Bundesnetzagentur

BNetzA-CAB-21/21-21

DAkkS Deutsche Akkreditierungsstelle D-PL-21375-01-02

INGENIEURBÜRO LENHARDT

Test Report

Test report no.: 22097815-29092-1

Date of issue: 2023-01-23

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

Applicant

Robert Bosch GmbH

Manufacturer

Robert Bosch GmbH

Test Item

C5CP12

RF-Spectrum Testing according to:

FCC 47 CFR Part 95
Personal radio services,
Subpart M - The 76-81 GHz Band Radar Service

Tested by (name, function, signature)	*Sebastian Janoschka* *Lab Manager RF*	signature
Approved by (name, function, signature)	*Karsten Geraldy* *Lab Manager RF*	signature

Applicant and Test item details	
Applicant	Robert Bosch GmbH Daimlerstr. 6 71229, Leonberg, Germany Phone: +49 711 400 40990 Fax: +49 711 400 40999
Manufacturer	Robert Bosch GmbH Daimlerstr. 6 71229, Leonberg, Germany
Test item description	Radar sensor
Model/Type reference	C5CP12
FCC ID	NF3-C5CP12
Frequency	76.0 GHz to 77.0 GHz
Antenna	Integrated patch antenna
Power supply	8.0 to 16.0 V DC
Temperature range	-40 °C to +85 °C

Disclaimer and Notes

The content of this test report relates to the mentioned test sample(s) only.
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The last valid version is available at TAMSys®.

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

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

Decision rule:
Decision rule based on simple acceptance without guard bands, binary statement, based on mutually agreed uncertainty tolerances with expansion factor k=2 according to ILAC-G8:09/2019

1 TABLE OF CONTENTS

2 GENERAL INFORMATION

2.1 Administrative details

Testing laboratory	**IBL-Lab GmbH** Heinrich-Hertz-Allee 7 66386 St. 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: • Electronics, EMC, Radio — D-PL-21375-01-01 • Electromagnetic Compatibility and Telecommunication (FCC requirements) — D-PL-21375-01-02 Testing Laboratory Designation Number — DE0024 • Telecommunication (TC) and Electromagnetic Compatibility (EMC) for Canadian Standards — D-PL-21375-01-03 ISED Company Number — 27156 Testing Laboratory CAB Identifier — DE0020 Website DAkkS: https://www.dakks.de/ The Deutsche Akkreditierungsstelle GmbH (DAkkS) is also a signatory to the ILAC Mutual Recognition Arrangement
Testing location	**IBL-Lab GmbH** Heinrich-Hertz-Allee 7 66386 St. Ingbert / Germany
Date of receipt of test samples	2022-11-28
Start – End of tests	2022-11-28 – 2022-12-20

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

-0 Initial Version

-1 Revision: FCC ID added

This test report 22097815-29092-1 replaces the previous test report 22097815-29092-0.
Utilisation, publication and control of previous report editions is under responsibility of the applicant.

2.6 Further documents

List of further applicable documents belonging to the present test report:
– no additional documents –

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	normal	maximum
Temperature	-40 °C	20 °C	+85 °C
Relative humidity	-/-	45 % r.h.	-/-
Power supply	7.0 V DC	13.4 V DC	16.0 V DC

4 TEST STANDARDS AND REFERENCES

Test standard (accredited)	Description
FCC 47 CFR Part 95	Personal radio services, Subpart M - The 76-81 GHz Band Radar Service

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
ANSI C63.26-2015	American National Standard for Compliance Testing of Transmitters Used in Licensed Radio Services
KDB 653005 D01, V01, R02	Equipment Authorization Guidance for 76-81 GHz Radar Devices

5 EQUIPMENT UNDER TEST (EUT)

5.1 Product description

Radar sensor

5.2 Description of test item

Model name*	C5CP12
Serial number*	1100010560900408519307010322195452391969
PCB identifier*	0265B63053-01
Hardware status*	0265B63053-01
Software status*	1037610198

*: as declared by applicant

5.3 Technical data of test item

Operational frequency band*	76.0 GHz to 77.0 GHz
Type of radio transmission*	modulated carrier
Modulation type*	FMCW
Number of channels*	1
Channel bandwidth*	< 1 GHz
Channel spacing*	N/A
Receiver category*	N/A
Receiver bandwidth*	N/A
Duty cycle*	DMP 6: 26.7 % DMP 8: 25.5 % DMP 12: 26.0 %
Antenna*	Integrated patch antenna
Rated RF output power*	< 50 dBm
Power supply*	8.0 to 16.0 V DC
Temperature range*	-40 °C to +85 °C

*: as declared by applicant

5.4 Additional information

Model differences	-/-
Ancillaries tested with	-/-
Additional equipment used for testing	*A notebook, 2 CAN converters and special test software was used, to change the running mode of the EUT*
Additional comments:	*EUT equipped with FOTA (flash memory), CAN1 and CAN2 interfaces. Operation mode: CAN1 and CAN2 communication active.*

5.5 Operating conditions

The following information is derived from the provided document “Technical Documentation C5CP12”

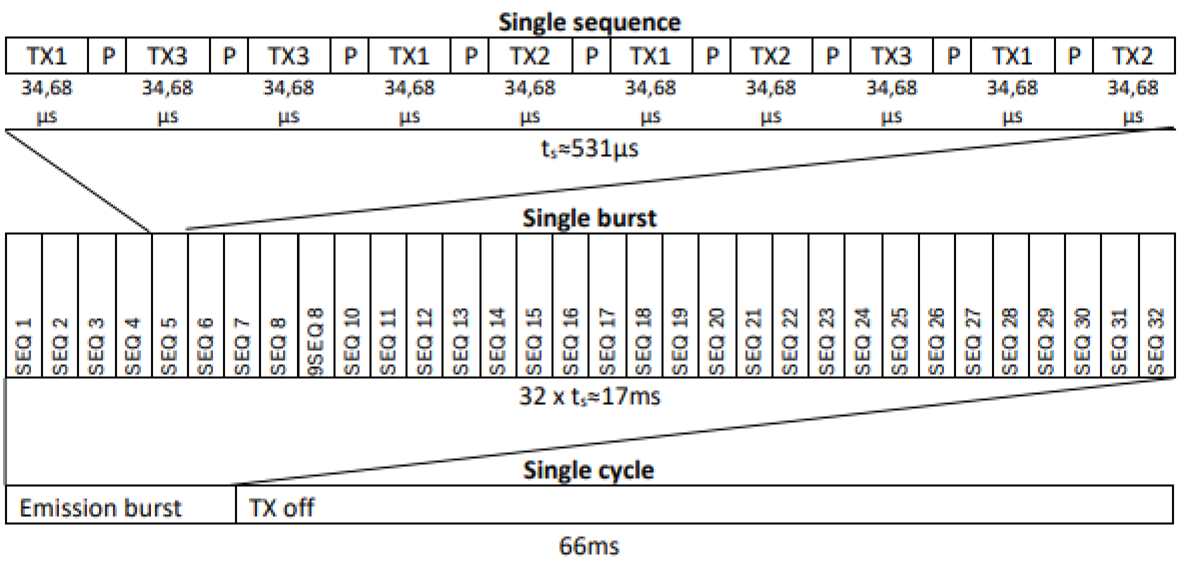
4.3 Modulation description

The sensor emits a series of fast FMCW chirps. The chirps are grouped in sequence and sequences are grouped in bursts. Parameters of the chirps and sequences vary between different modulation schemes (DMP – Detection and Measurement Program).
The CR5TPCC sensor modulation mode depends on vehicle speed.

Vehicle speed	**Modulation mode**	**Active TX channels**
up to 3km/h	DMP12	TX1, TX2, TX3
3km/h – 30 km/h	DMP8	TX1, TX2, TX3 (normal); TX2, TX3 (boost)
above 30 km/h	DMP6	TX1, TX2, TX3

4.3.1 DMP12 modulation

A single sequence takes 531µs and consists of 10 chirps around constant centre frequency. Each chirp is emitted on different TX channel and takes 34,68µs. In between chirps transmitter is turned off. In every sequence, 4 chirps are emitted on TX1 antenna, 3 chirps on TX2 and 3 chirps on TX3.
A burst takes 17ms and consists of 32 sequences (320 chirps). Centre frequency of each sequence is shifted slightly. Once burst emission is completed, transmitter is turned off until end of cycle.
A single cycle takes 66ms.



Chirp frequency span: 274MHz
Burst frequency span: 572MHz
Occupied bandwidth: 846 MHz

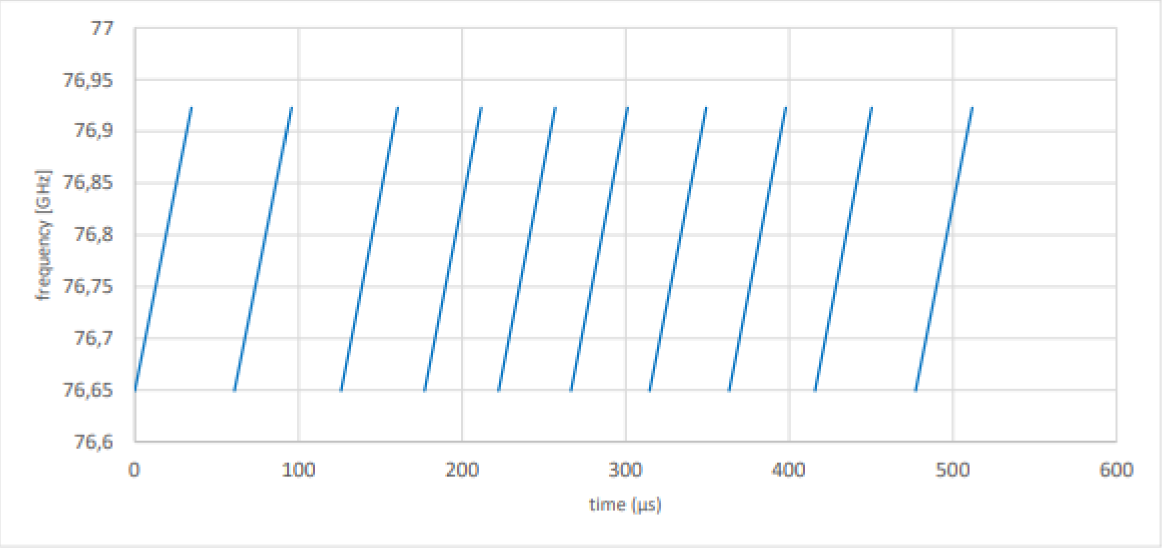


Figure 6: DMP12 single sequence

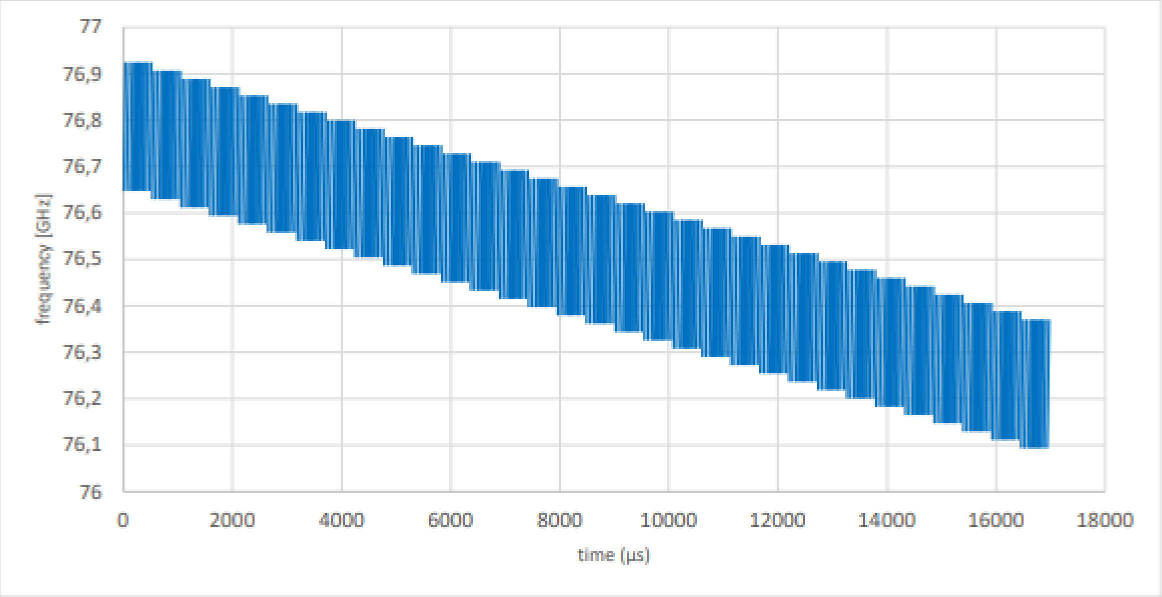


Figure 7: DMP12 single burst

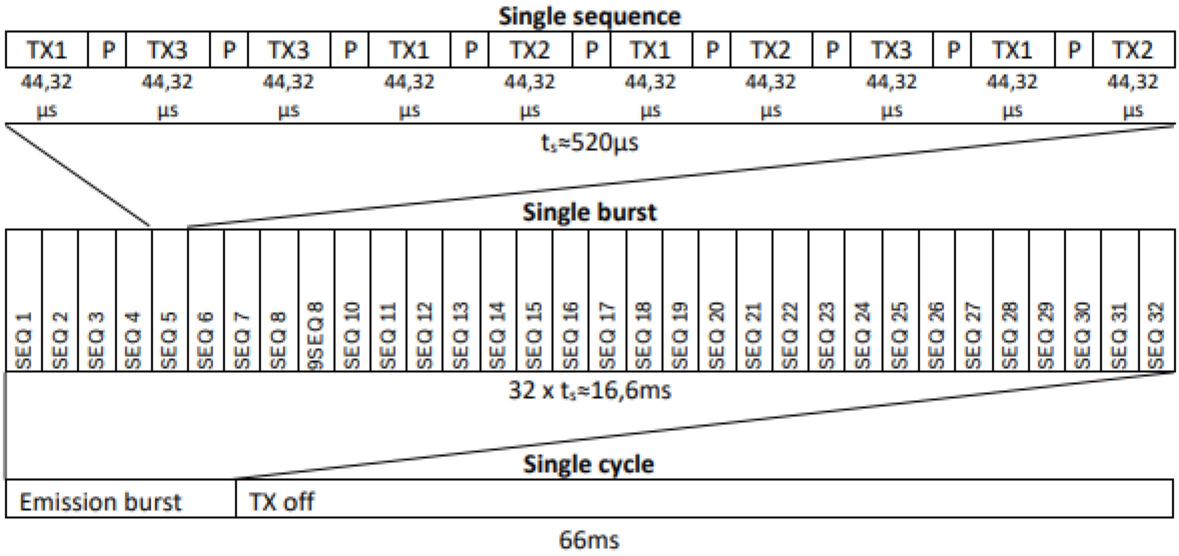
4.3.2 DMP8 modulation

DMP8 uses two different sequences: “normal” and “boost”. The sequences are emitted alternately:

Normal 66ms cycle	Boost 66ms cycle	Normal 66ms cycle	Boost 66ms cycle	Normal 66ms cycle	Boost 66ms cycle

4.3.2.1 DMP8 modulation normal

A single sequence takes 520µs and consists of 10 chirps around constant centre frequency. Each chirp is emitted on different TX channel and takes 44,32µs. In between chirps transmitter is turned off. In every sequence, 4 chirps are emitted on TX1 antenna, 3 chirps on TX2 and 3 chirps on TX3.
A burst takes 16,6ms and consists of 32 sequences (320 chirps). Centre frequency of each sequence is shifted slightly. Once burst emission is completed, transmitter is turned off until end of cycle.
A single cycle takes 66ms.



Chirp frequency span: 215 MHz
Burst frequency span: 634 MHz
Occupied bandwidth: 849 MHz

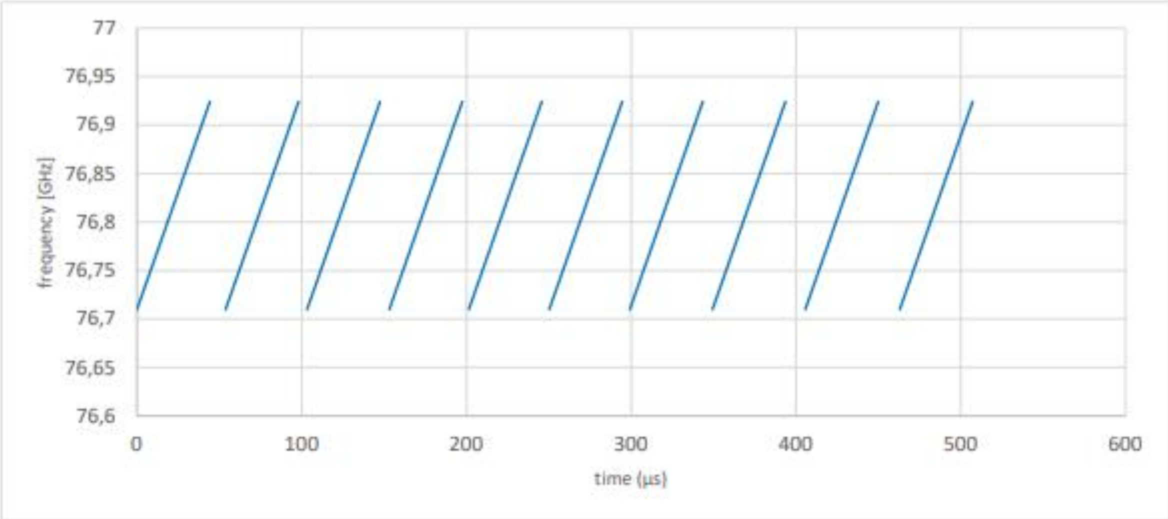


Figure 8: DMP8 normal single sequence

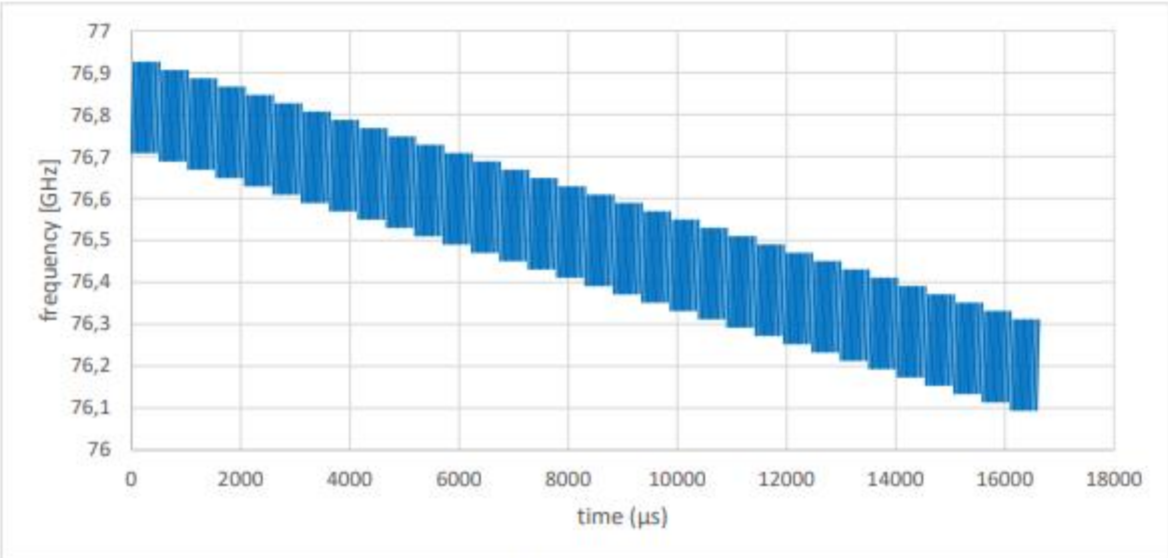
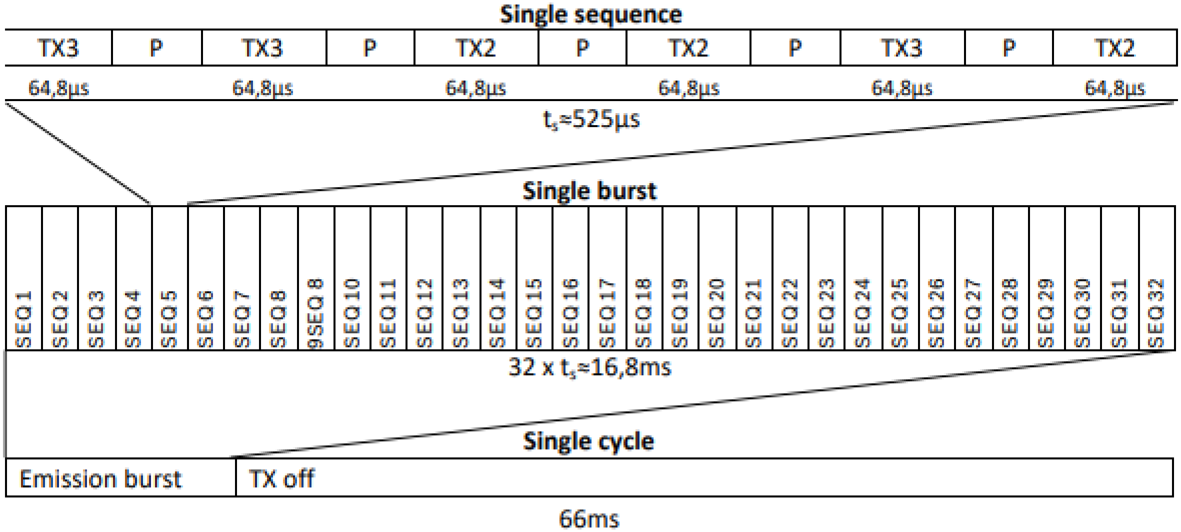


Figure 9: DMP8 normal single burst

4.3.2.2 DMP8 modulation boost

A single sequence takes 525µs and consists of 6 chirps around constant centre frequency. Each chirp is emitted on different TX channel and takes 64,8µs. In between chirps transmitter is turned off. In every sequence, 3 chirps on TX2 and 3 chirps on TX3.
A burst takes 16,8ms and consists of 32 sequences (192 chirps). Centre frequency of each sequence is shifted slightly. Once burst emission is completed, transmitter is turned off until end of cycle.
A single cycle takes 66ms.



