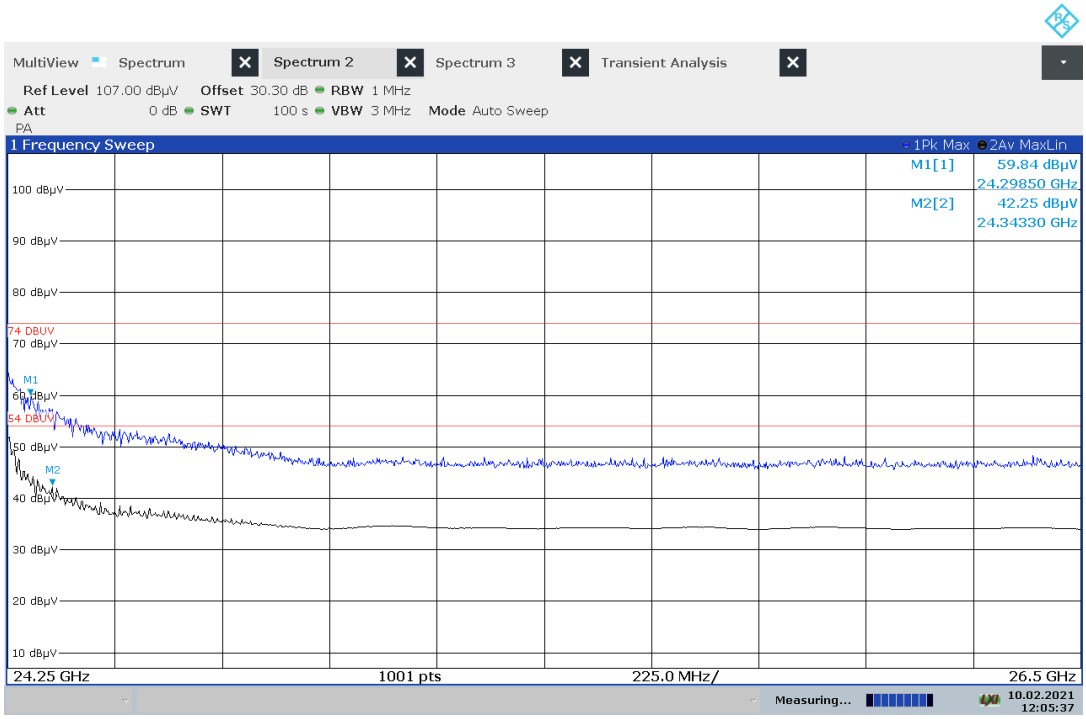


Plot no. 23: band edge compliance 24.25 GHz, hor./vert. polarization, normal mode, FIP EUT



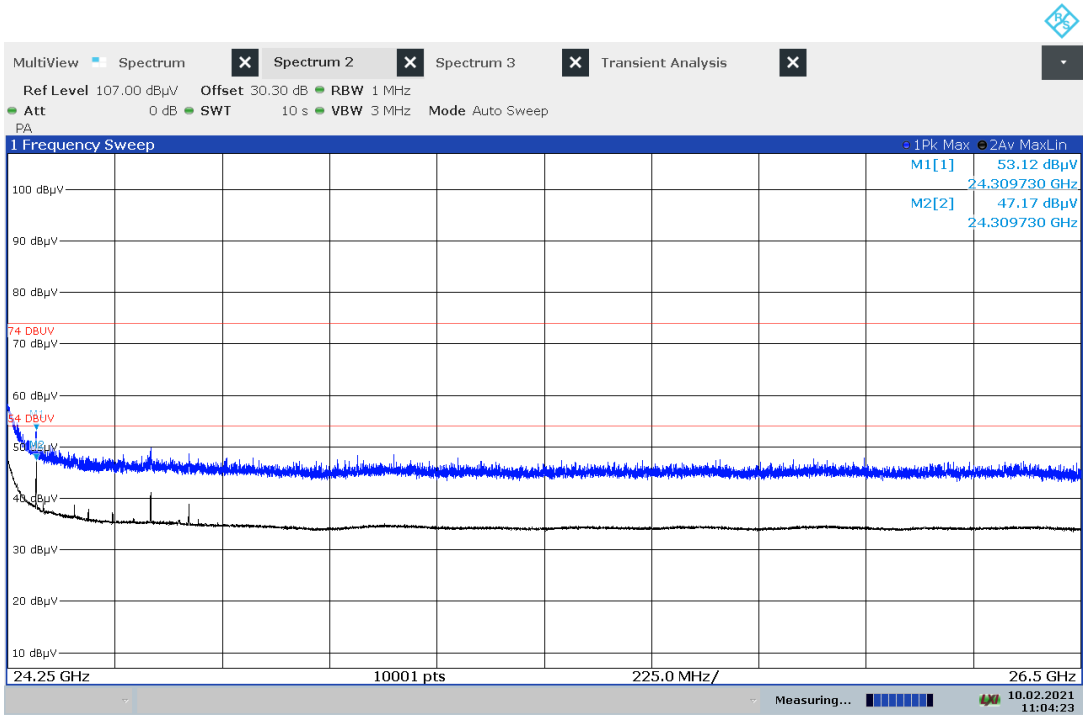
12:03:58 11.02.2021

Plot no. 24: radiated emissions 24.25 GHz – 26.5 GHz, hor./vert. polarization, normal mode, NON-FIP EUT



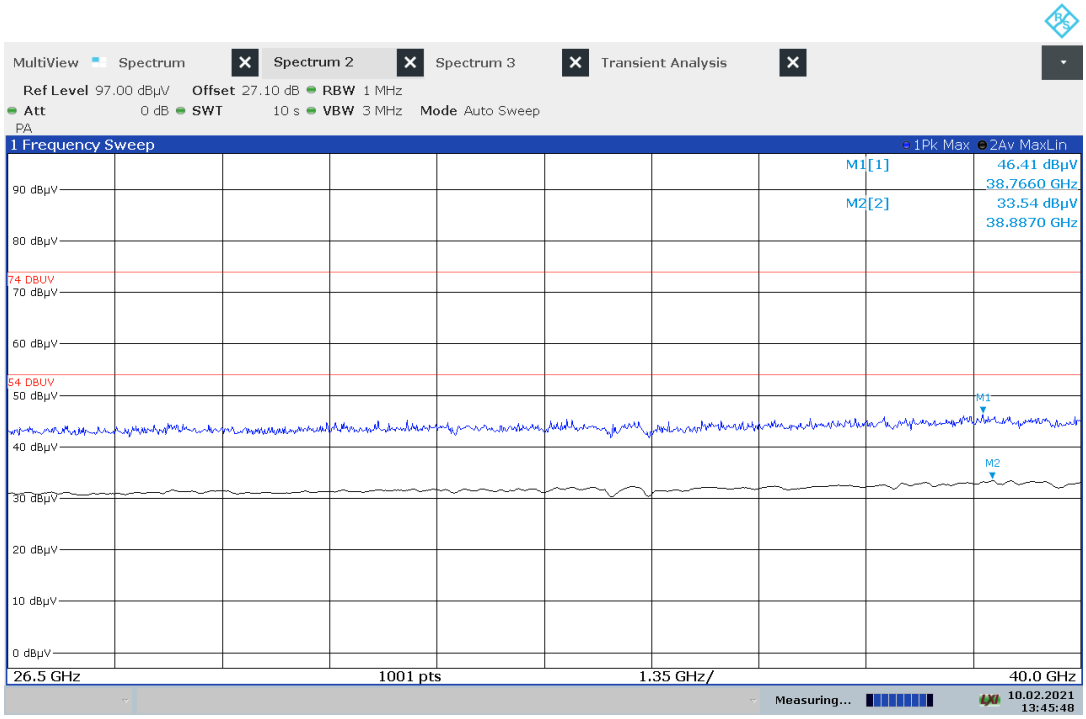
12:05:37 10.02.2021

Plot no. 25: radiated emissions 24.25 GHz – 26.5 GHz, hor./vert. polarization, FMCW stop mode, top, NON-FIP



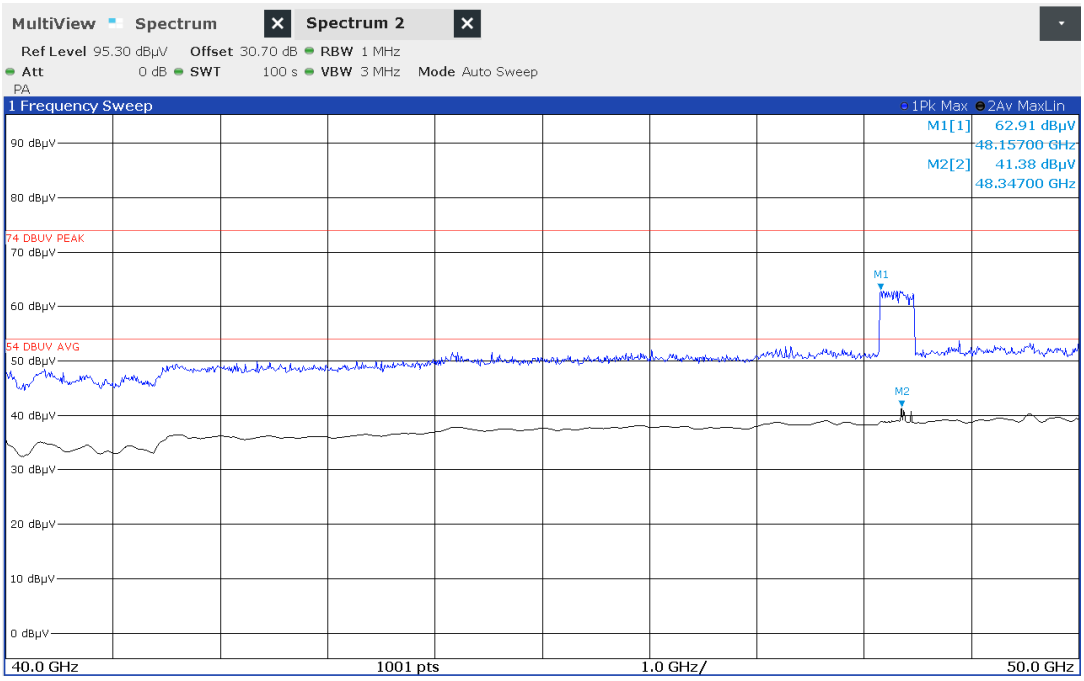
11:04:24 10.02.2021

Plot no. 26: radiated emissions 26.5 GHz – 40 GHz, hor./vert. polarization, normal mode, NON-FIP EUT