Chirp frequency span: 213 MHz
Burst frequency span: 630 MHz
Occupied bandwidth: 843 MHz

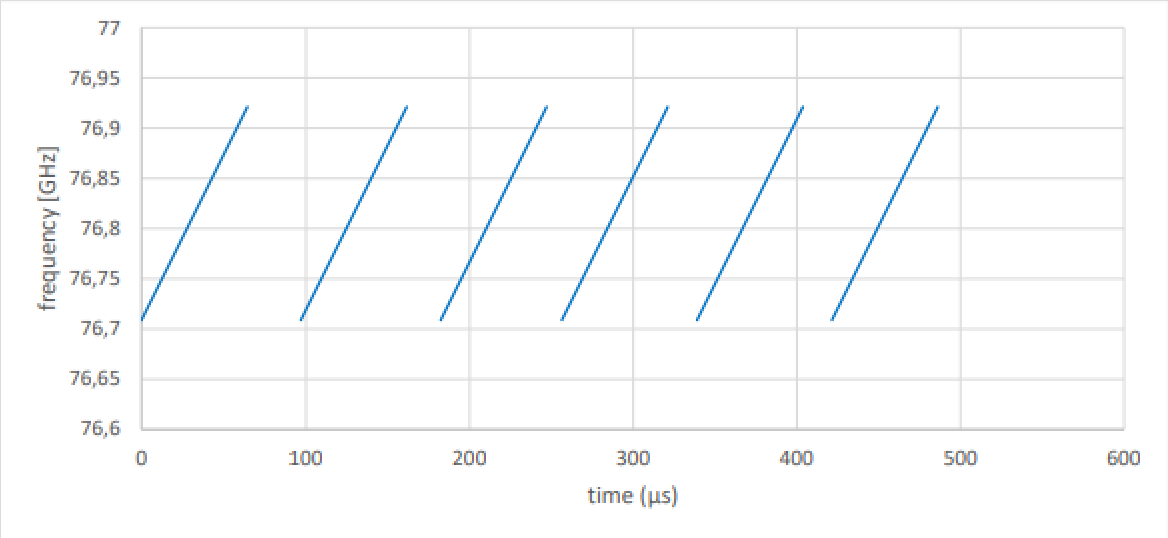


Figure 10: DMP8 boost single sequence

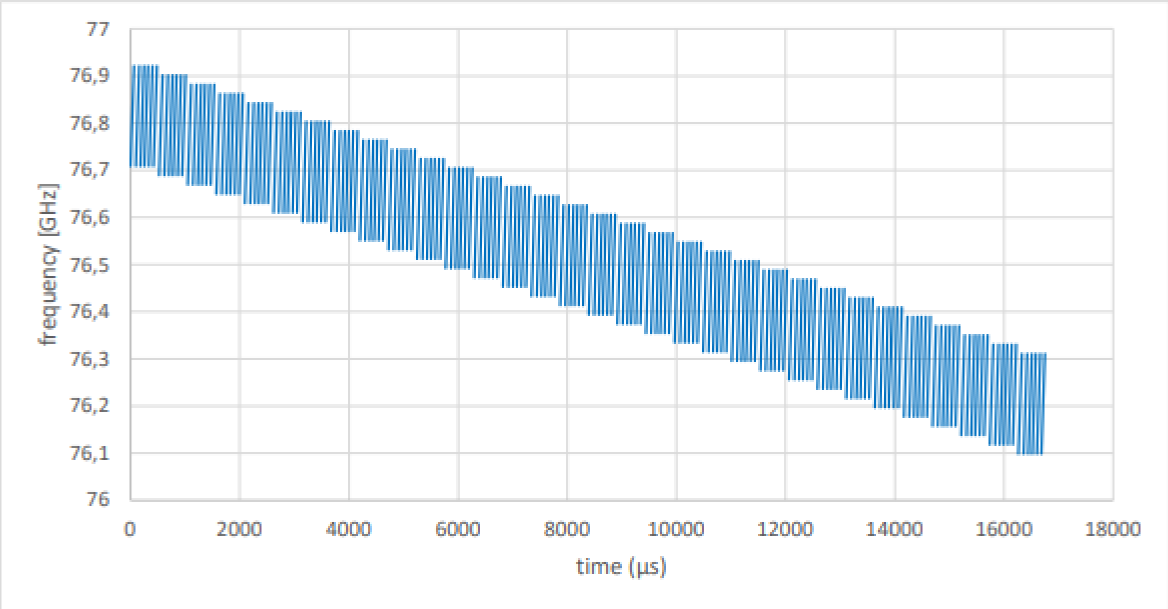
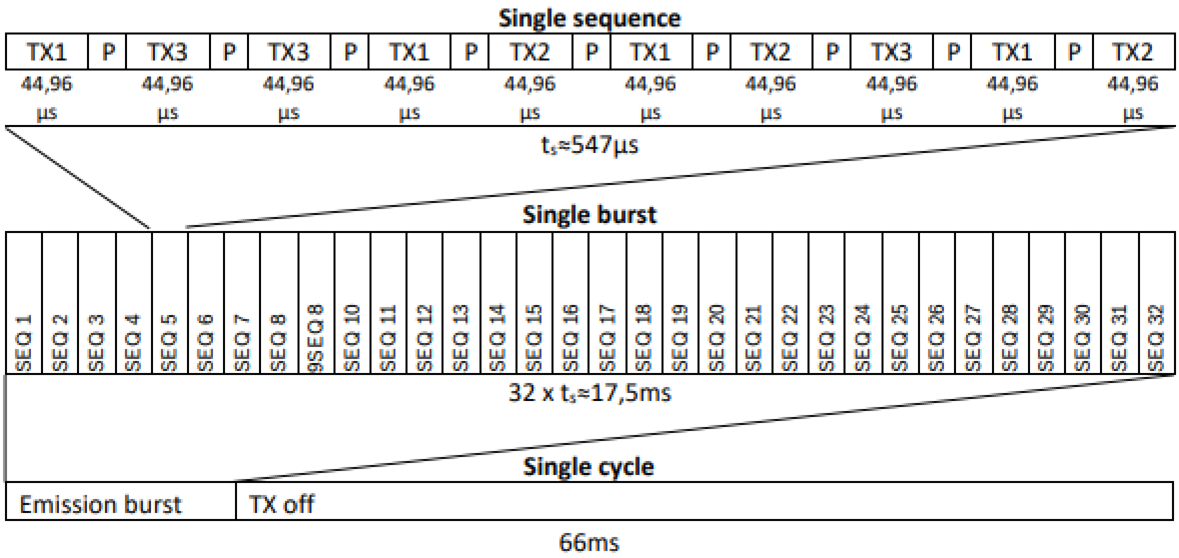


Figure 11: DMP8 boost single burst

4.3.3 DMP6 modulation

A single sequence takes 547µs and consists of 10 chirps around constant centre frequency. Each chirp is emitted on different TX channel and takes 44,96µs. In between chirps transmitter is turned off. In every sequence, 4 chirps are emitted on TX1 antenna, 3 chirps on TX2 and 3 chirps on TX3.
A burst takes 17,5ms and consists of 32 sequences (320 chirps). Centre frequency of each sequence is shifted slightly. Once burst emission is completed, transmitter is turned off until end of cycle.
A single cycle takes 66ms.



Chirp frequency span: 274 MHz
Burst frequency span: 572 MHz
Occupied bandwidth: 846 MHz

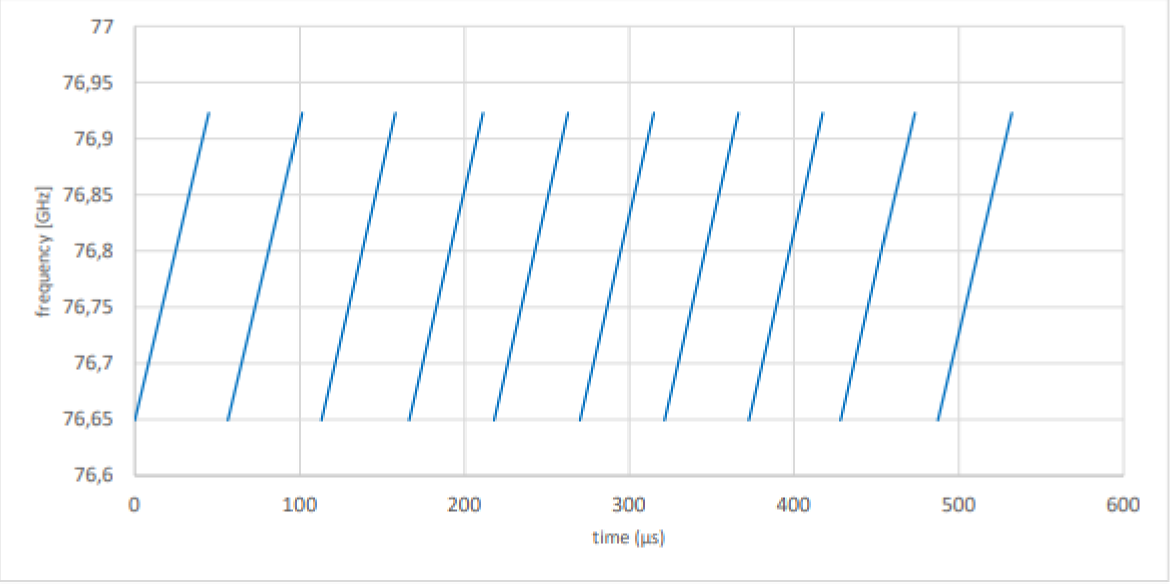


Figure 12: DMP6 single sequence

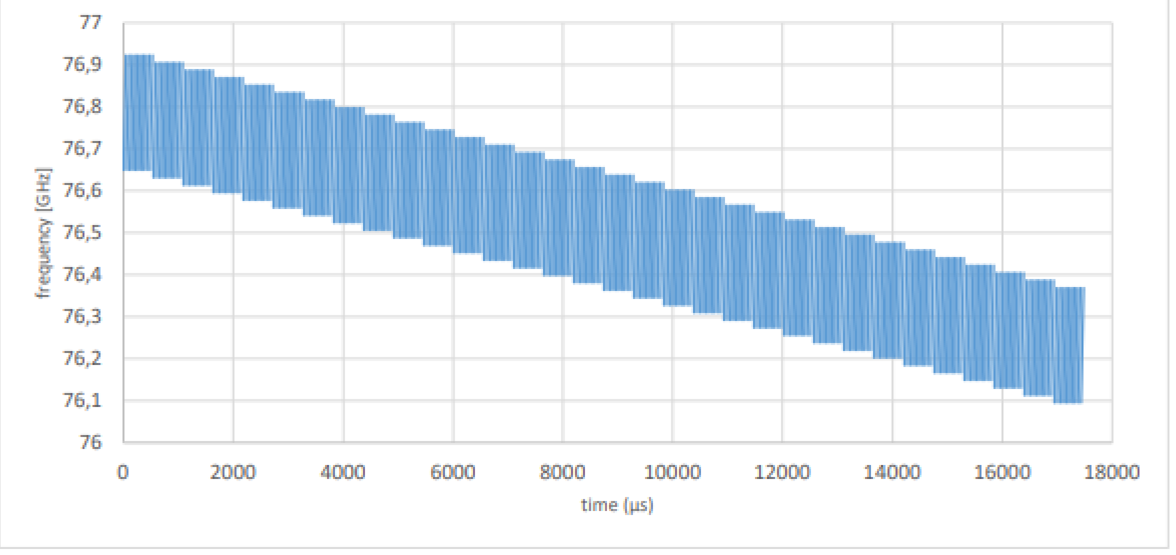
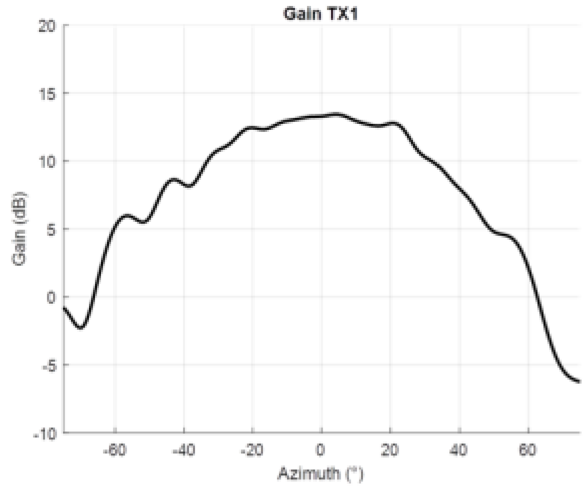


Figure 13: DMP6 single burst

5.6 Antenna characteristics

4.2.1 TX1 antenna characteristic

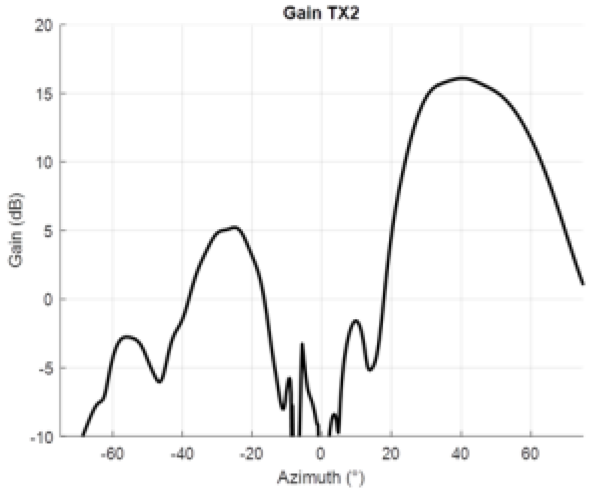
Simulation result of TX1 azimuth antenna characteristic is presented below:



Maximum gain is: 13,3dBi at 0deg and 9,07dBi at 36deg

4.2.2 TX2 antenna characteristics

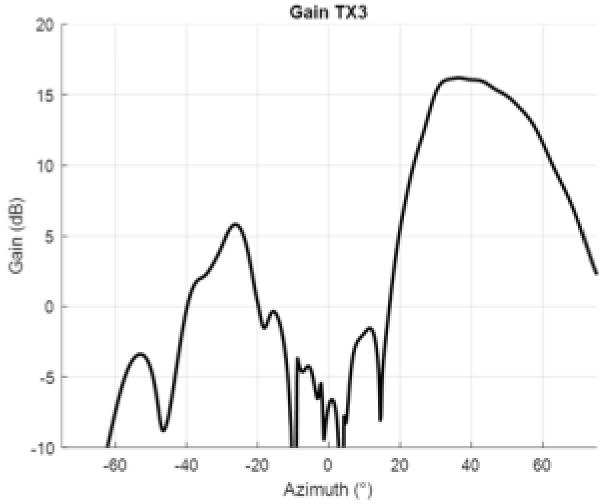
Simulation result of TX2 azimuth antenna characteristic is presented below:



Maximum gain is 15,87dBi at 36deg.

4.2.3 TX3 antenna characteristics

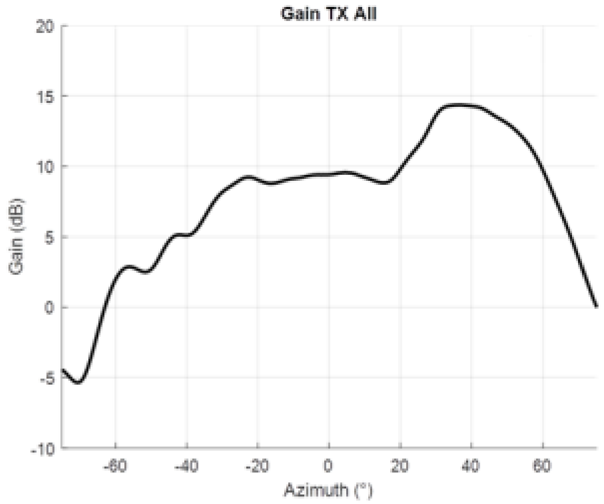
Simulation result of TX3 azimuth antenna characteristic is presented below:



Maximum gain is 16,2dBi at 36deg.

4.2.4 TXall antenna characteristics

Simulation result of all channels (TX1, TX2, TX3) combined azimuth antenna characteristic is presented below:



Maximum gain is 14,37dBi at 36deg.

4.2.5 Calculation of effective sensor antenna gain

Every chirp is sent though single TX channel and antenna. Details about number of chirps and TX channels are provided in Chapter 4.3. With these details effective antenna gain of the sensor can be calculated:

4.2.5.1 Antenna gain of sensor in DMP12 and DMP6 modes

In these modes sensor emits 4 chirps on TX1, 3 chirps on TX2 and 3 chirps on TX3, total 10 chirps. Therefore effective antenna gain:

$$G = 10log\left(\frac{4 * 10^{\frac{9,07}{10}} + 3 * 10^{\frac{15,87}{10}} + 3 * 10^{\frac{16,2}{10}}}{10}\right) = 14,37dBi$$

See also Chapter 4.2.4

4.2.5.2 Antenna gain of sensor in DMP8 mode

DMP8 modes uses two sequences, normal and boost (as described in Chapter 4.3.2). In normal sequence sensor emits 4 chirps on TX1, 3 chirps on TX2 and 3 chirps on TX3, total 10 chirps. In boost sequence sensor emits 3 chirps on TX2 and 3 chirps on TX3, total 6 chirps (TX1 is not used).
Combined sequence contains 4 chirps on TX1, 6 chirps on TX2 and 6 chirps on TX3, total 16 chirps. Therefore effective antenna gain:

$$G = 10log\left(\frac{4 * 10^{\frac{9,07}{10}} + 6 * 10^{\frac{15,87}{10}} + 6 * 10^{\frac{16,2}{10}}}{16}\right) = 15,07dBi$$

4.4 Duty Cycle

Total duration of a single CR5TPCC cycle is always 66ms. Within this time, the sensor transmits a single burst of length depending on DMP mode. Additionally, every 2nd cycle, sensor emits a monitoring signal, which takes 0,29ms.
Therefore, sensor duty cycle:

$$Duty\_cycle = \frac{burst\_length + \frac{monitoring\_length}{2}}{cycle\_length} * 100$$

Modulation mode	Burst length	Duty cycle
DMP12	17ms	26%
DMP8 (average of normal and boost)	16,7ms	25,5%
DMP6	17,5ms	26,7%

6 SUMMARY OF TEST RESULTS

Test specification
FCC 47 CFR Part 95 – Subpart M

Clause	Requirement / Test case	Test Conditions	Result / Remark	Verdict
§2.1046 §95.3367 (a) (b)	RF power output	Nominal	27.92 dBm peak 18.51 dBm mean	P
§2.1047	Modulation characteristics	Nominal	-	P
§2.1049 §95.3379 (b)	Occupied bandwidth	Nominal	891.309 MHz	P
§2.1051	Spurious emissions at antenna terminals	Nominal	see note	N/A
§2.1053 §95.3379 (a)(1) §95.3379 (a)(2) §95.3379 (a)(3)	Field strength of spurious radiation	Nominal	< limit	P
§2.1055 §95.3379 (b)	Frequency stability	Nominal Extreme	within band	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

7 TEST RESULTS

7.1 RF power output (§2.1046 & §95.3367)

Description

§2.1046 Measurements required: RF power output.