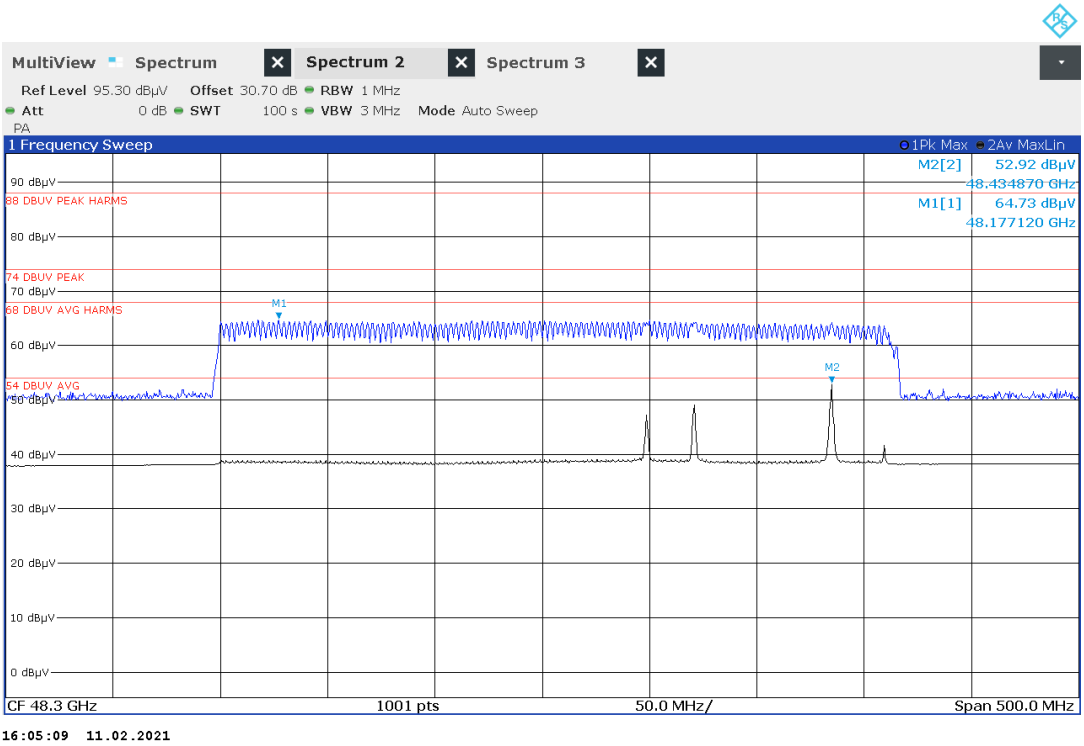


13:45:48 10.02.2021

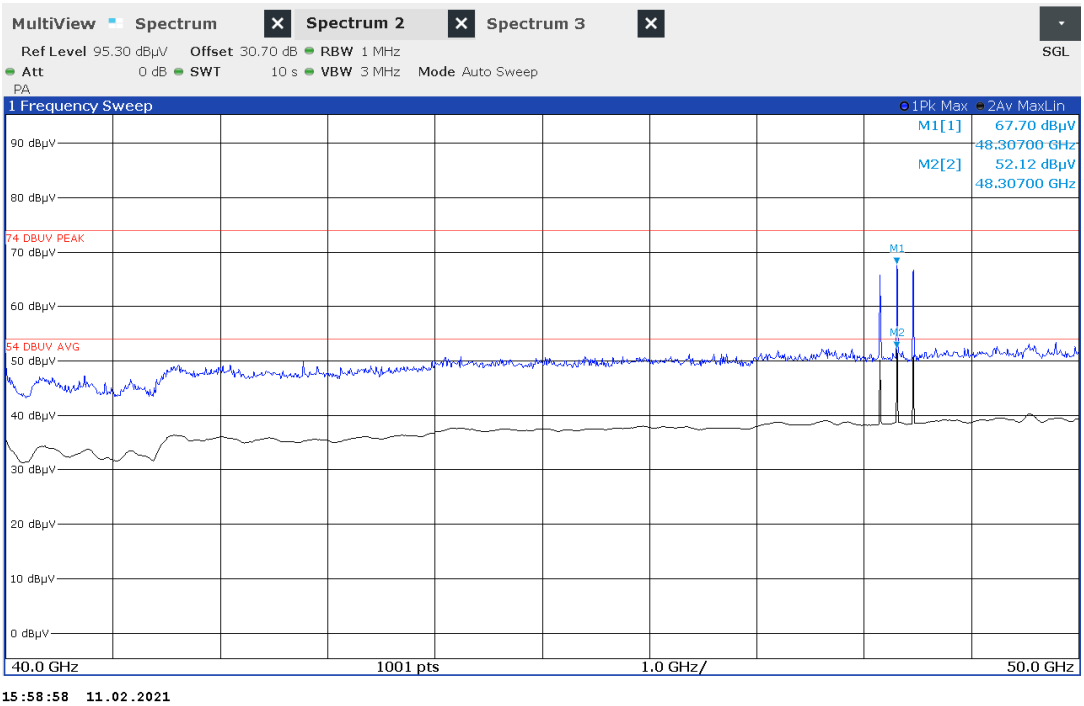
Plot no. 27: radiated emissions 40 GHz – 50 GHz, hor./vert. polarization, normal operation, NON-FIP EUT



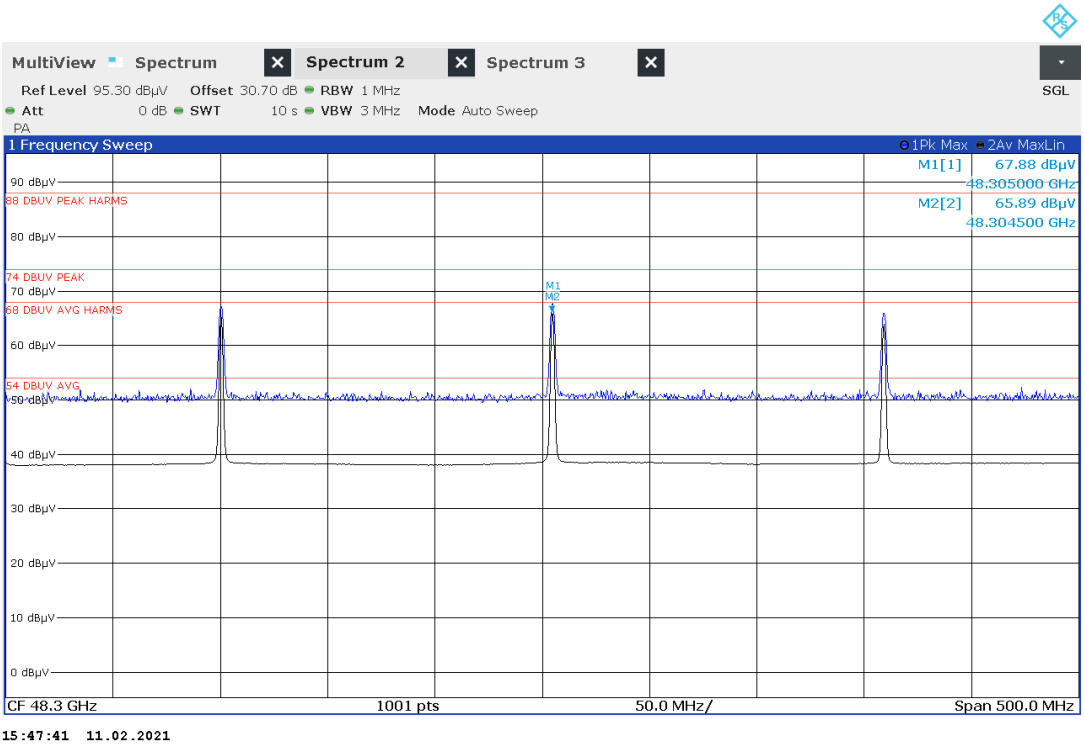
Plot no. 28: radiated emissions 48.3 GHz range (2nd harmonic), hor./vert. polarization, normal mode, NON-FIP



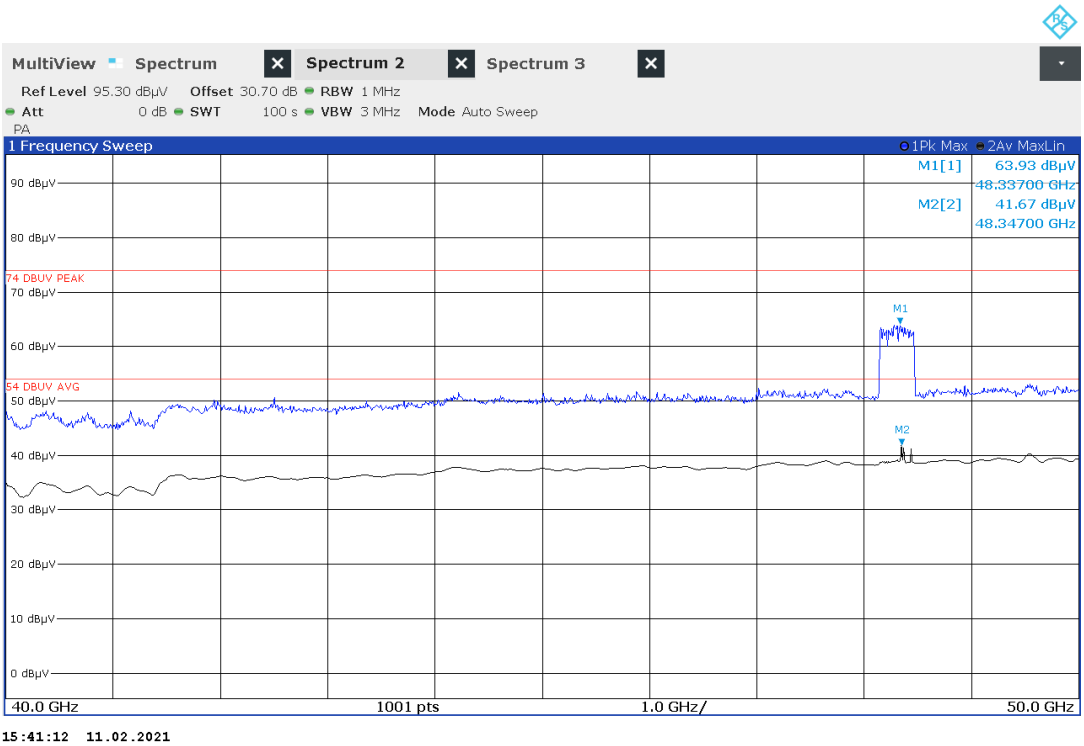
Plot no. 29: radiated emissions 40 GHz – 50 GHz, hor./vert. polarization, FMCW stop mode B/M/T, NON-FIP