(a) For transmitters other than single sideband, independent sideband and controlled carrier radiotelephone, power output shall be measured at the RF output terminals when the transmitter is adjusted in accordance with the tune-up procedure to give the values of current and voltage on the circuit elements specified in §2.1033(c)(8). The electrical characteristics of the radio frequency load attached to the output terminals when this test is made shall be stated.

Limits

§95.3367 76-81 GHz Band Radar Service radiated power limits

The fundamental radiated emission limits within the 76-81 GHz band are expressed in terms of Equivalent Isotropically Radiated Power (EIRP) and are as follows:

(a) The maximum power (EIRP) within the 76-81 GHz band shall not exceed 50 dBm based on measurements employing a power averaging detector with a 1 MHz Resolution Bandwidth (RBW).

(b) The maximum peak power (EIRP) within the 76-81 GHz band shall not exceed 55 dBm based on measurements employing a peak detector with a 1 MHz RBW.

Test procedure

Mean Power

Method with spectrum analyser

A spectrum analyser with the following settings is used as measuring receiver in the test set-up:

- Start frequency: lower than the lower edge of the operating frequency range.
- Stop frequency: higher than the upper edge of the operating frequency range.
- Resolution bandwidth: 1 MHz.
- Video bandwidth: 3 MHz.
- Detector mode: RMS.
- Display mode: clear write.
- Averaging time: larger than one EUT cycle time.
- Sweep time: averaging time × number of sweep points.

Channel Power function needs to be used to calculate the average power. Boundaries for the calculation needs to be defined. This is typically the operating frequency range.

Method with power meter

The power meter shall be connected to the measurement antenna. The frequency correction factor shall be taken into account. The power meter shall be a true RMS power meter. The measurement time shall be equal or longer than the EUT cycle time.

KDB 653005 D01 76-81 GHz Radars v01r02, 4. b)

The maximum fundamental emission power (EIRP) shall be measured using a power averaging (rms) detector with a 1 MHz resolution bandwidth (RBW) and integrated over the full 99% occupied bandwidth (OBW) to obtain the data necessary to demonstrate compliance to the 50 dBm limit.

Test procedure

Peak Power

Method with a spectrum analyser

A spectrum analyser with the following settings is used as measuring receiver in the test set-up:
- Start frequency: lower than the lower edge of the operating frequency range.
- Stop frequency: higher than the upper edge of the operating frequency range.
- Resolution bandwidth: 1 MHz.
- Video bandwidth: 3 MHz.
- Detector mode: Peak detector.
- Display mode: Maxhold.
- Sweep time: EUT cycle time × number of sweep points.
- Measurement is done until trace is stabilised.

The peak power to be considered is the maximum value recorded.

KDB 653005 D01 76-81 GHz Radars v01r02, 4. c)

The maximum peak fundamental emission power (EIRP) measurement shall be performed by sweeping over the transmitted occupied bandwidth using a positive peak power detector with peak hold activated, and a 1 MHz RBW. Power integration is not to be used in performing this measurement. The resultant peak power spectral density (maximum in any 1 MHz) data shall be used to demonstrate compliance to the 55 dBm/MHz limit.

Peak power measurements of swept frequency radar implementations (e.g., high sweep rate FMCW) may require a desensitization correction factor to be applied to the measurement results. See relevant Application Note(s) from the measurement instrumentation vendor for details.

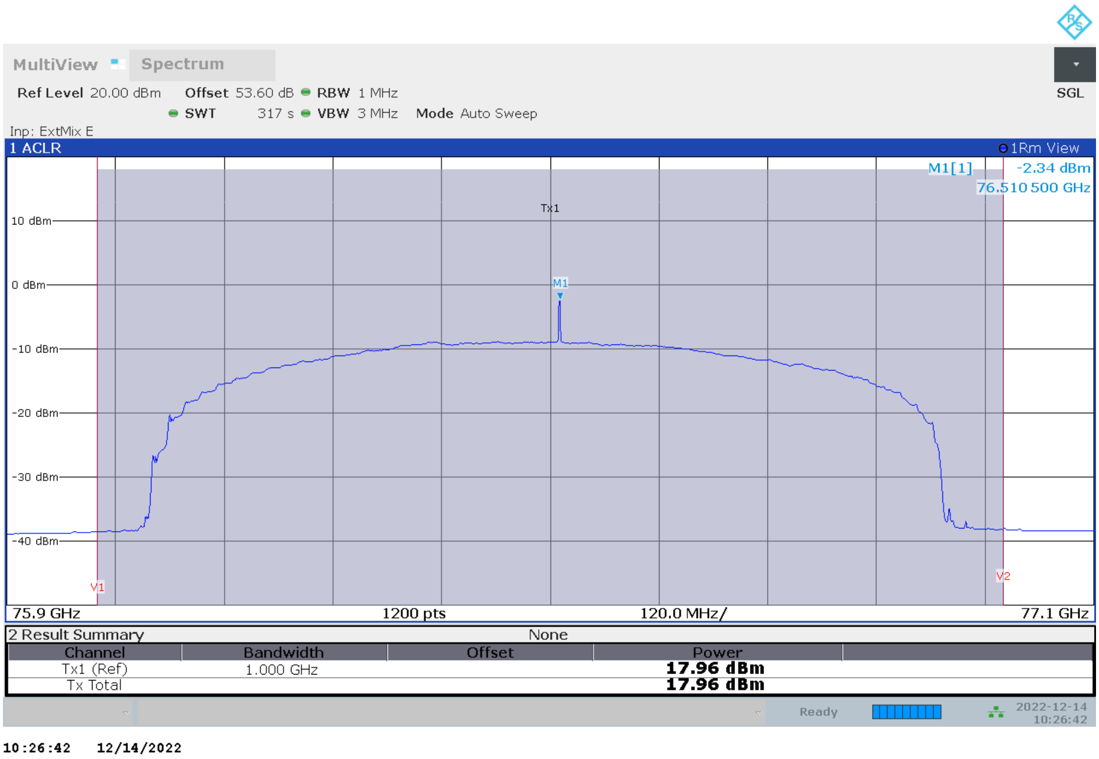
Test procedure used: Method with Spectrum Analyzer

Test setup: 8.3

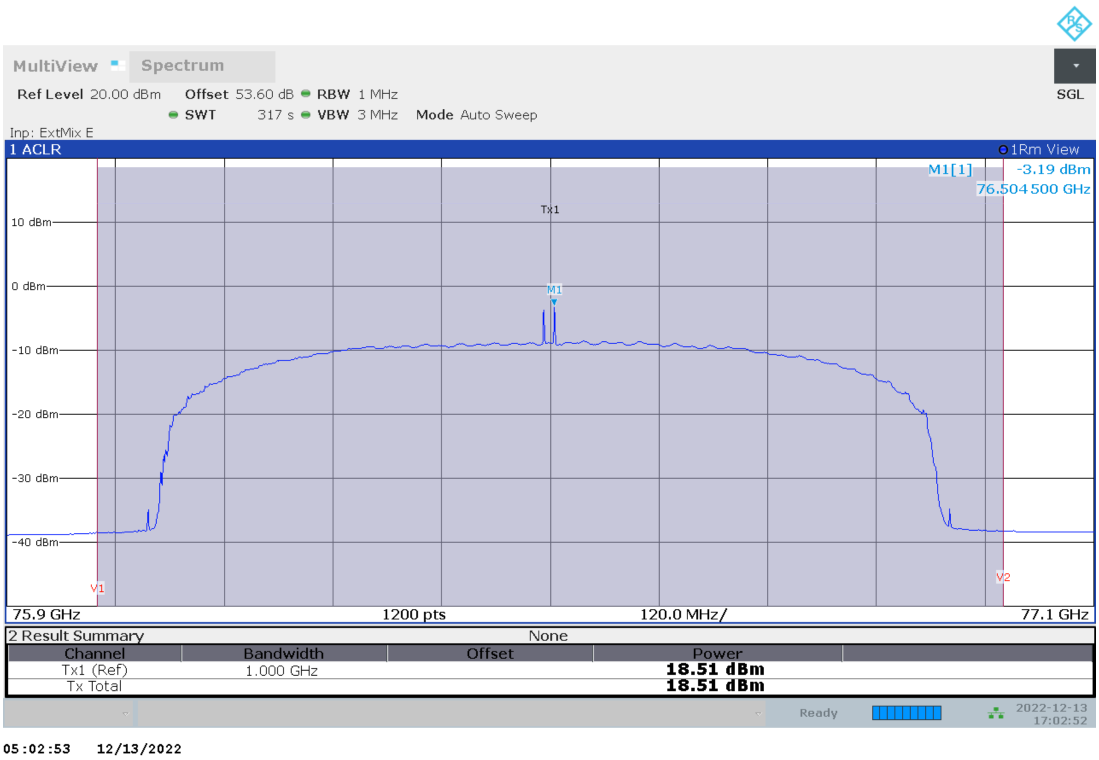
Test results

EUT mode	Test distance	Radiated Mean Power (EIRP) [dBm]	Radiated Peak Power (EIRP) [dBm]
DMP06	1.5 m	17.96	27.85
DMP08	1.5 m	18.51	27.92
DMP12	1.5 m	16.71	27.77

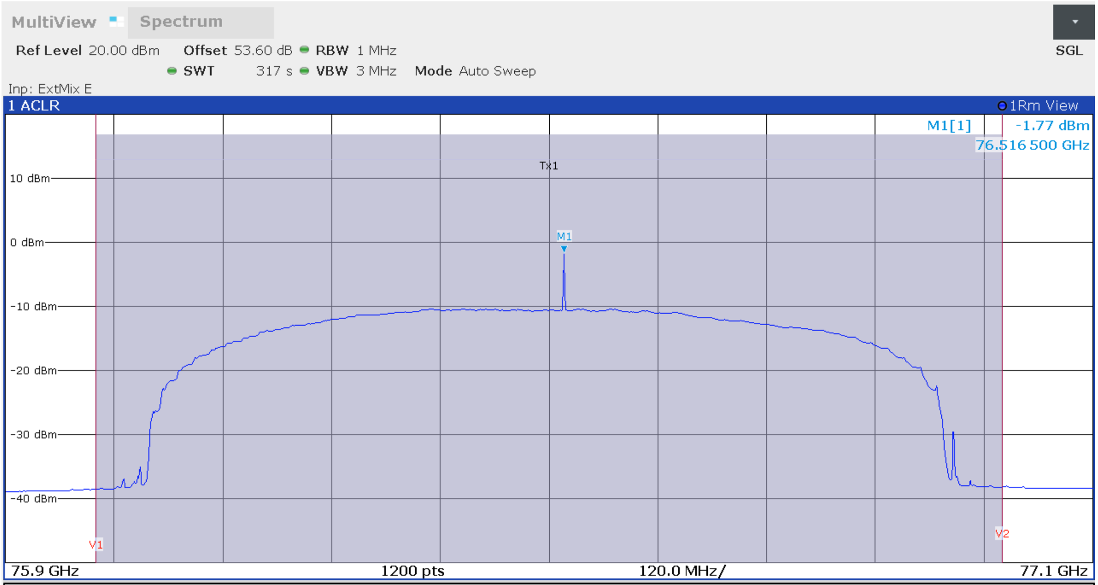
Plot no. 1: Mean Power EIRP, RMS detector / Channel Power, DMP06



Plot no. 2: Mean Power EIRP, RMS detector / Channel Power, DMP08



Plot no. 3: Mean Power EIRP, RMS detector / Channel Power, DMP12



Channel	Bandwidth	Offset	Power
Tx1 (Ref)	1.000 GHz		**16.78 dBm**
Tx Total			**16.78 dBm**

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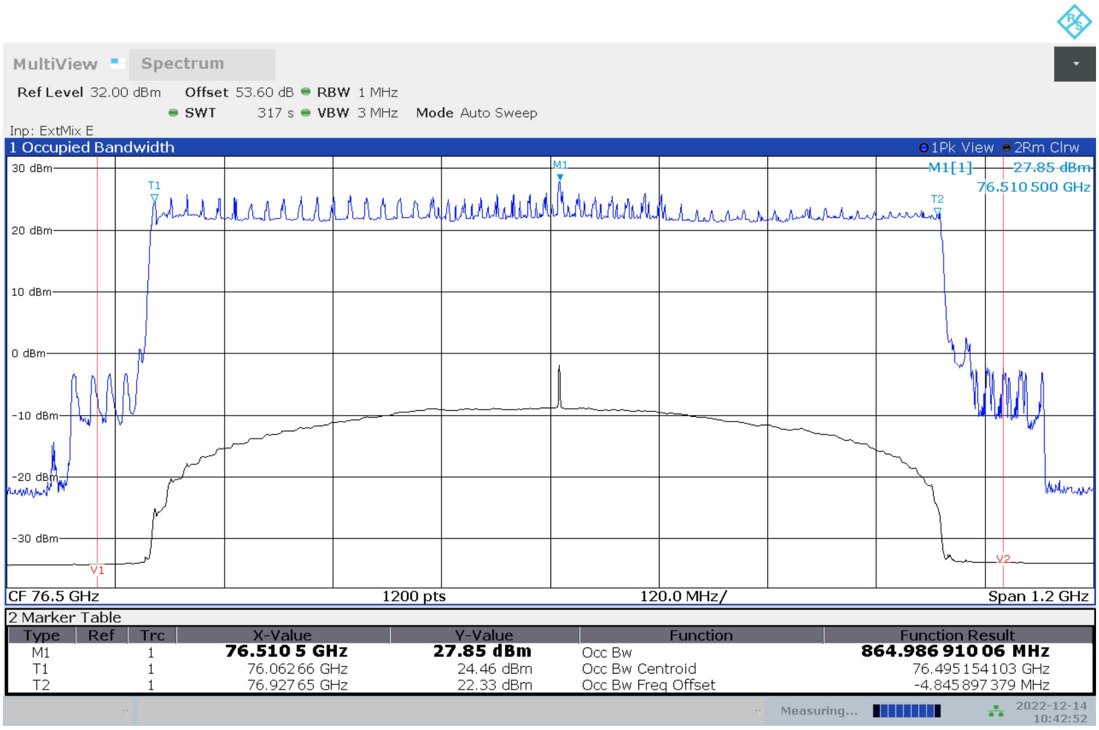
Plot no. 4: Peak Power EIRP, Peak detector, DMP06



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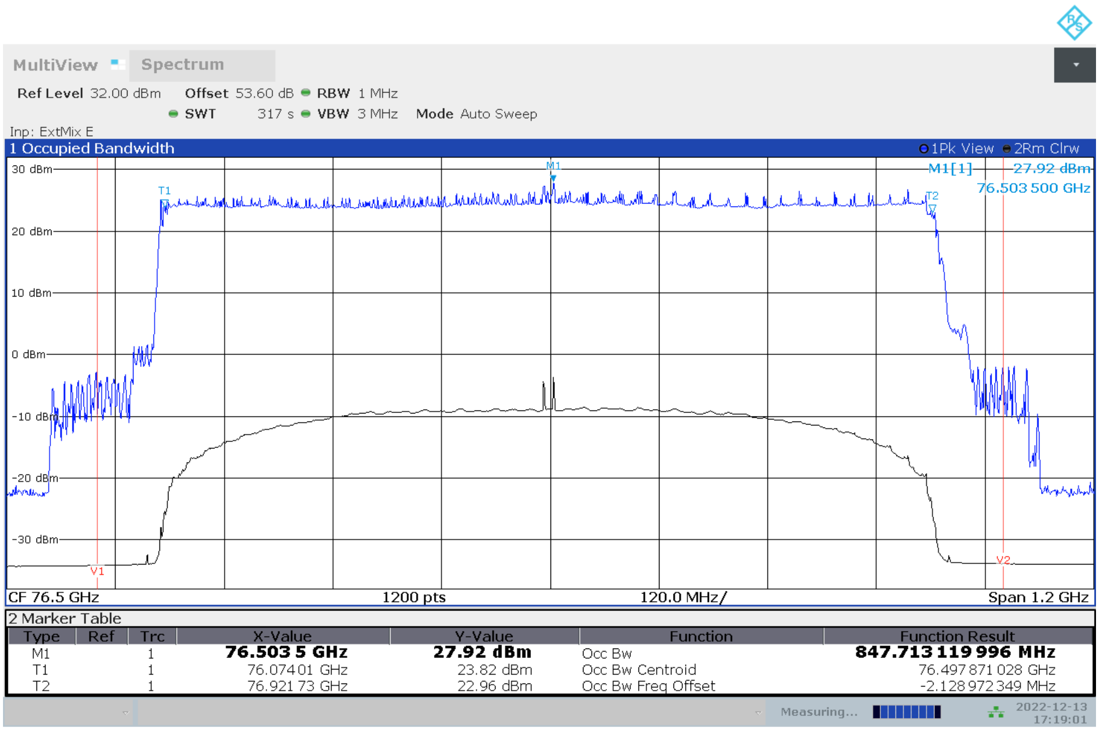
Plot no. 5: Peak Power EIRP, Peak detector, DMP08



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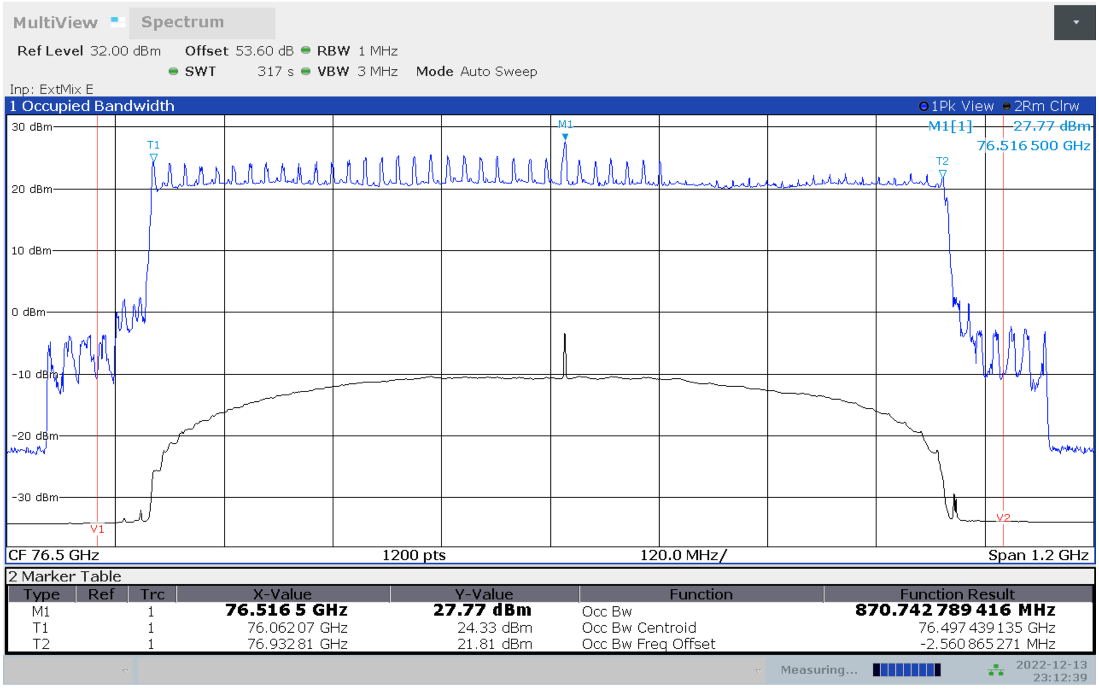
Plot no. 6: Peak Power EIRP, Peak detector, DMP12



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7.2 Modulation characteristics (§2.1047 & KDB 653005 D01 76-81 GHz Radars)

Description

§2.1047 Modulation characteristics

(d) Other types of equipment. A curve or equivalent data which shows that the equipment will meet the modulation requirements of the rules under which the equipment is to be licensed.

KDB 653005 D01 76-81 GHz Radars v01r02, 3. g)

Concerning the Section 2.1047 modulation characteristics requirement, the following information should be provided:

1) Pulsed radar: pulse width and pulse repetition frequency (if PRF is variable, then report maximum and minimum values).
2) Non-pulsed radar (*e.g.,* FMCW): modulation type (i.e., sawtooth, sinusoid, triangle, or square wave) and sweep characteristics (sweep bandwidth, sweep rate, sweep time).

Statement of applicant / manufacturer concerning modulation characteristics of EUT

Please refer to chapter 5

7.3 Occupied bandwidth (§2.1049 & §95.3379)

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

§95.3379 (b)

Fundamental emissions (i.e. 99% emission bandwidth) must be contained within the frequency bands specified in this section during all conditions of operation.