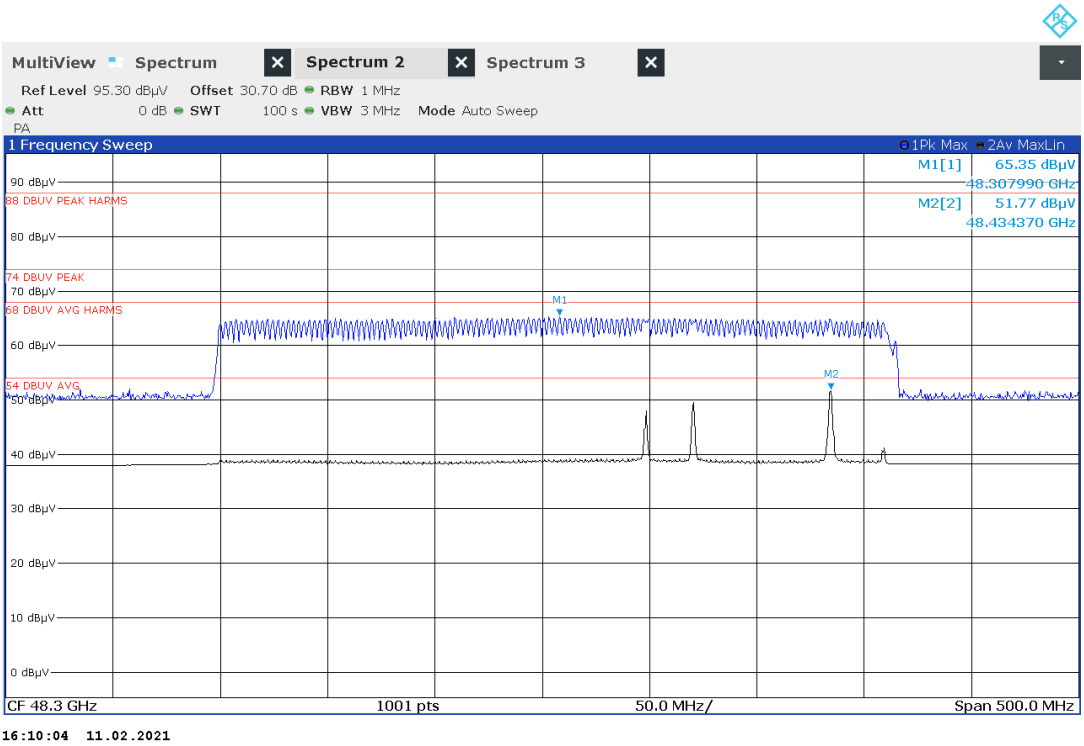
Plot no. 30: radiated emissions 48.3 GHz range (2nd harmonic), hor./vert. polarization, B/M/T, NON-FIP EUT



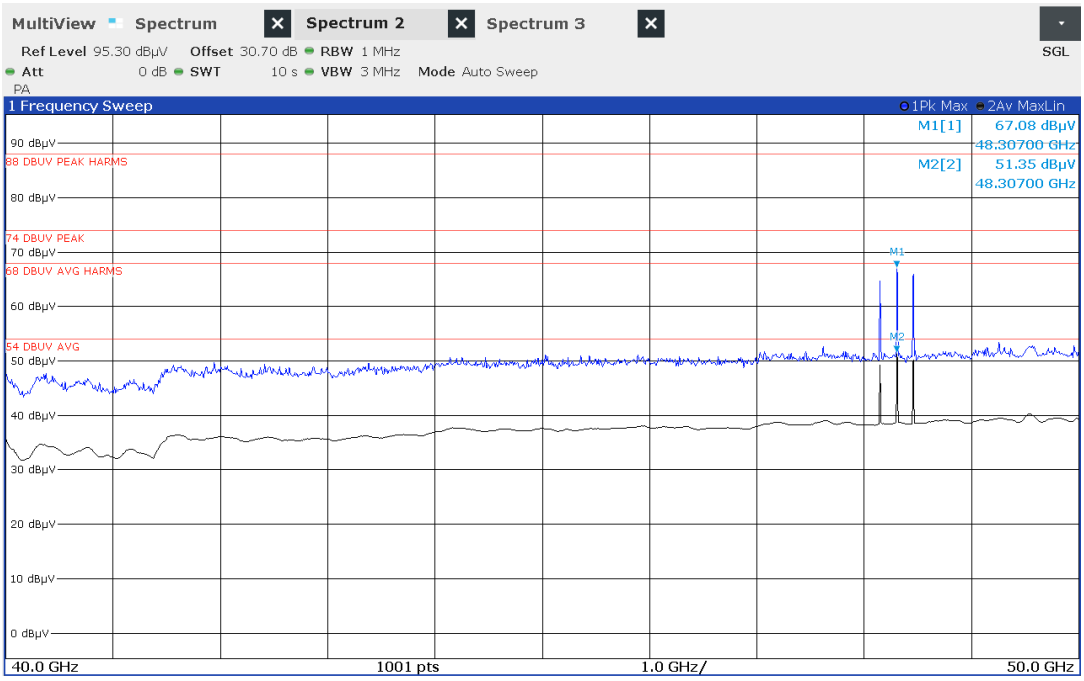
Plot no. 31: radiated emissions 40 GHz – 50 GHz, hor./vert. polarization, normal operation, FIP EUT