Test procedure

ANSI C63.26, 5.4.4

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.
Note: Step a) through step c) may require iteration to adjust within the specified tolerances.

d) Set the detection mode to peak, and the trace mode to max-hold.

e) If the instrument does not have a 99% OBW function, recover the trace data points and sum directly in linear power terms. Place the recovered amplitude data points, beginning at the lowest frequency, in a running sum until 0.5% of the total is reached. Record that frequency as the lower OBW frequency. Repeat the process until 99.5% of the total is reached and record that frequency as the upper OBW frequency. The 99% power OBW can be determined by computing the difference these two frequencies.

f) The OBW shall be reported and plot(s) of the measuring instrument display shall be provided with the test report. The frequency and amplitude axis and scale shall be clearly labeled. Tabular data can be reported in addition to the plot(s)

KDB 653005 D01 76-81 GHz Radars v01r02, 4. d)

The occupied bandwidth of the radar device shall be measured, reported, and shown to be fully contained within the designated 76-81 GHz frequency band under normal operating conditions as well as under those extreme ambient temperature and input voltage conditions as described in Section 2.1057.

The OBW measurement of an FMCW radar shall be performed with the transmitter operating in normal mode (i.e., with frequency sweep or step active).

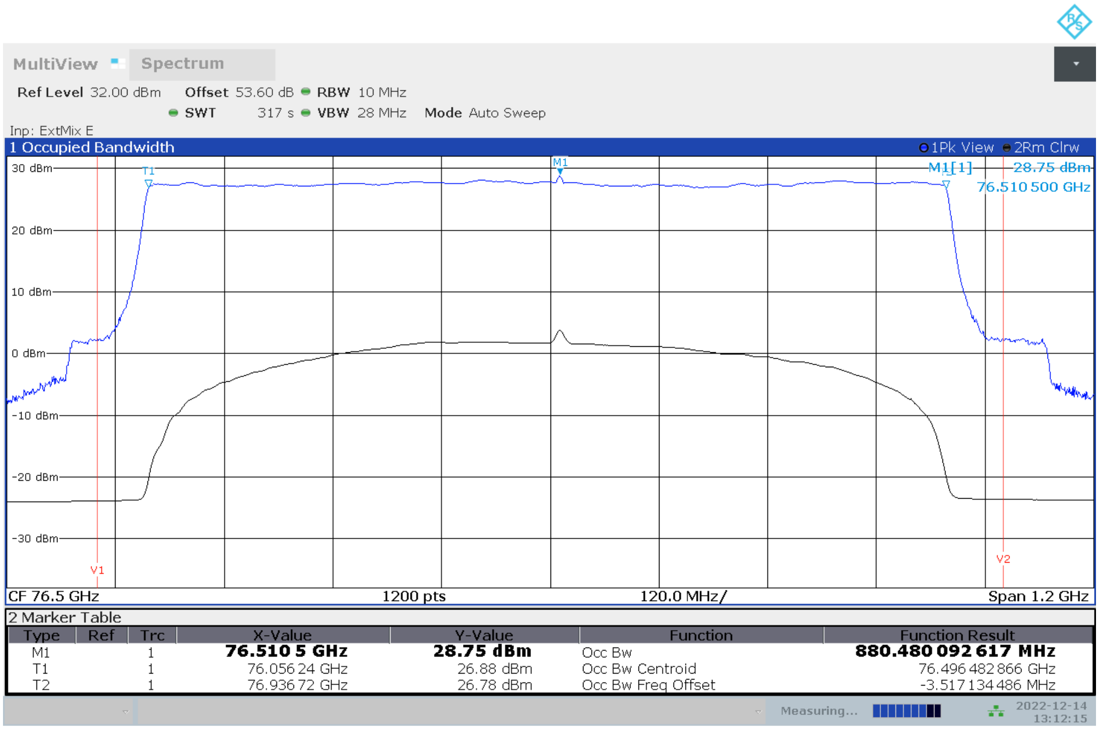
Note

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 C63.26, chapter D2: general considerations).

Test setup: 8.3, 8.4

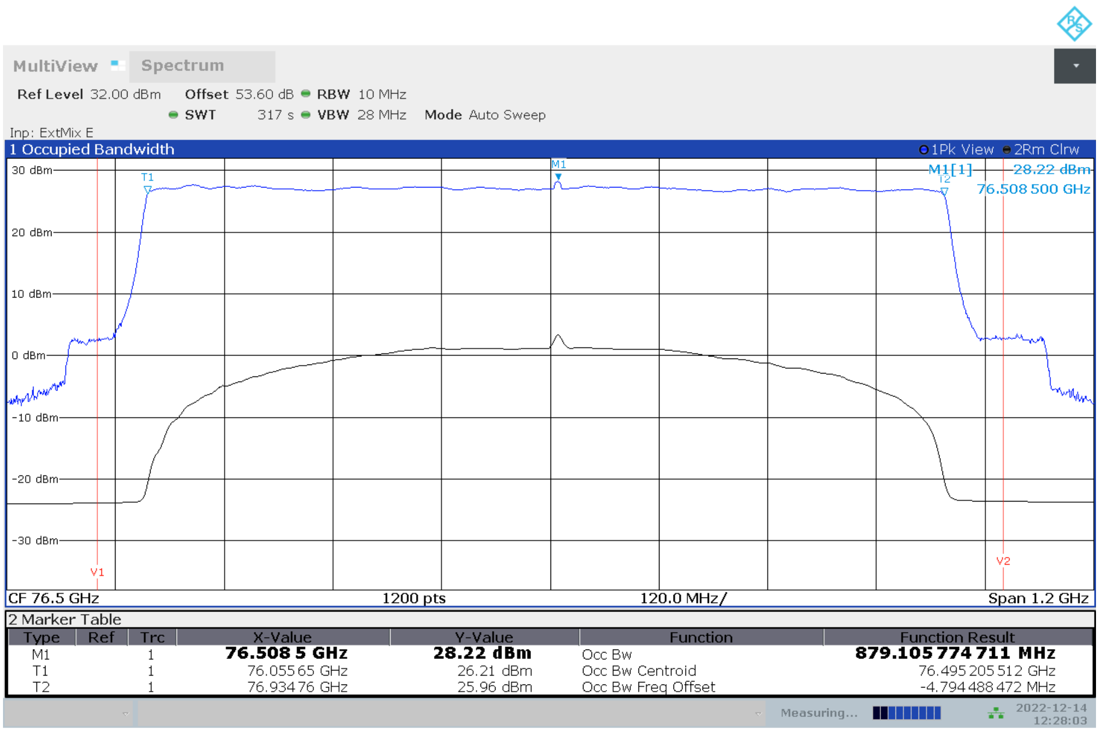
Test results under normal and extreme test conditions:				
EUT mode	**Test conditions**	**f_L [GHz]**	**f_H [GHz]**	**99% OBW [MHz]**
DMP06	85 °C	76.056	76.937	880.480
DMP06	50 °C	76.056	76.935	879.106
DMP06	40 °C	76.055	76.935	879.972
DMP06	30 °C	76.055	76.935	879.242
DMP06	20 °C / V_{max}	76.056	76.935	879.410
DMP06	20 °C / V_{nom}	76.056	76.935	879.418
DMP06	20 °C / V_{min}	76.055	76.935	880.194
DMP06	10 °C	76.055	76.935	880.204
DMP06	0 °C	76.056	76.936	879.670
DMP06	-10 °C	76.057	76.936	879.152
DMP06	-20 °C	76.058	76.937	878.962
DMP06	-30 °C	76.058	76.937	879.140
DMP06	-40 °C	76.059	76.937	878.871
DMP08	85 °C	76.050	76.967	916.887
DMP08	50 °C	76.060	76.952	**891.309**
DMP08	40 °C	76.064	76.950	885.108
DMP08	30 °C	76.065	76.946	880.894
DMP08	20 °C / V_{max}	76.065	76.942	877.460
DMP08	20 °C / V_{nom}	76.065	76.941	875.769
DMP08	20 °C / V_{min}	76.065	76.941	876.416
DMP08	10 °C	76.066	76.938	872.073
DMP08	0 °C	76.066	76.936	870.554
DMP08	-10 °C	76.067	76.935	868.043
DMP08	-20 °C	76.067	76.935	867.638
DMP08	-30 °C	76.068	76.934	866.384
DMP08	-40 °C	76.068	76.935	866.806
DMP12	85 °C	76.054	76.941	886.442
DMP12	50 °C	76.056	76.941	884.548
DMP12	40 °C	76.056	76.940	884.011
DMP12	30 °C	76.057	76.940	883.415
DMP12	20 °C / V_{max}	76.057	76.940	883.385
DMP12	20 °C / V_{nom}	76.056	76.940	884.157
DMP12	20 °C / V_{min}	76.056	76.940	884.152
DMP12	10 °C	76.058	76.940	882.176
DMP12	0 °C	76.057	76.941	883.731
DMP12	-10 °C	76.089	76.942	882.661
DMP12	-20 °C	76.059	76.942	882.838
DMP12	-30 °C	76.060	76.942	882.104
DMP12	-40 °C	76.060	76.942	882.439
With voltage variation				
Input voltage variation does not affect the transmitted signal (see plots for ambient/normal temperature).				

Plot no. 7: 99% OBW, Peak detector, 85 °C, DMP06



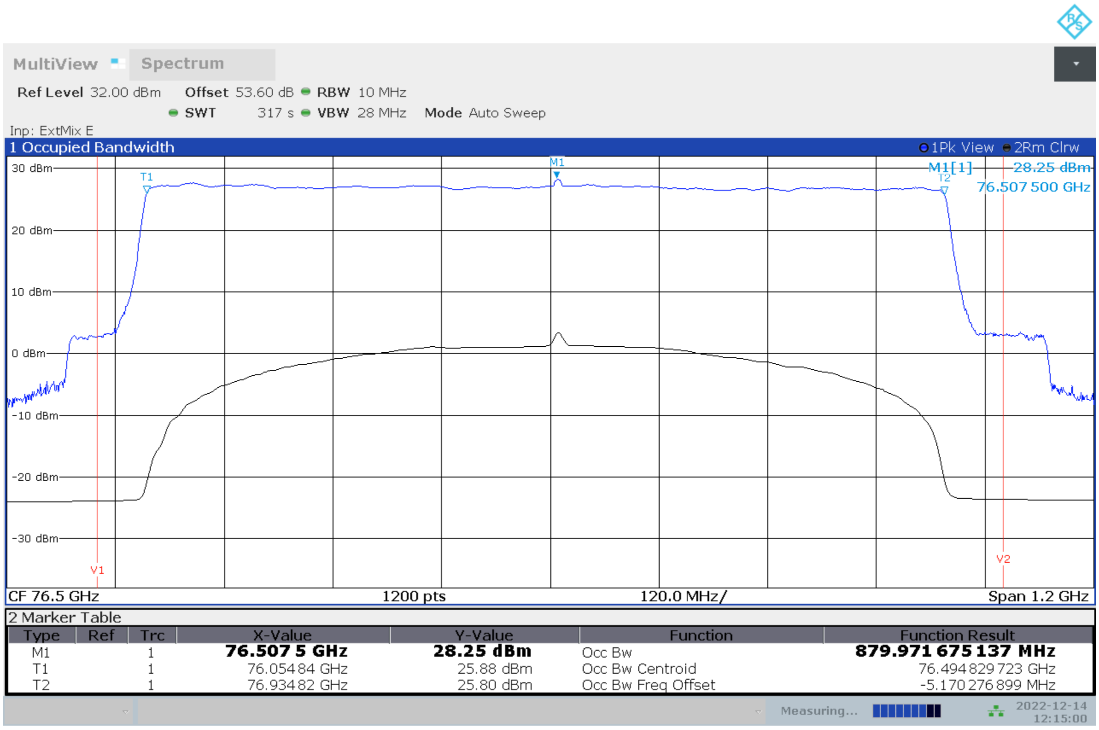
01:12:15 12/14/2022

Plot no. 8: 99% OBW, Peak detector, 50 °C, DMP06



12:28:03 12/14/2022

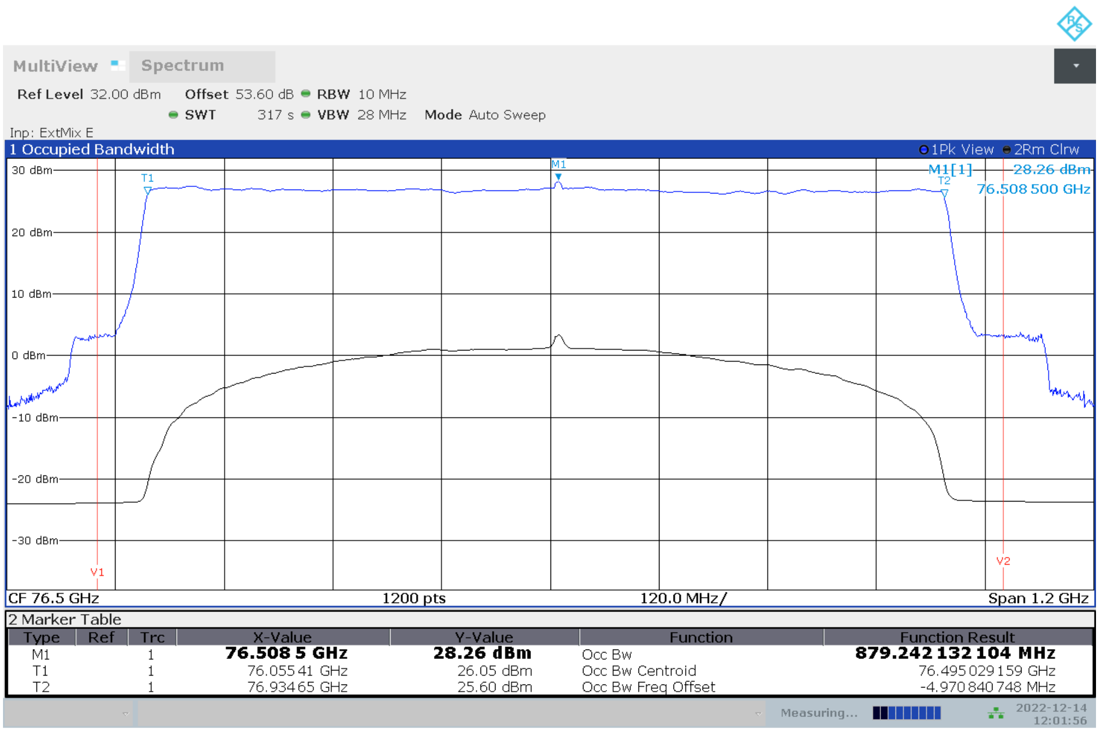
Plot no. 9: 99% OBW, Peak detector, 40 °C, DMP06



Type	Ref	Trc	X-Value	Y-Value	Function	Function Result
M1		1	**76.507 5 GHz**	**28.25 dBm**	Occ Bw	**879.971 675 137 MHz**
T1		1	76.054 84 GHz	25.88 dBm	Occ Bw Centroid	76.494 829 723 GHz
T2		1	76.934 82 GHz	25.80 dBm	Occ Bw Freq Offset	-5.170 276 899 MHz

12:15:00 12/14/2022

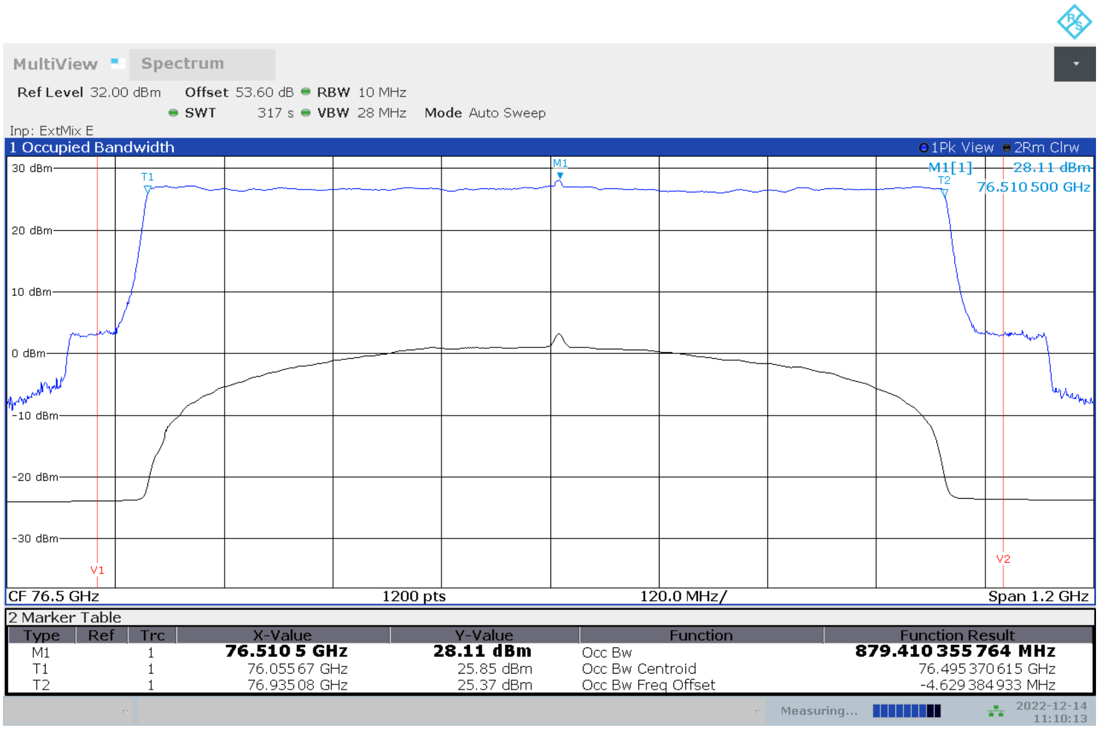
Plot no. 10: 99% OBW, Peak detector, 30 °C, DMP06



Type	Ref	Trc	X-Value	Y-Value	Function	Function Result
M1		1	**76.508 5 GHz**	**28.26 dBm**	Occ Bw	**879.242 132 104 MHz**
T1		1	76.055 41 GHz	26.05 dBm	Occ Bw Centroid	76.495 029 159 GHz
T2		1	76.934 65 GHz	25.60 dBm	Occ Bw Freq Offset	-4.970 840 748 MHz