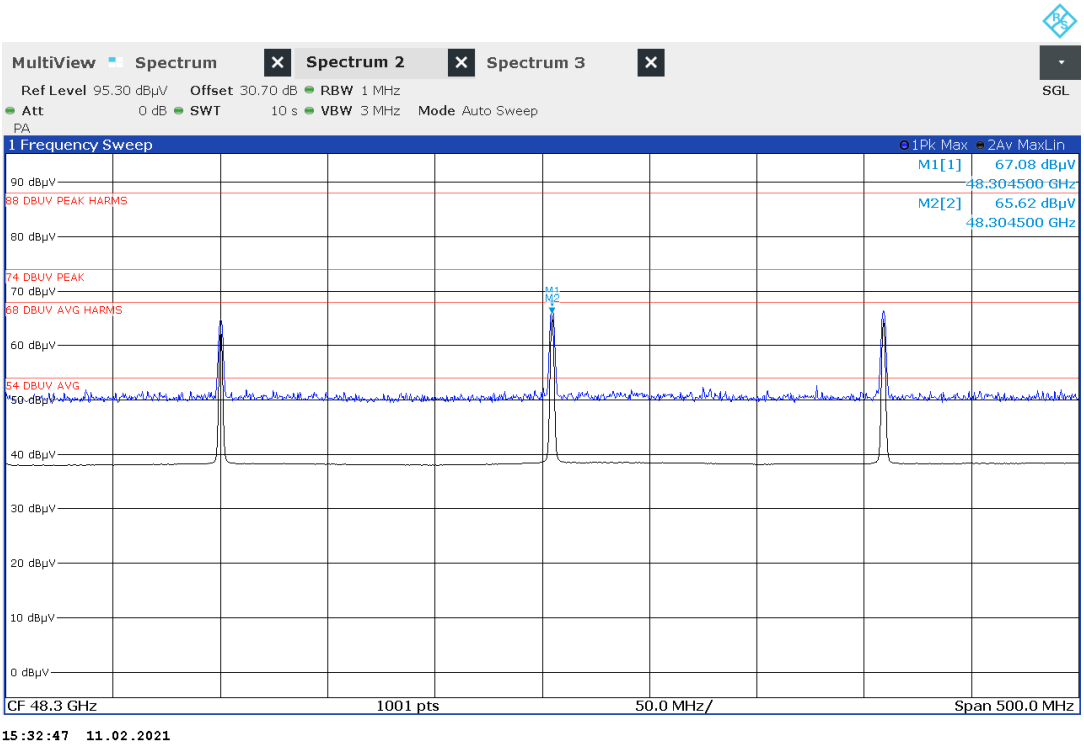
Plot no. 32: radiated emissions 48.3 GHz range (2nd harmonic), hor./vert. polarization, normal mode, FIP EUT



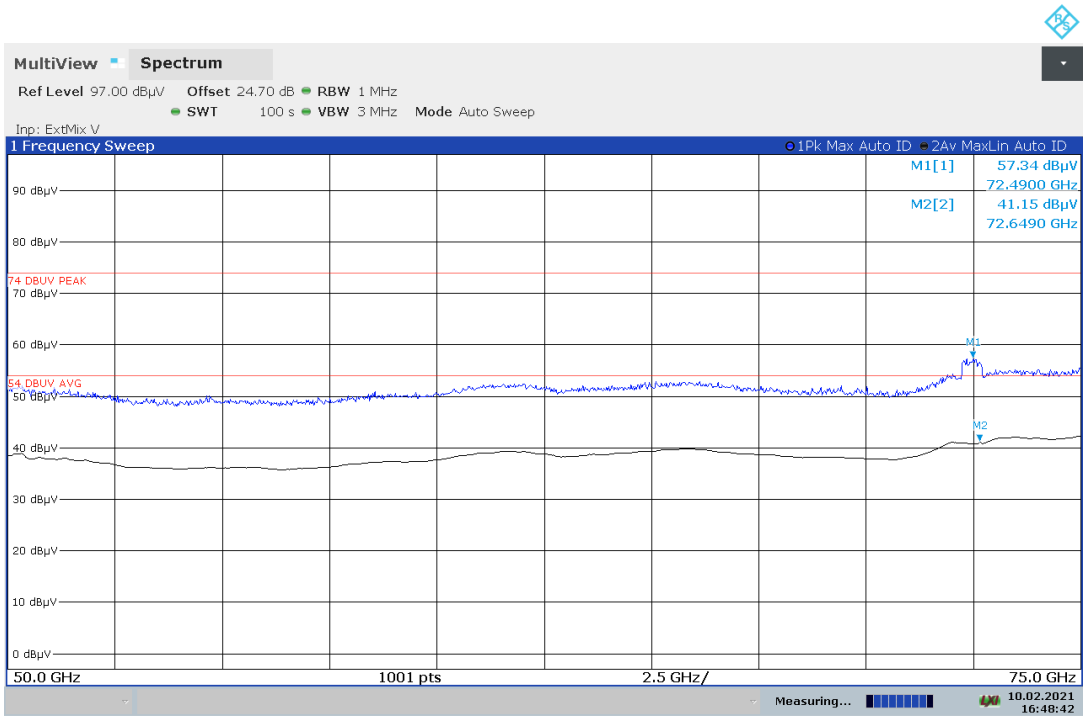
Plot no. 33: radiated emissions 40 GHz – 50 GHz, hor./vert. polarization, FMCW stop mode B/M/T, FIP EUT



Plot no. 34: radiated emissions 48.3 GHz range (2nd harmonic), hor./vert. polarization, B/M/T, FIP EUT