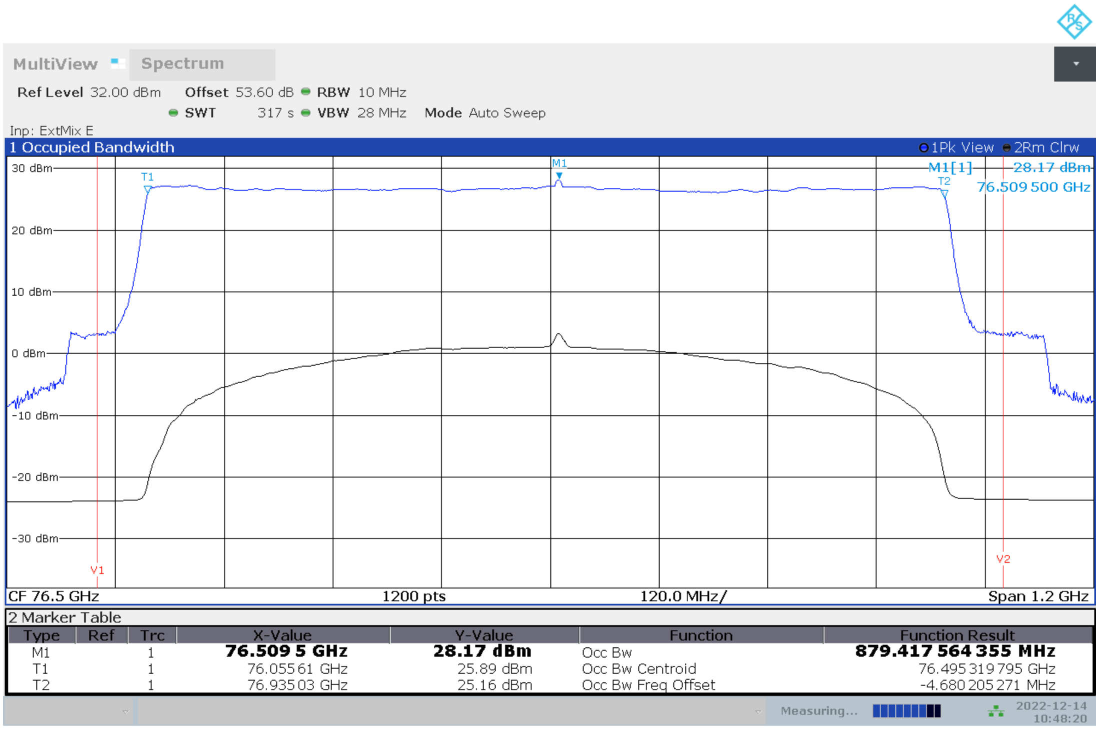
12:01:56 12/14/2022

Plot no. 11: 99% OBW, Peak detector, 20 °C, V_{max}, DMP06



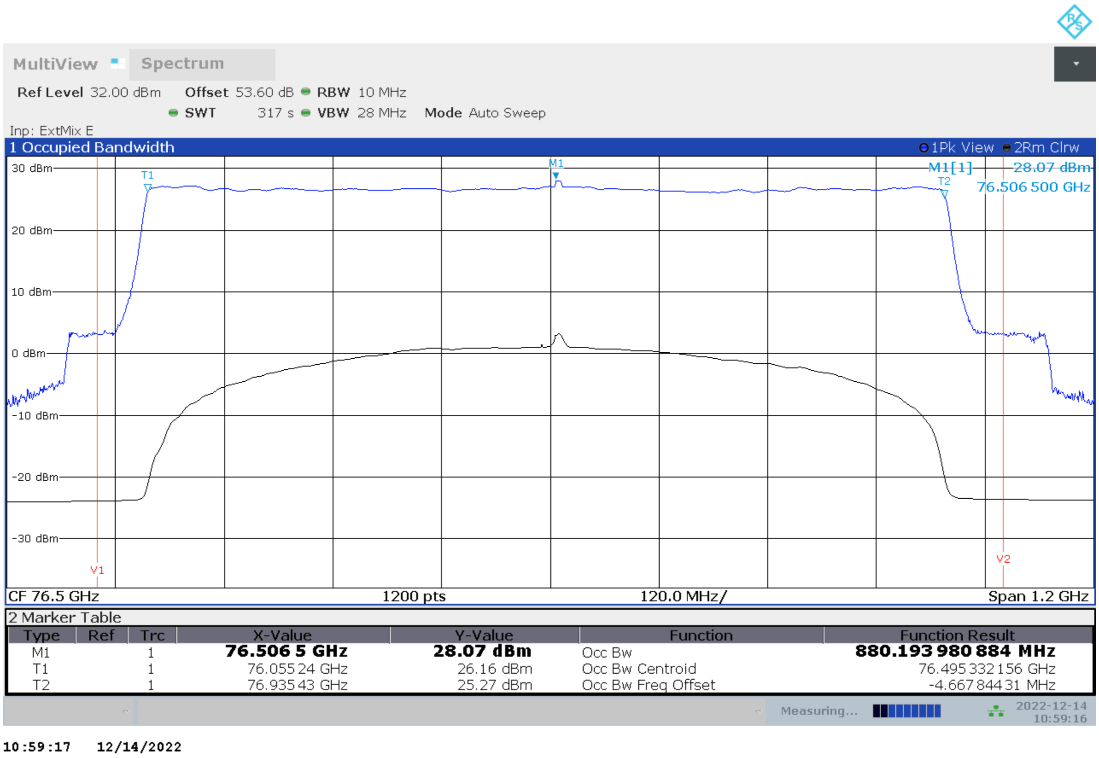
11:10:14 12/14/2022

Plot no. 12: 99% OBW, Peak detector, 20 °C, V_{nom}, DMP06

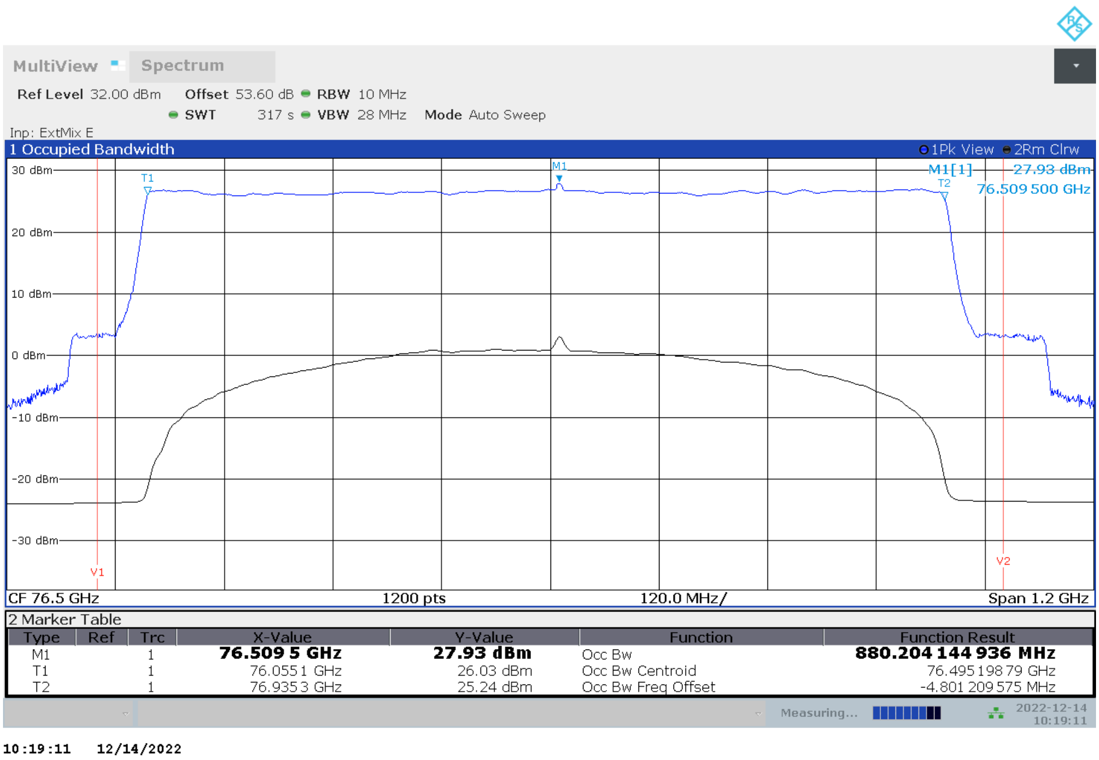


10:48:20 12/14/2022

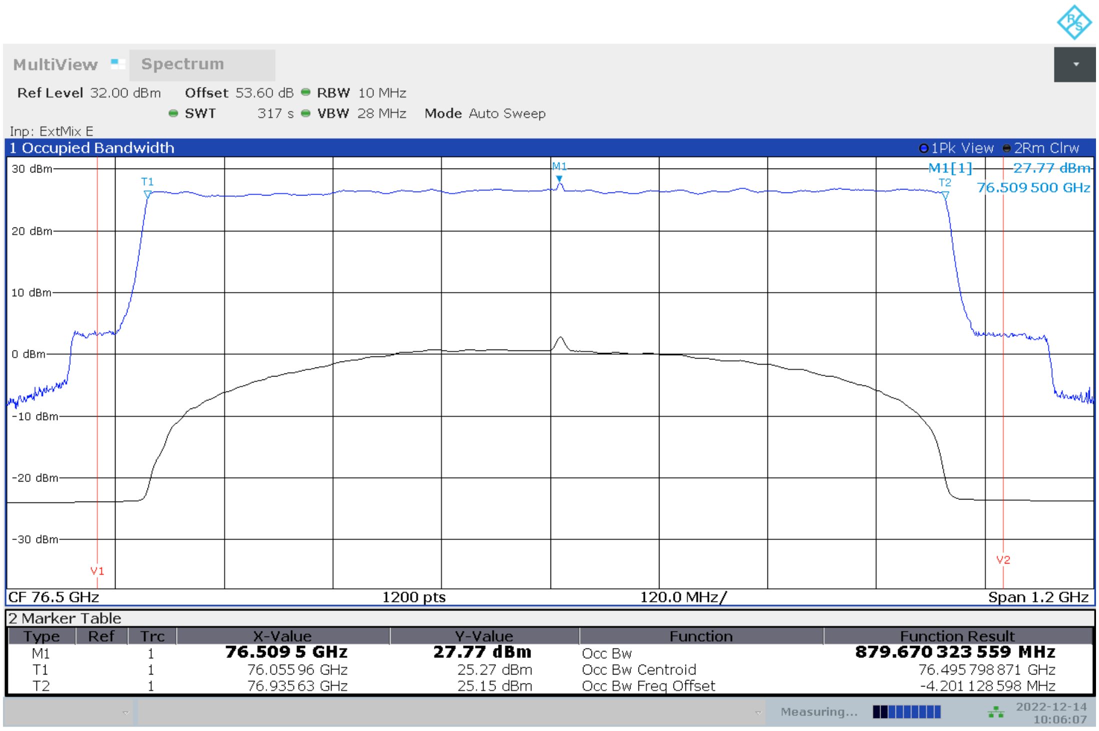
Plot no. 13: 99% OBW, Peak detector, 20 °C, V_{min}, DMP06



Plot no. 14: 99% OBW, Peak detector, 10 °C, DMP06

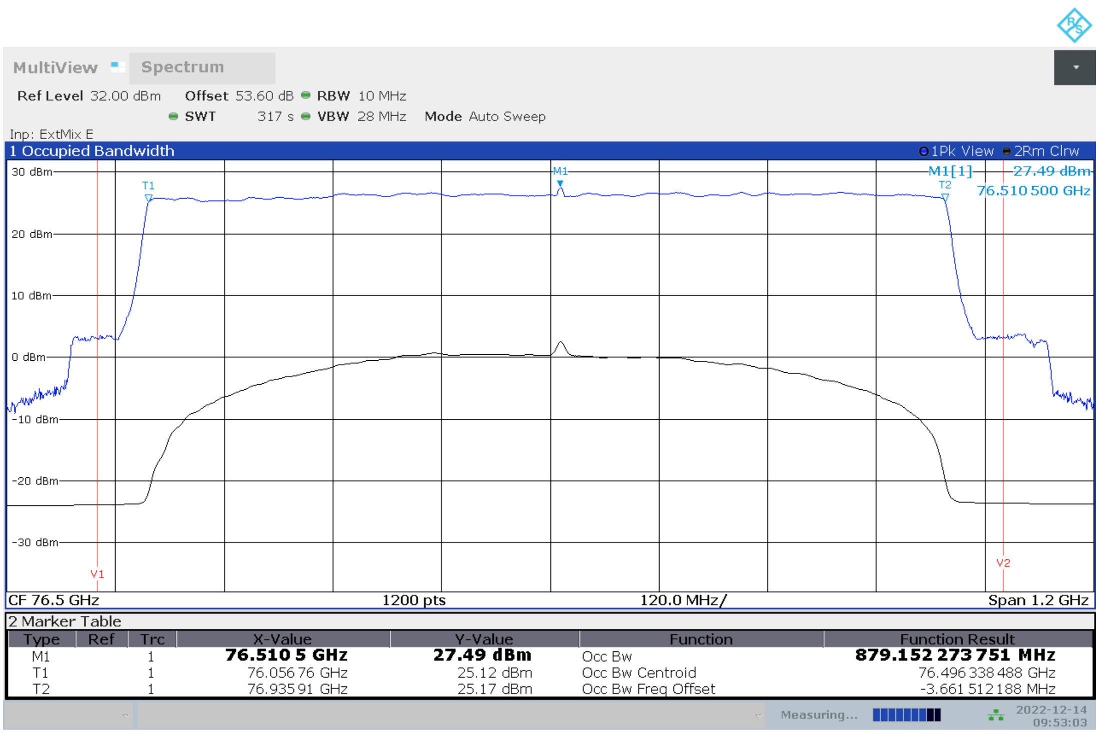


Plot no. 15: 99% OBW, Peak detector, 0 °C, DMP06



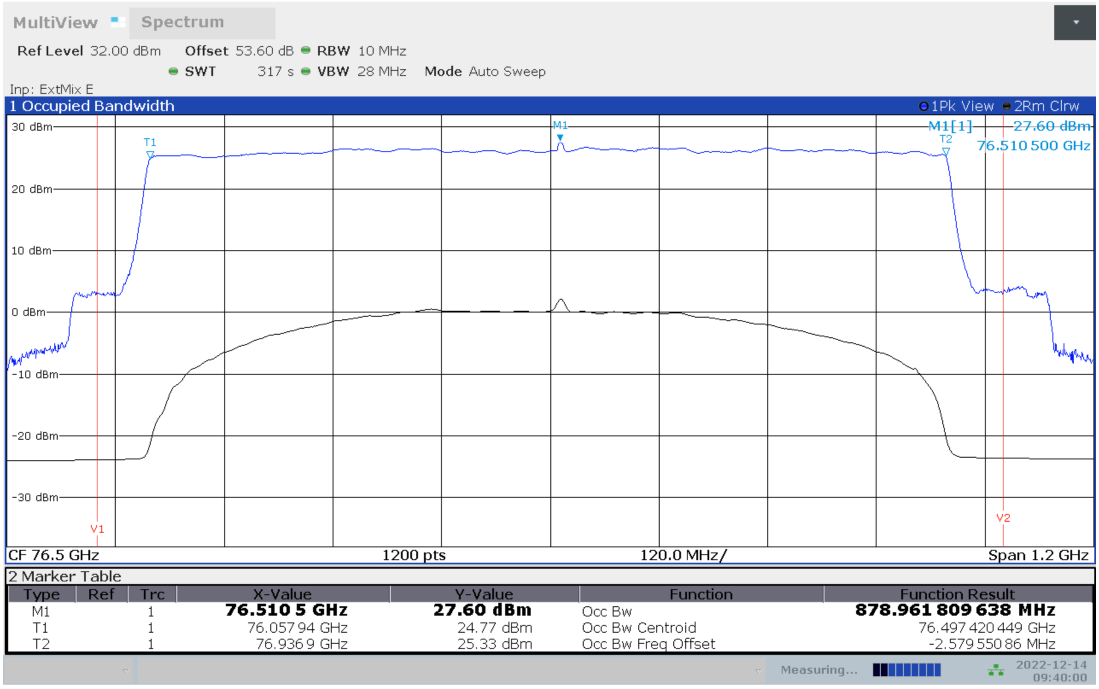
10:06:07 12/14/2022

Plot no. 16: 99% OBW, Peak detector, -10 °C, DMP06



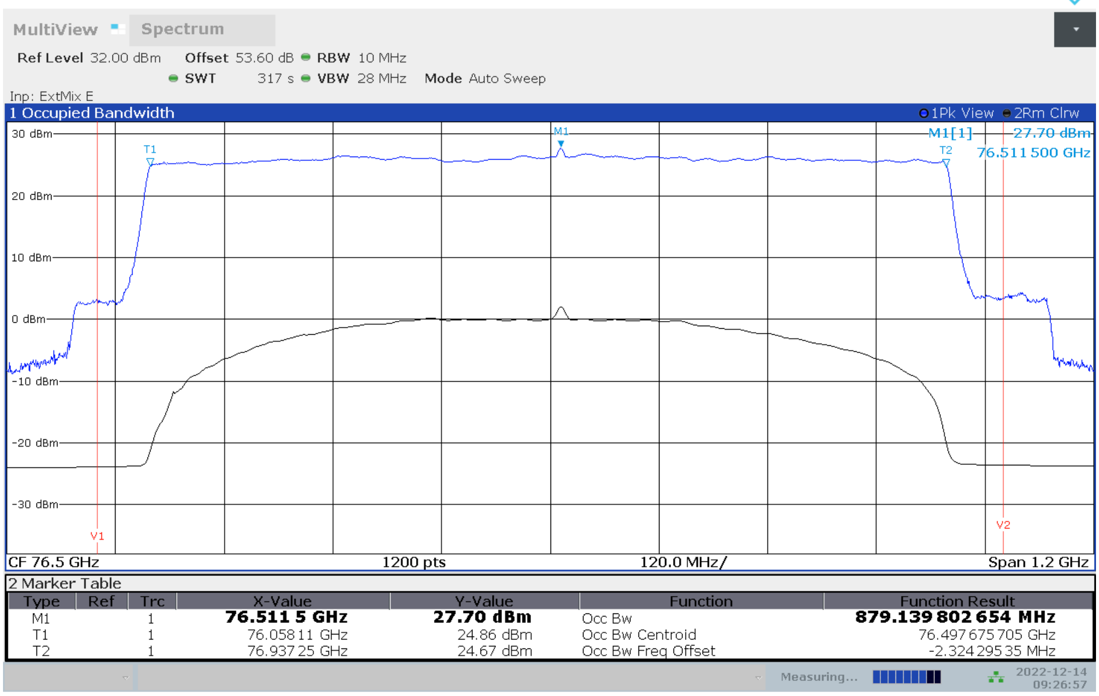
09:53:04 12/14/2022

Plot no. 17: 99% OBW, Peak detector, -20 °C, DMP06



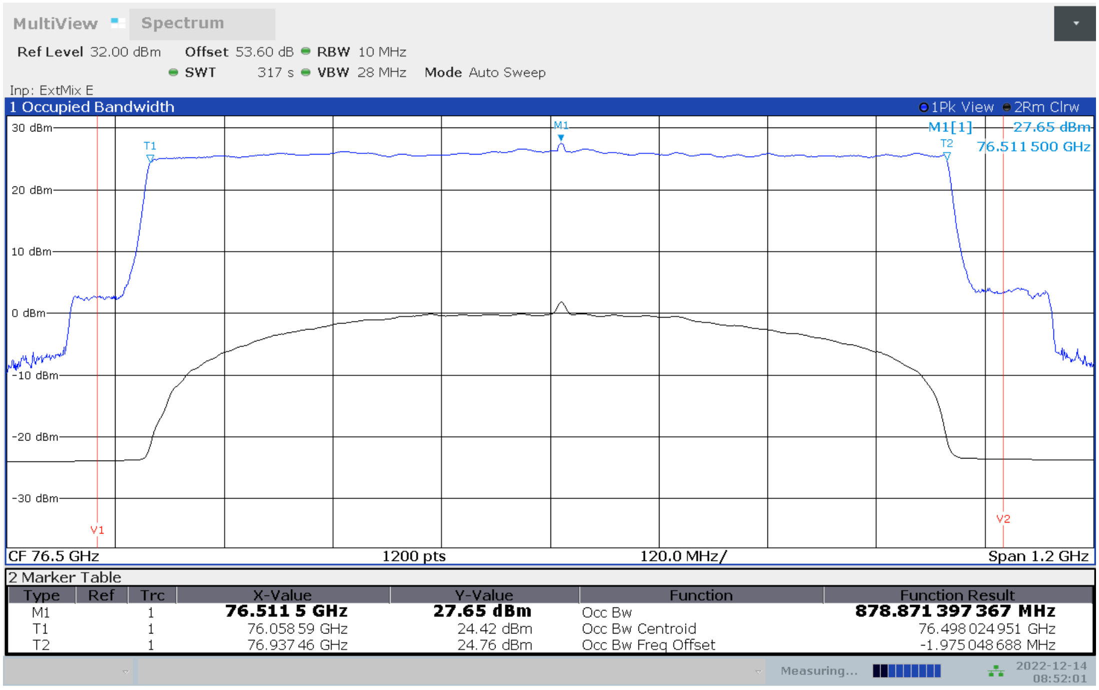
09:40:01 12/14/2022

Plot no. 18: 99% OBW, Peak detector, -30 °C, DMP06



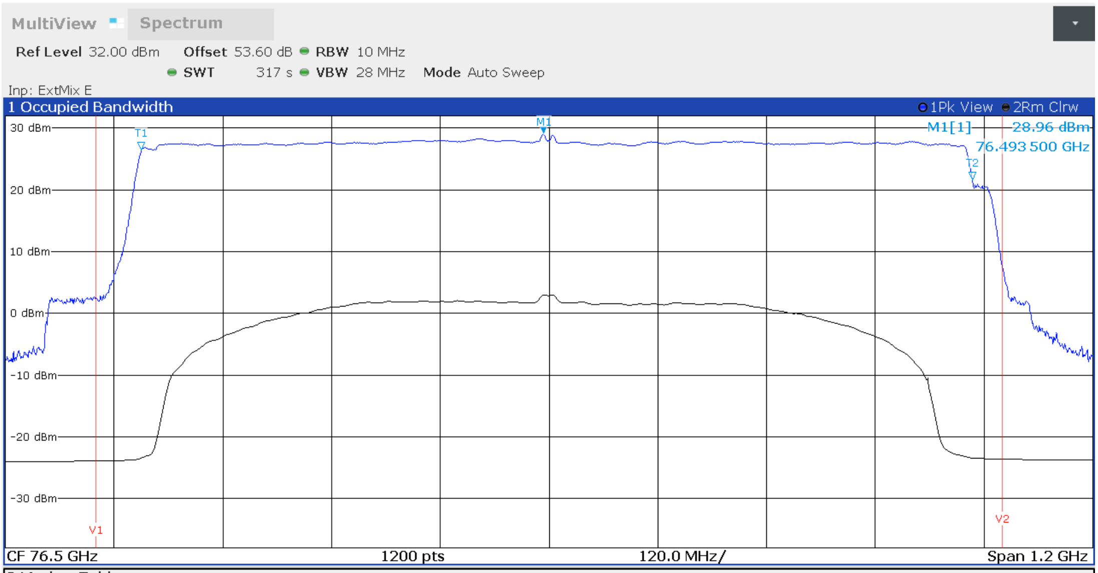
09:26:57 12/14/2022

Plot no. 19: 99% OBW, Peak detector, -40 °C, DMP06



08:52:01 12/14/2022

Plot no. 20: 99% OBW, Peak detector, 85 °C, DMP08



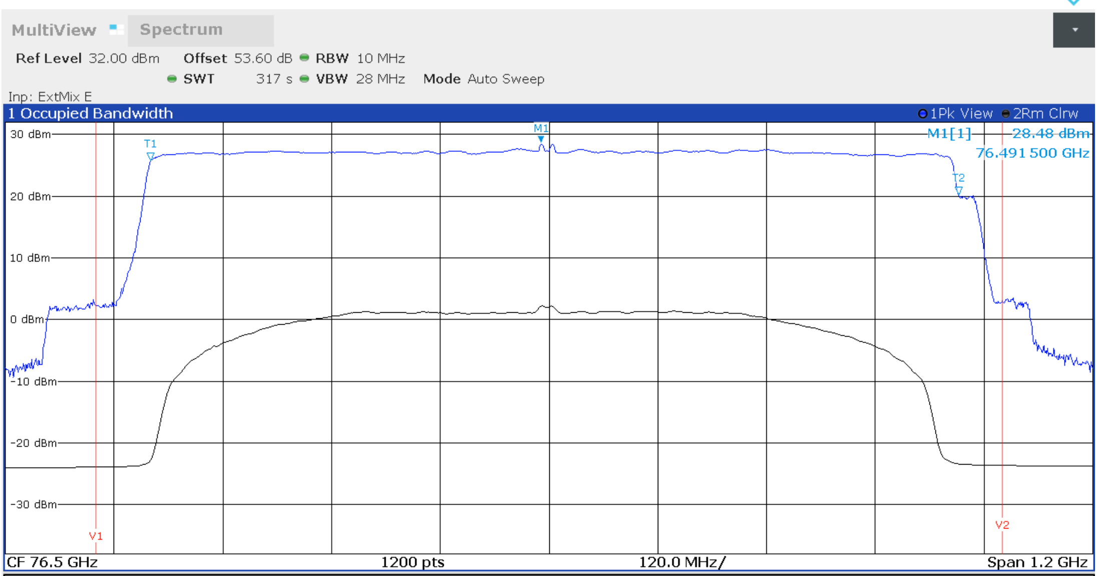
2 Marker Table

Type	Ref	Trc	X-Value	Y-Value	Function	Function Result
M1		1	**76.493 5 GHz**	**28.96 dBm**	Occ Bw	**916.887 018 154 MHz**
T1		1	76.0501 GHz	26.49 dBm	Occ Bw Centroid	76.508 539 298 GHz
T2		1	76.966 98 GHz	21.66 dBm	Occ Bw Freq Offset	8.539 297 549 MHz

Measuring... 2022-12-13 19:48:25

07:48:26 12/13/2022

Plot no. 21: 99% OBW, Peak detector, 50 °C, DMP08



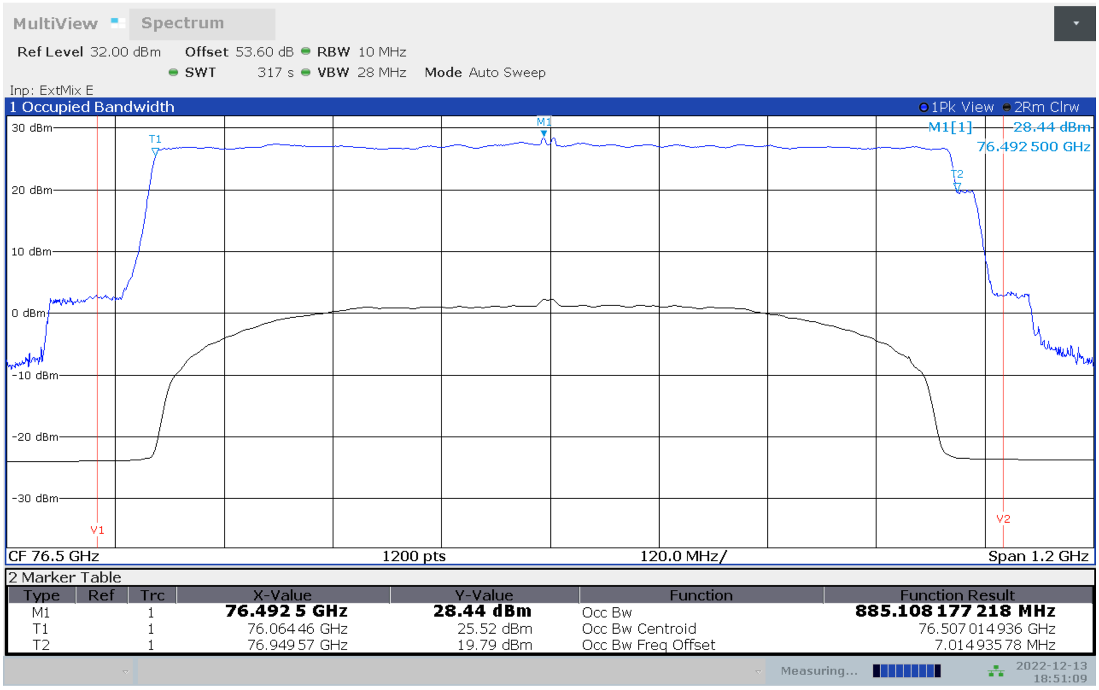
2 Marker Table

Type	Ref	Trc	X-Value	Y-Value	Function	Function Result
M1		1	**76.491 5 GHz**	**28.48 dBm**	Occ Bw	**891.308 965 952 MHz**
T1		1	76.060 36 GHz	25.79 dBm	Occ Bw Centroid	76.506 012 848 GHz
T2		1	76.951 67 GHz	20.21 dBm	Occ Bw Freq Offset	6.012 848 347 MHz

Measuring... 2022-12-13 19:04:13

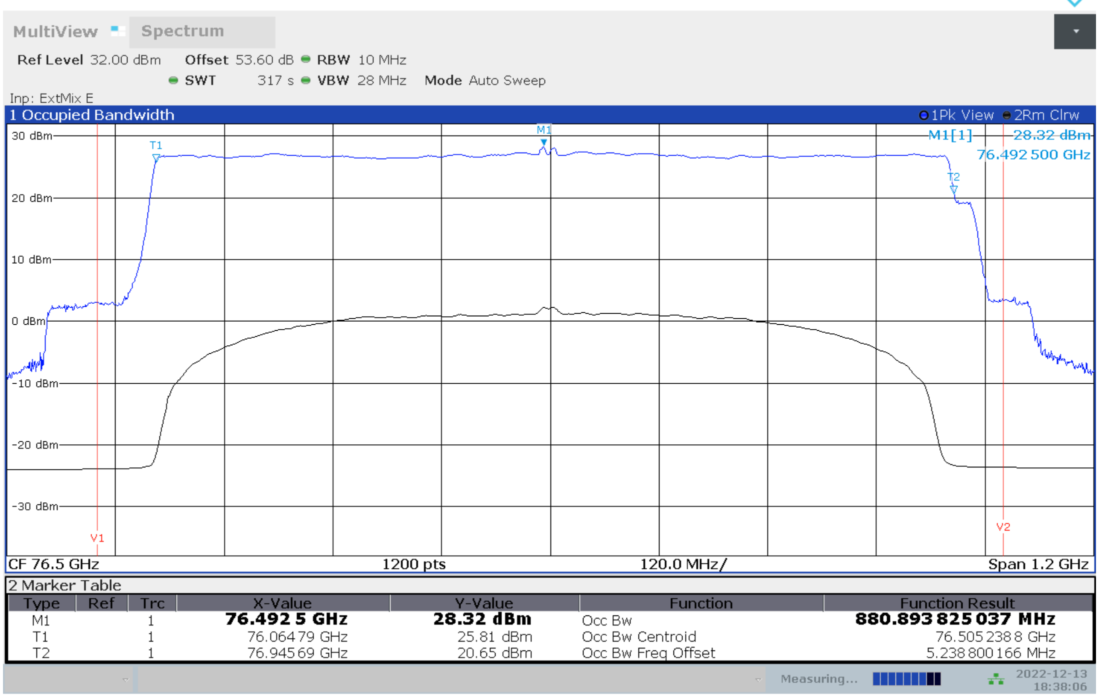
07:04:13 12/13/2022

Plot no. 22: 99% OBW, Peak detector, 40 °C, DMP08



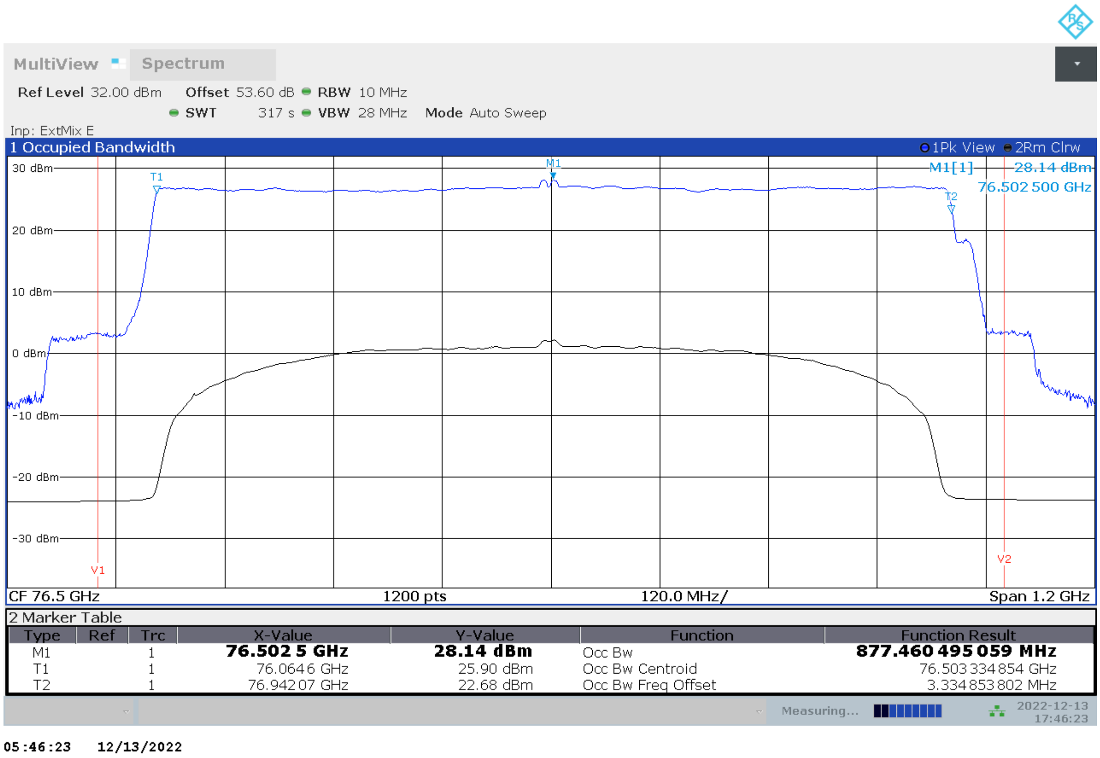
06:51:10 12/13/2022

Plot no. 23: 99% OBW, Peak detector, 30 °C, DMP08

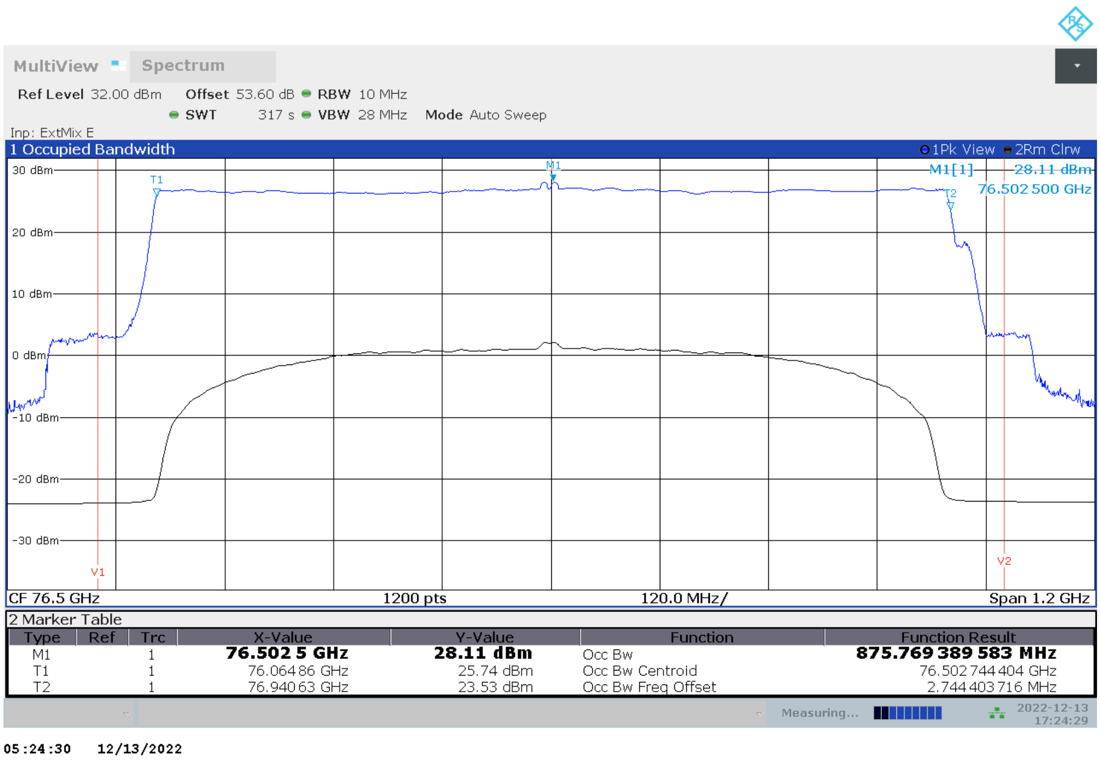


06:38:06 12/13/2022

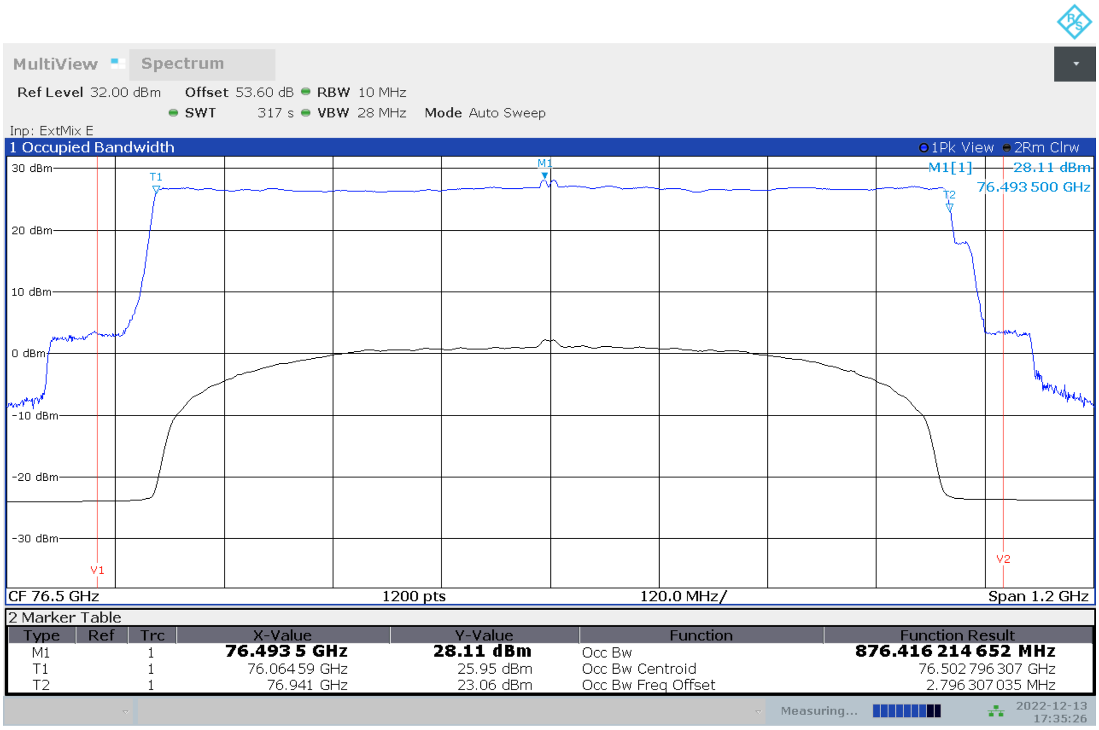
Plot no. 24: 99% OBW, Peak detector, 20 °C, V_{max}, DMP08