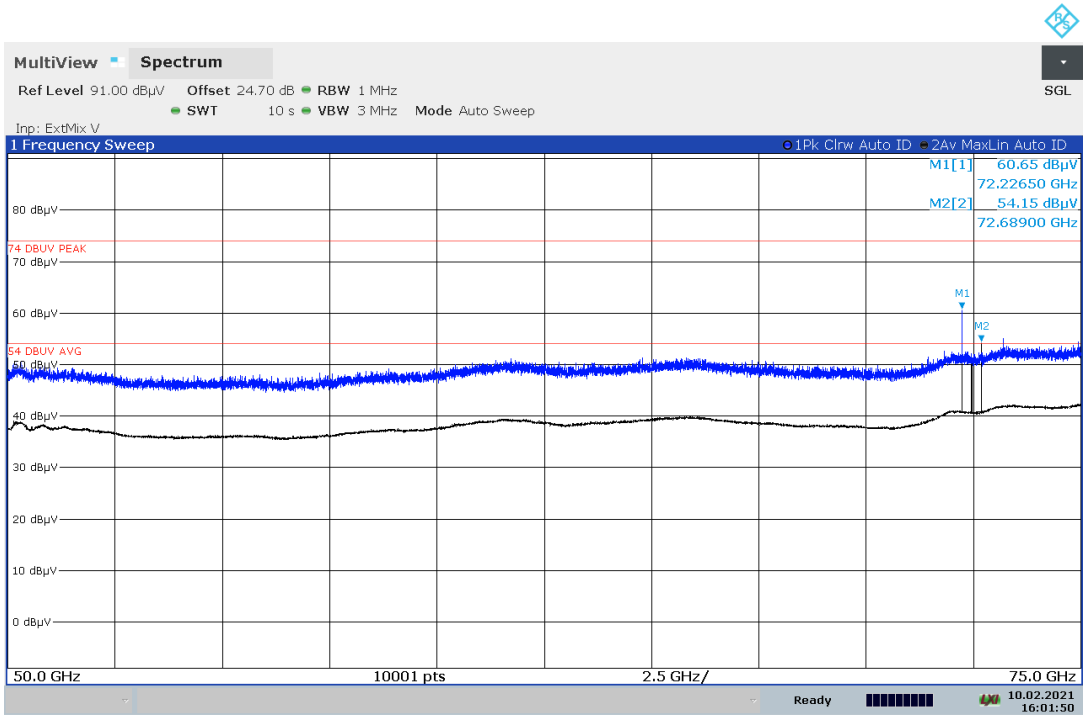


Plot no. 35: radiated emissions 50 GHz – 75 GHz, hor./vert. polarization, normal mode, NON-FIP EUT



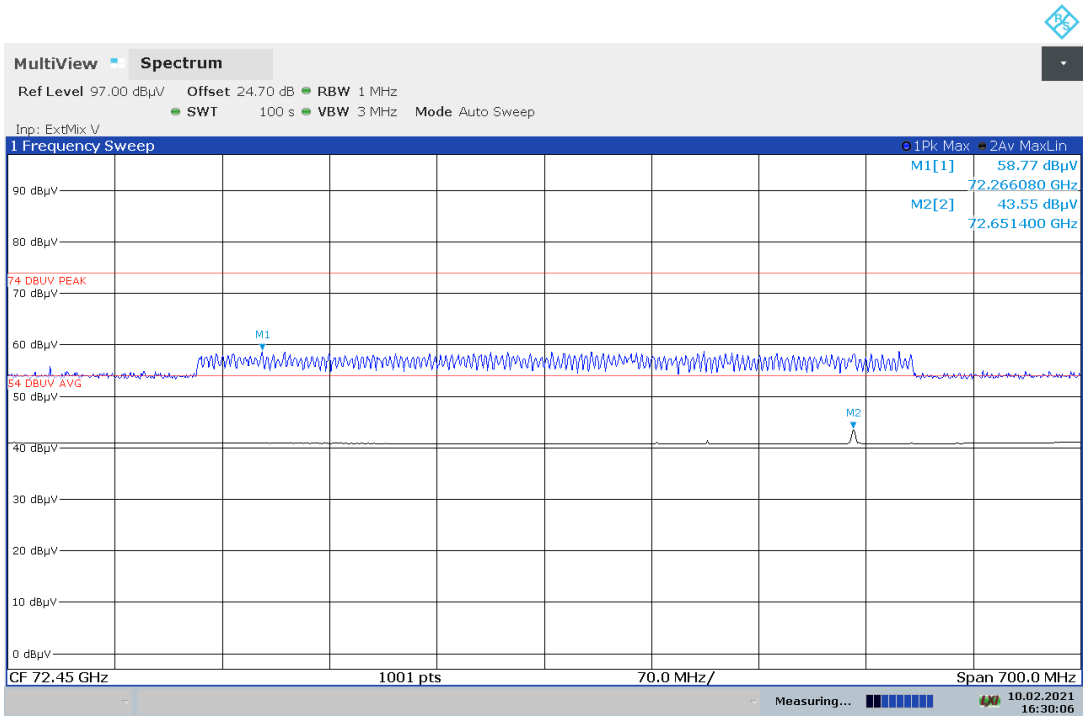
16:48:42 10.02.2021

Plot no. 36: radiated emissions 50 GHz – 75 GHz, hor./vert. polarization, FMCW stop mode B/M/T, NON-FIP EUT