Plot no. 25: 99% OBW, Peak detector, 20 °C, V_{nom}, DMP08

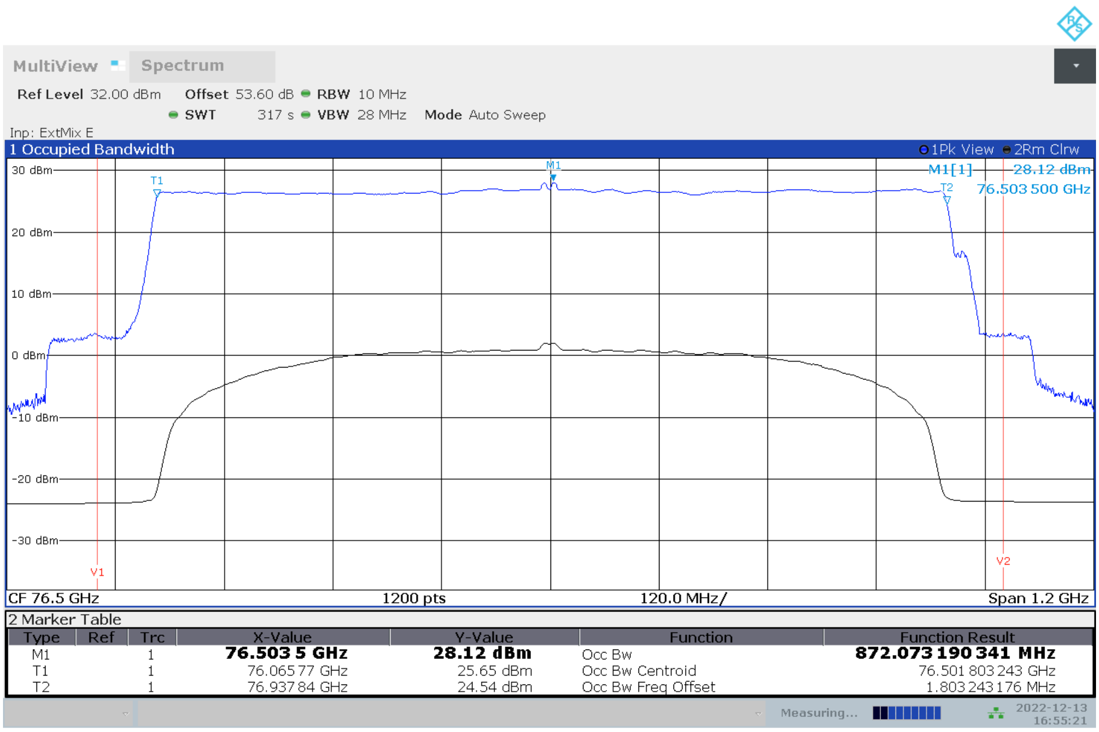


Plot no. 26: 99% OBW, Peak detector, 20 °C, V_{min}, DMP08



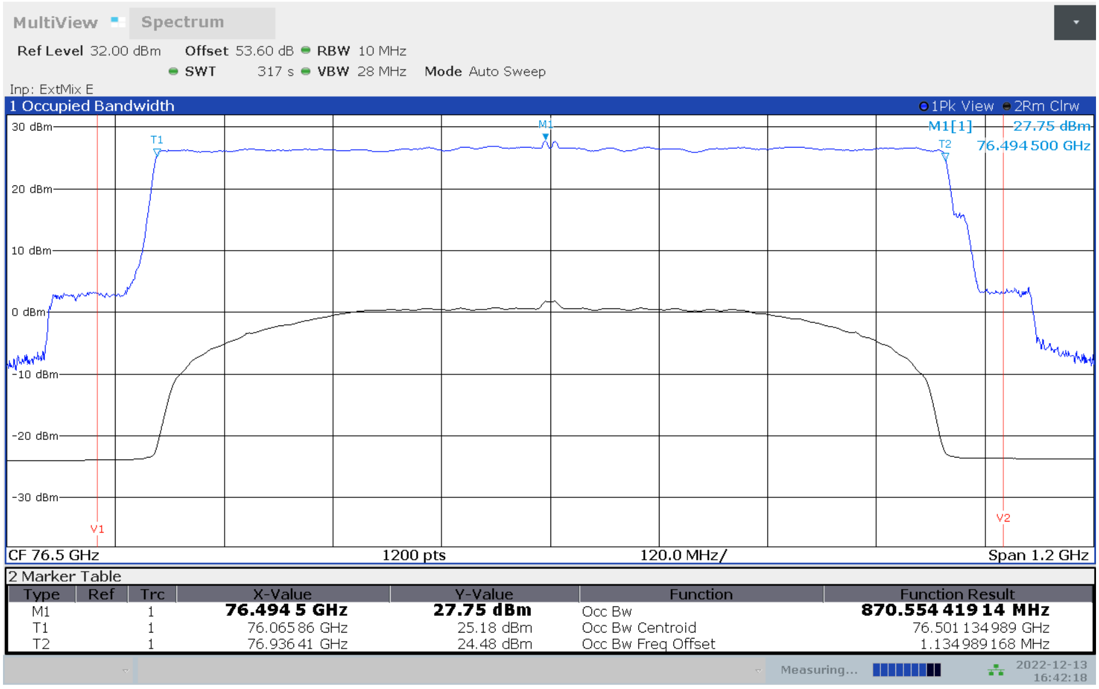
05:35:27 12/13/2022

Plot no. 27: 99% OBW, Peak detector, 10 °C, DMP08



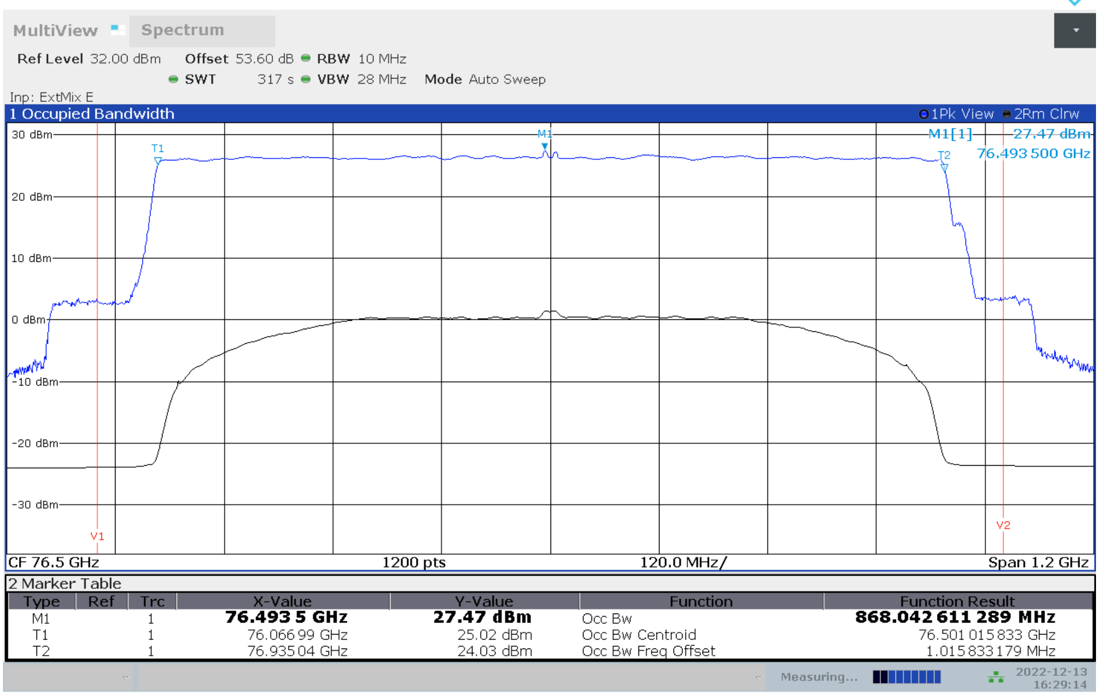
04:55:21 12/13/2022

Plot no. 28: 99% OBW, Peak detector, 0 °C, DMP08



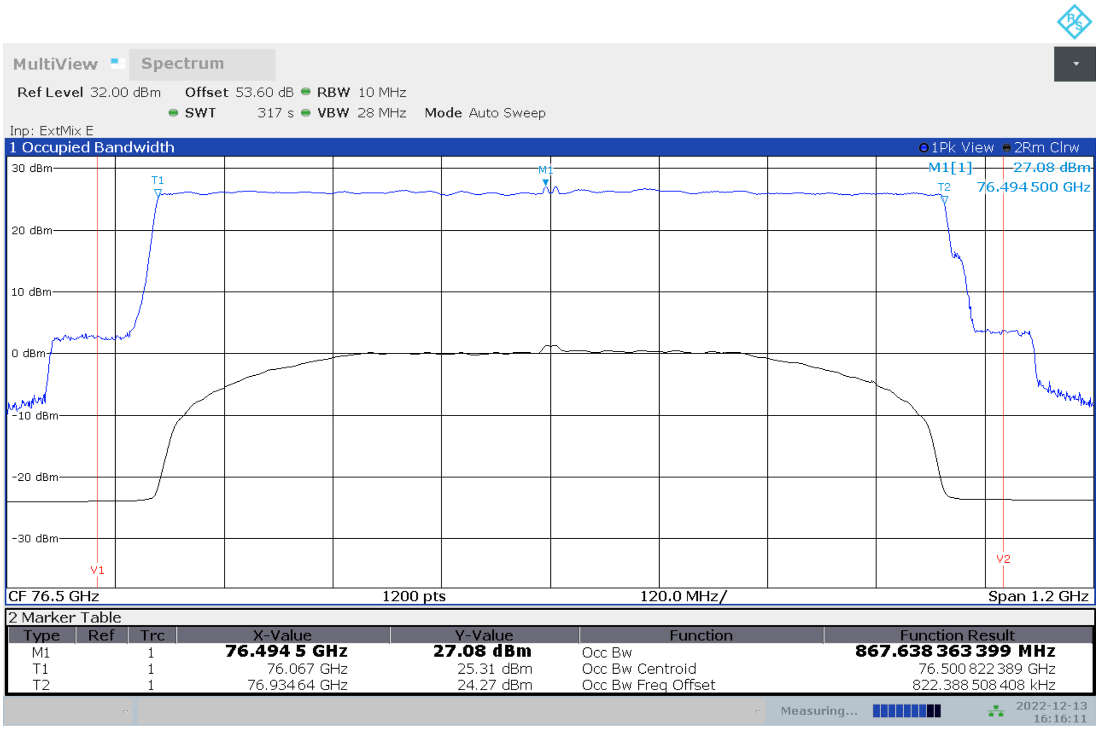
04:42:18 12/13/2022

Plot no. 29: 99% OBW, Peak detector, -10 °C, DMP08



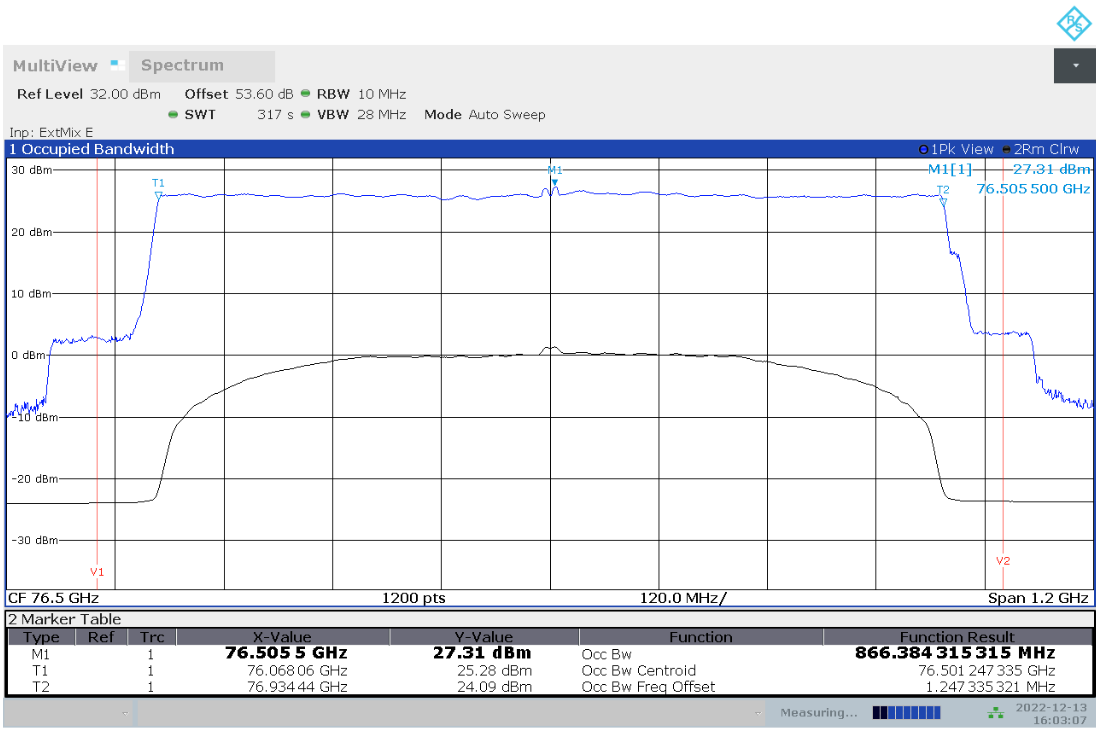
04:29:15 12/13/2022

Plot no. 30: 99% OBW, Peak detector, -20 °C, DMP08



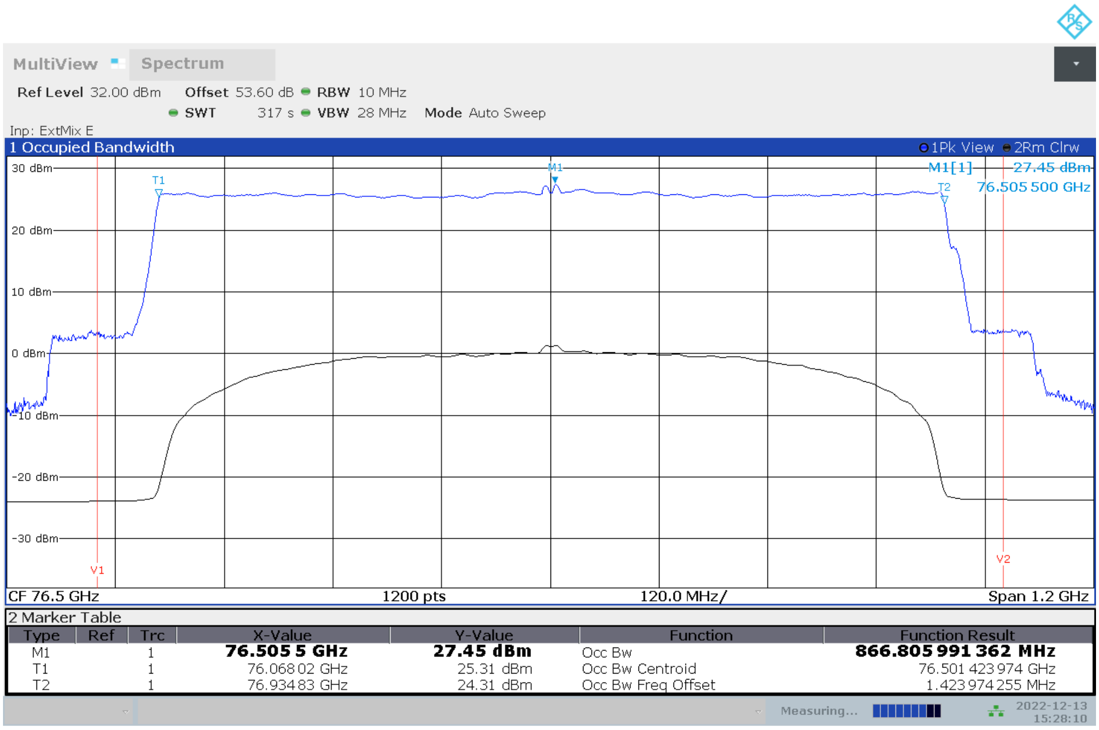
04:16:11 12/13/2022

Plot no. 31: 99% OBW, Peak detector, -30 °C, DMP08



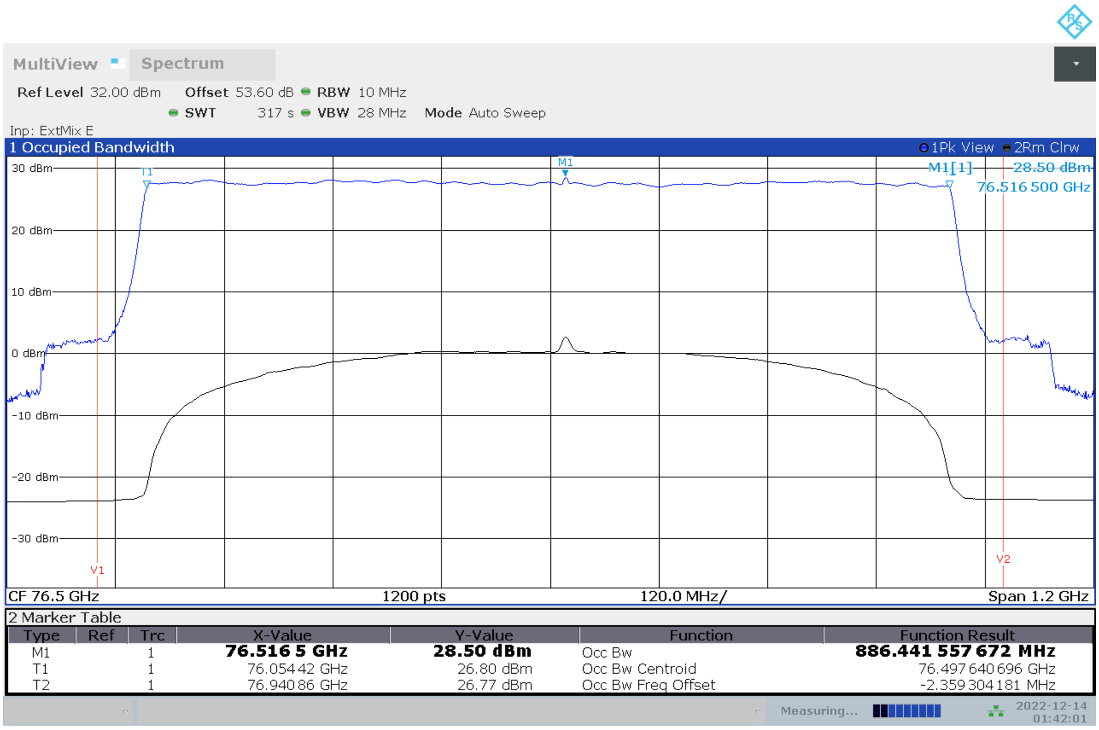
04:03:07 12/13/2022

Plot no. 32: 99% OBW, Peak detector, -40 °C, DMP08



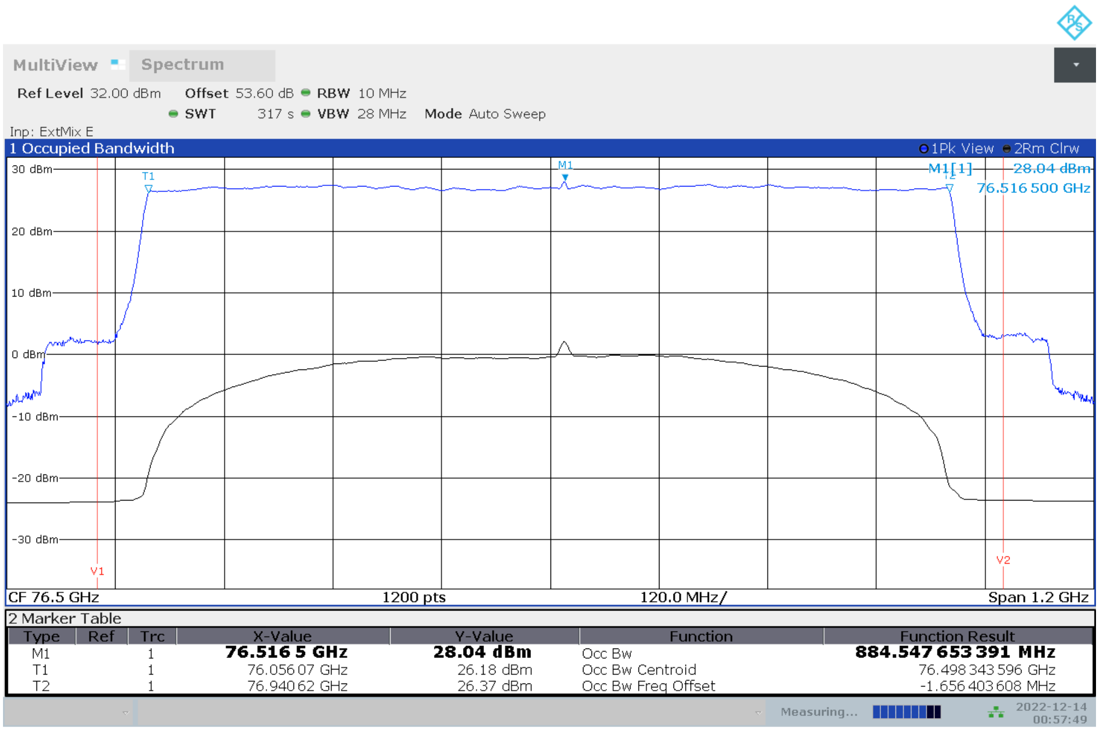
03:28:10 12/13/2022

Plot no. 33: 99% OBW, Peak detector, 85 °C, DMP12



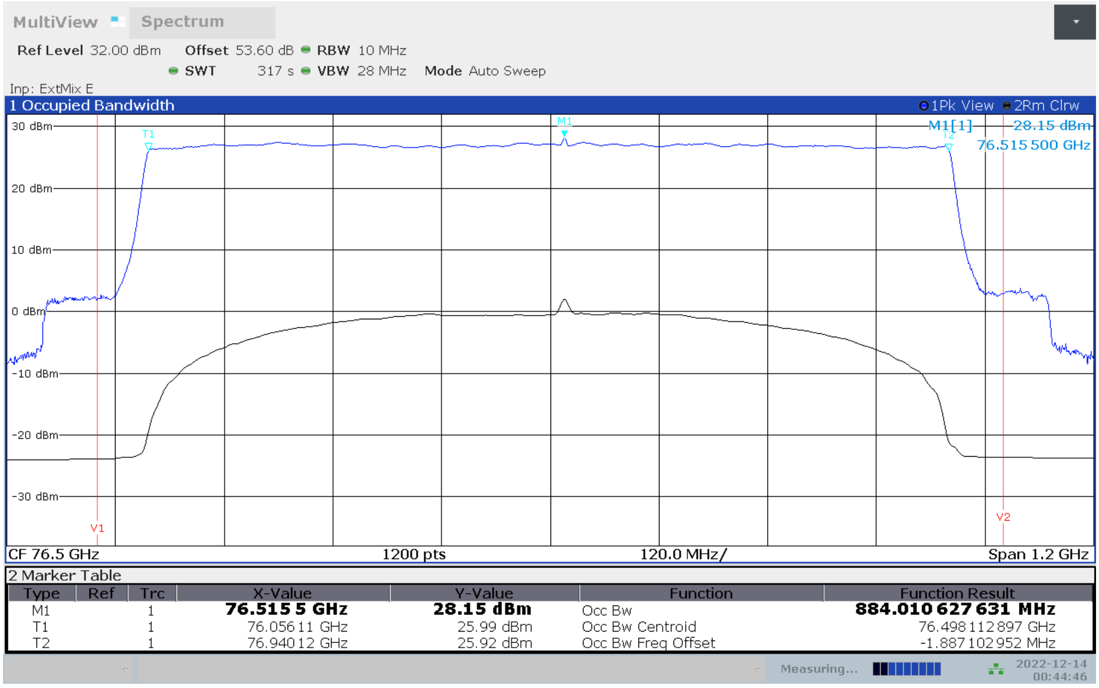