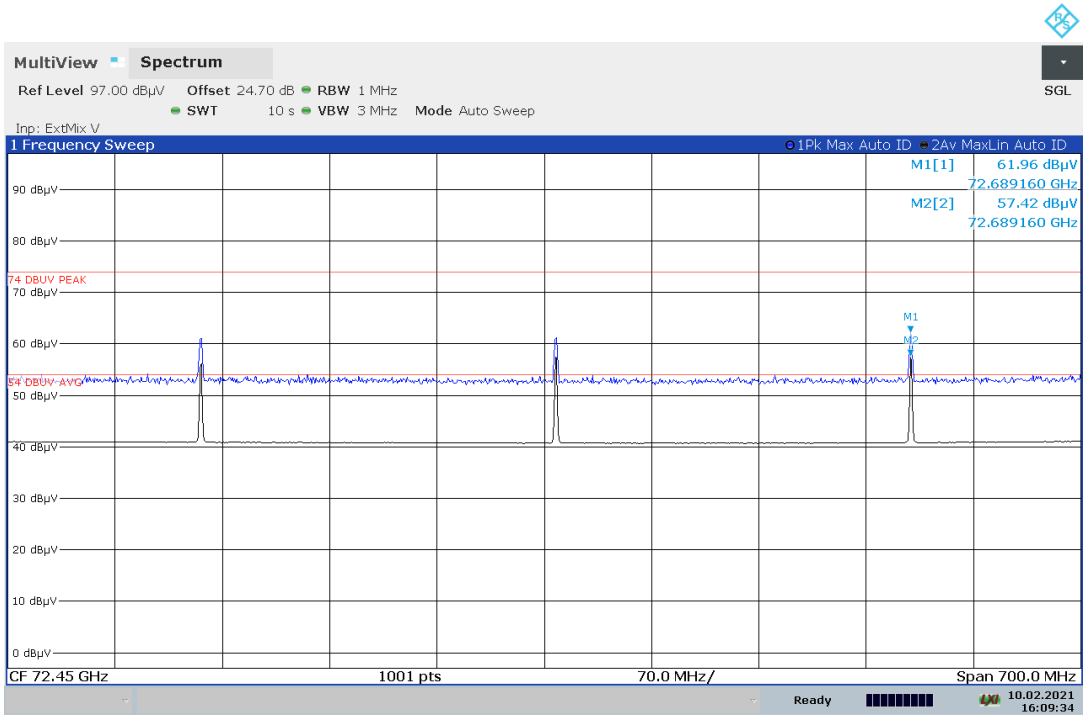
16:01:51 10.02.2021

Plot no. 37: radiated emissions 72.45 GHz range (3rd harmonic), hor./vert. polarization, normal mode, NON-FIP



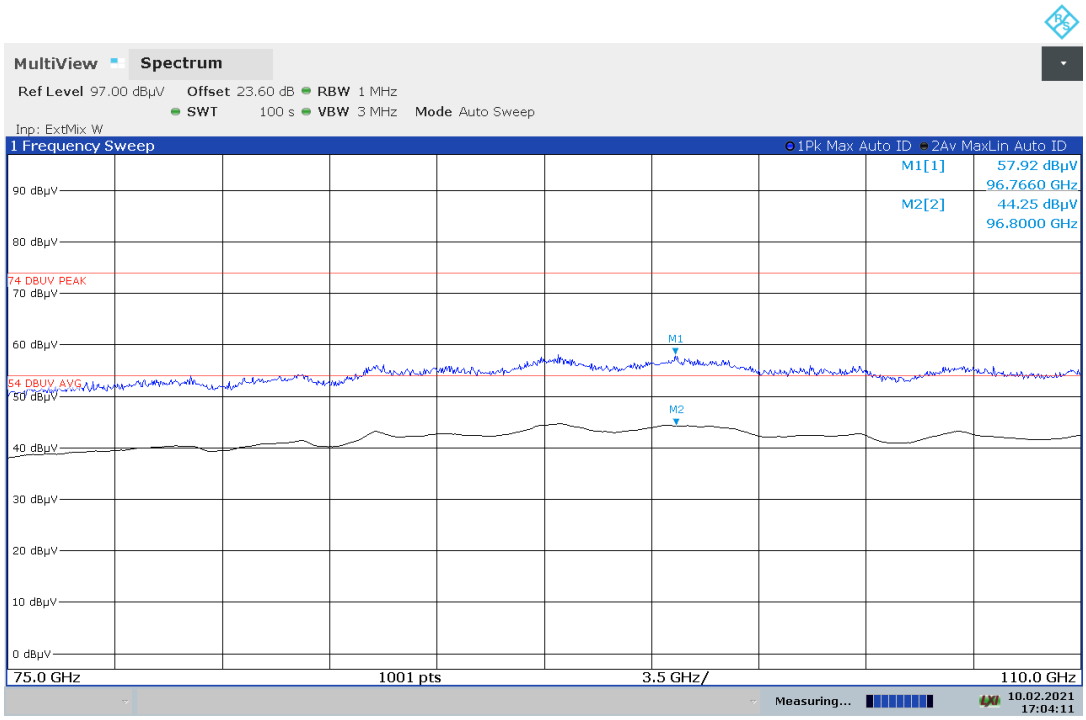
16:30:07 10.02.2021

Plot no. 38: radiated emissions 72.45 GHz range (3rd harmonic), hor./vert. polarization, B/M/T, NON-FIP



16:09:35 10.02.2021

Plot no. 39: radiated emissions 75 GHz – 110 GHz, hor./vert. polarization, NON-FIP EUT



10 MEASUREMENT UNCERTAINTIES

Radio frequency	≤ ± 10 ppm
Radiated emission	≤ ± 6 dB
Temperature	≤ ± 1 °C
Humidity	≤ ± 5 %
DC and low frequency voltages	≤ ± 3 %

The indicated expanded measurement uncertainty corresponds to the standard measurement uncertainty for the measurement results multiplied by the coverage factor k = 2. It was determined in accordance with EA-4/02 M:2013. The true value is located in the corresponding interval with a probability of 95 %.

End of Test Report