01:42:02 12/14/2022

Plot no. 34: 99% OBW, Peak detector, 50 °C, DMP12



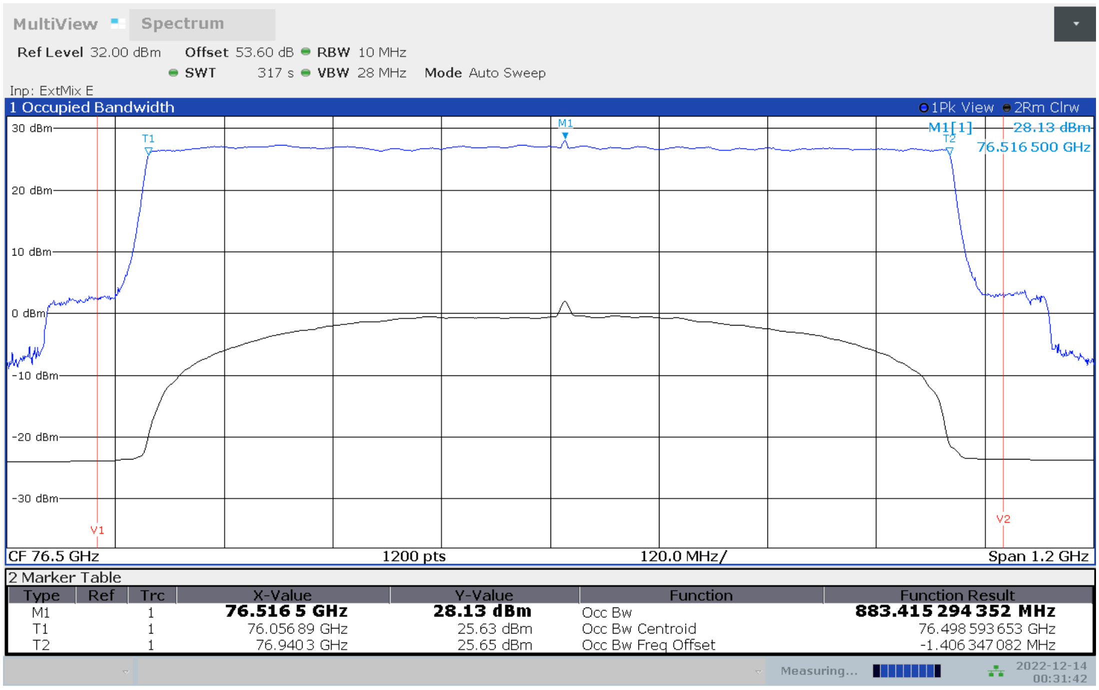
12:57:50 12/14/2022

Plot no. 35: 99% OBW, Peak detector, 40 °C, DMP12



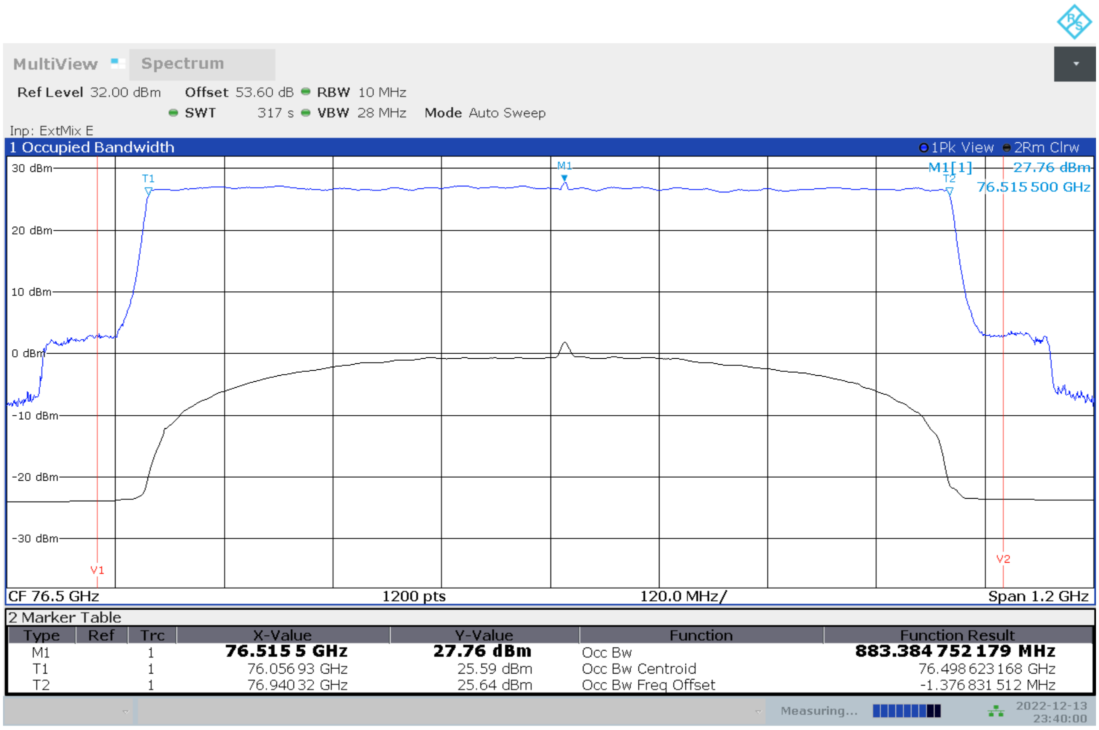
12:44:47 12/14/2022

Plot no. 36: 99% OBW, Peak detector, 30 °C, DMP12



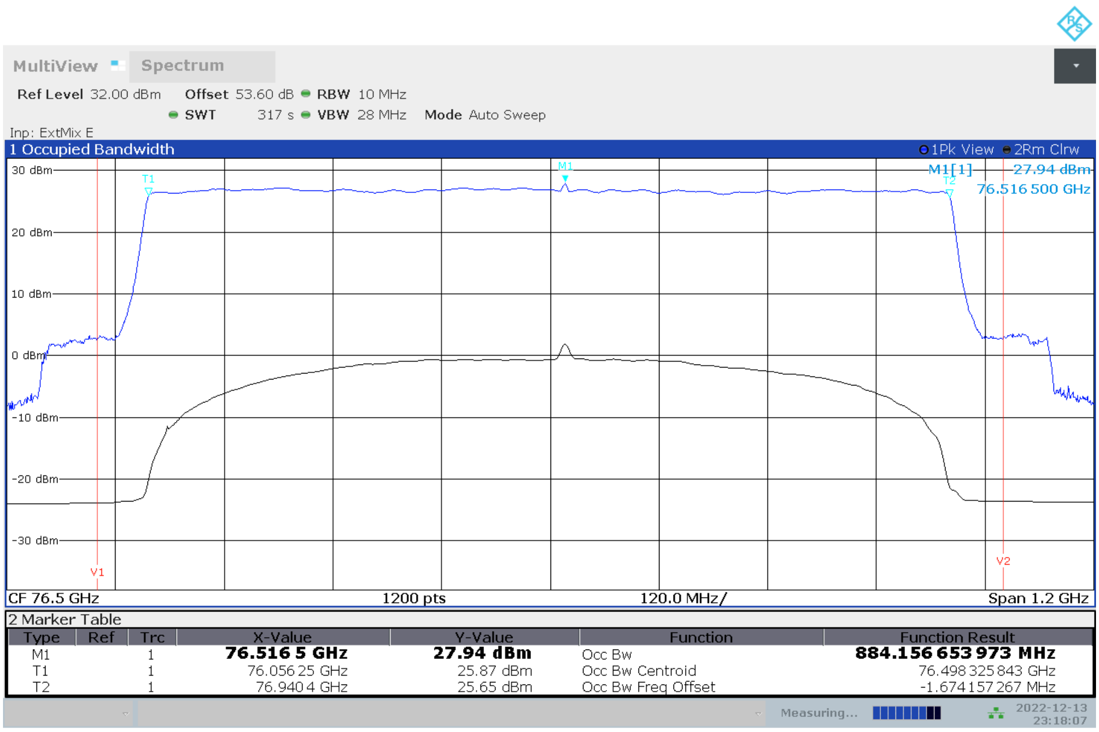
12:31:43 12/14/2022

Plot no. 37: 99% OBW, Peak detector, 20 °C, V_{max}, DMP12



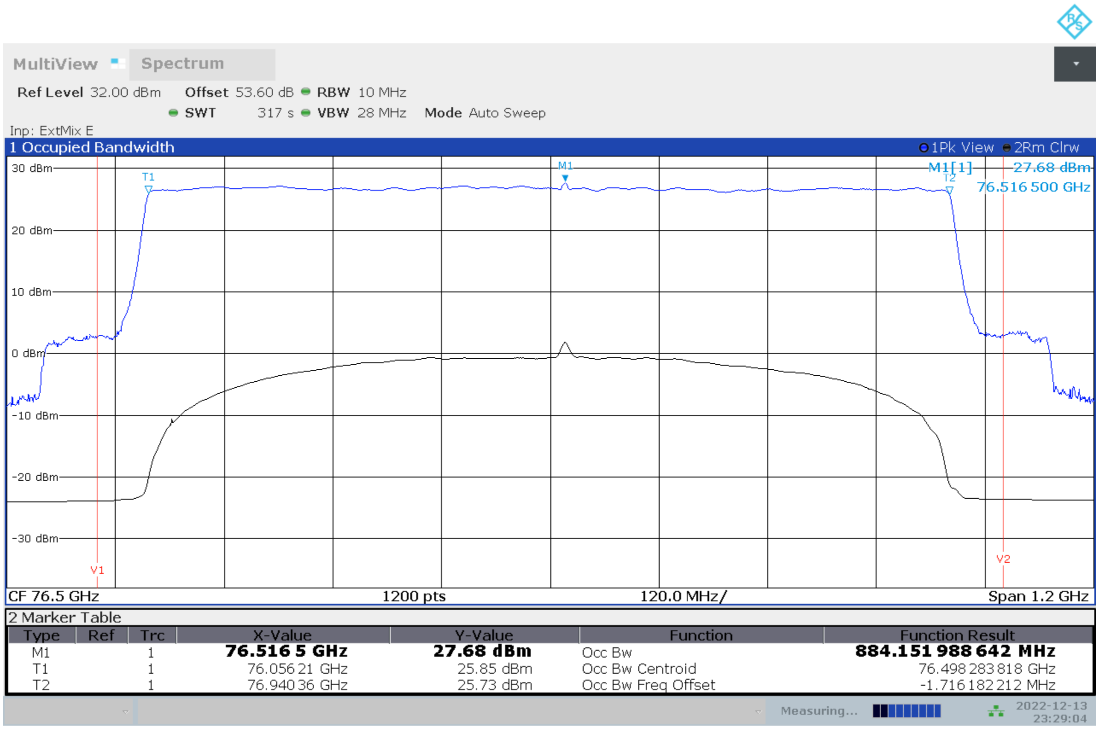
11:40:01 12/13/2022

Plot no. 38: 99% OBW, Peak detector, 20 °C, V_{nom}, DMP12



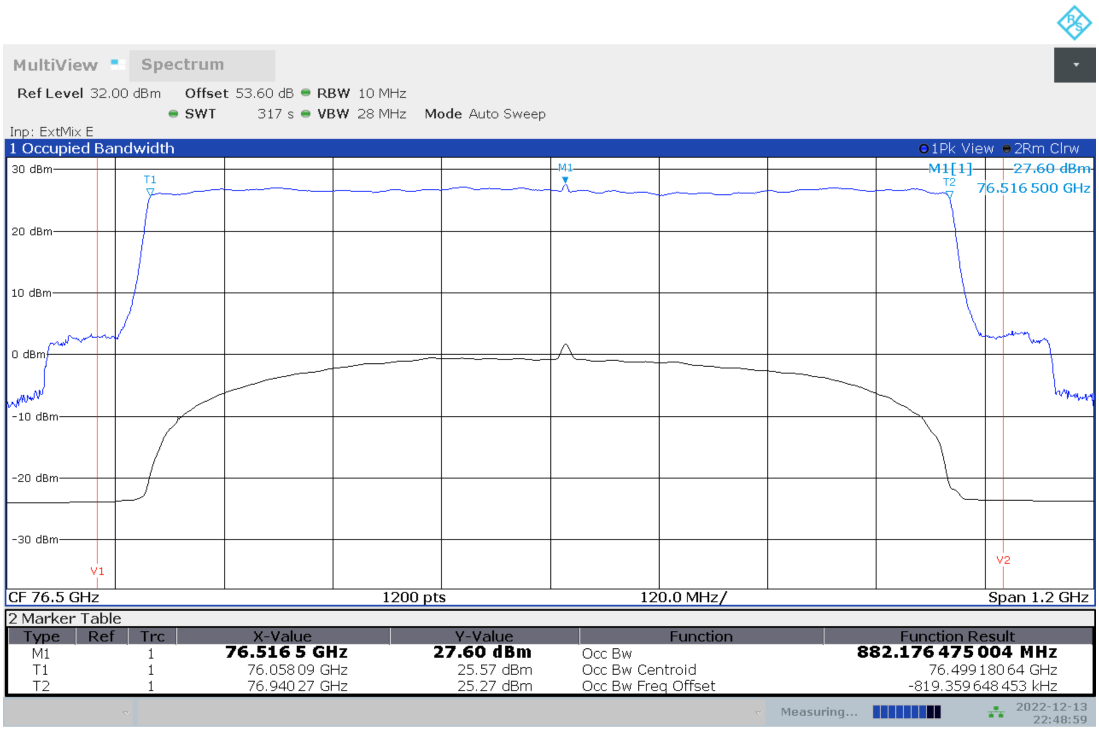
11:18:08 12/13/2022

Plot no. 39: 99% OBW, Peak detector, 20 °C, V_{min}, DMP12



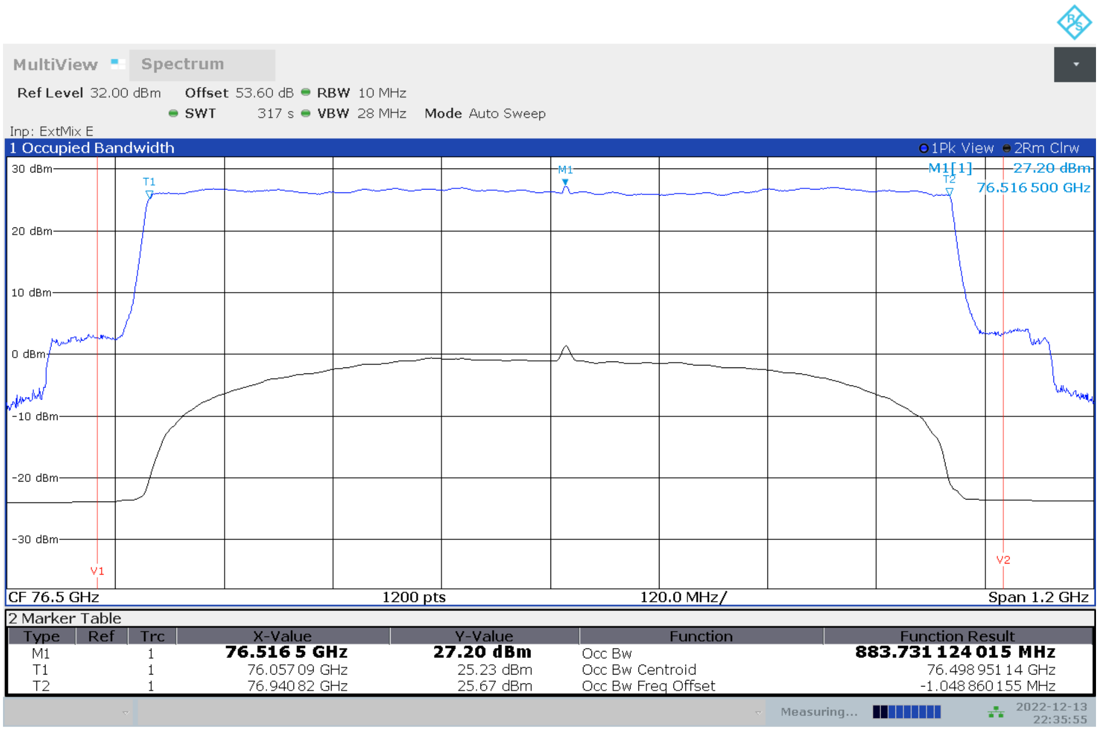
11:29:04 12/13/2022

Plot no. 40: 99% OBW, Peak detector, 10 °C, DMP12



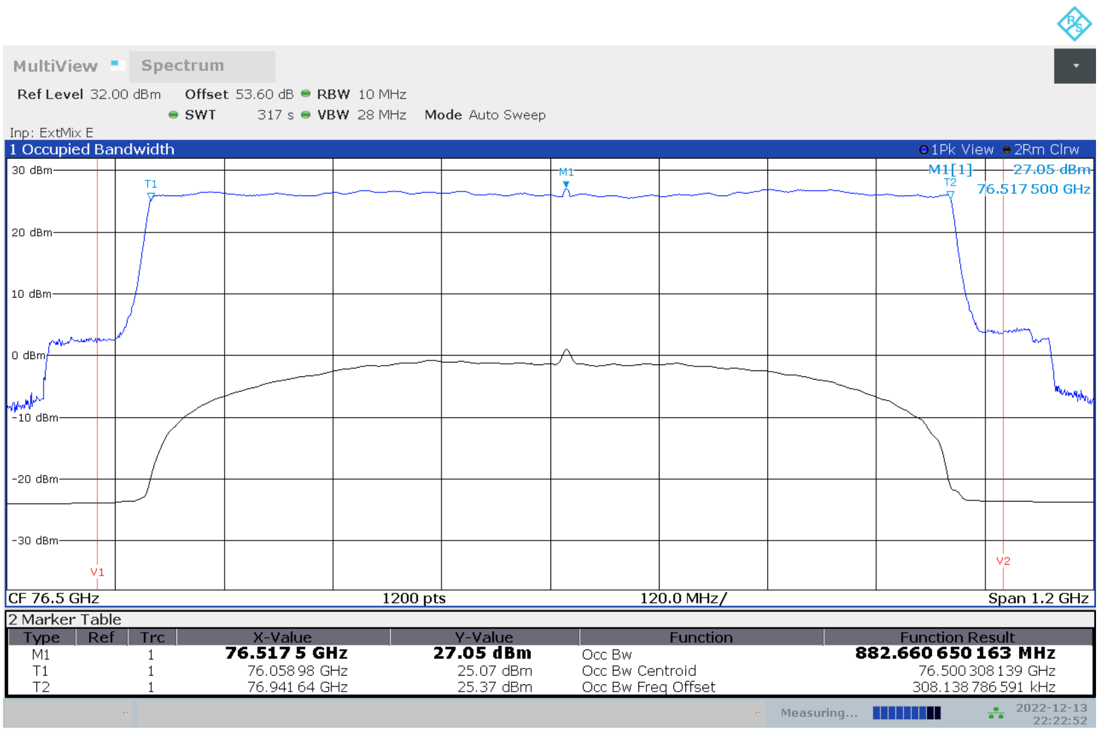
10:48:59 12/13/2022

Plot no. 41: 99% OBW, Peak detector, 0 °C, DMP12



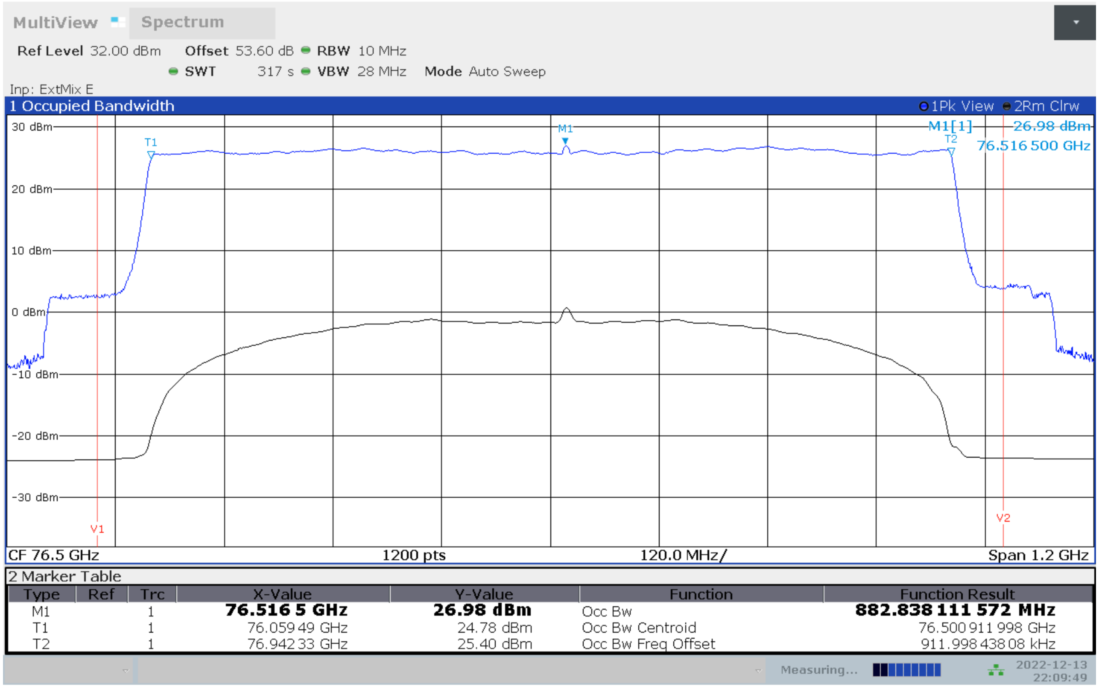
10:35:55 12/13/2022

Plot no. 42: 99% OBW, Peak detector, -10 °C, DMP12



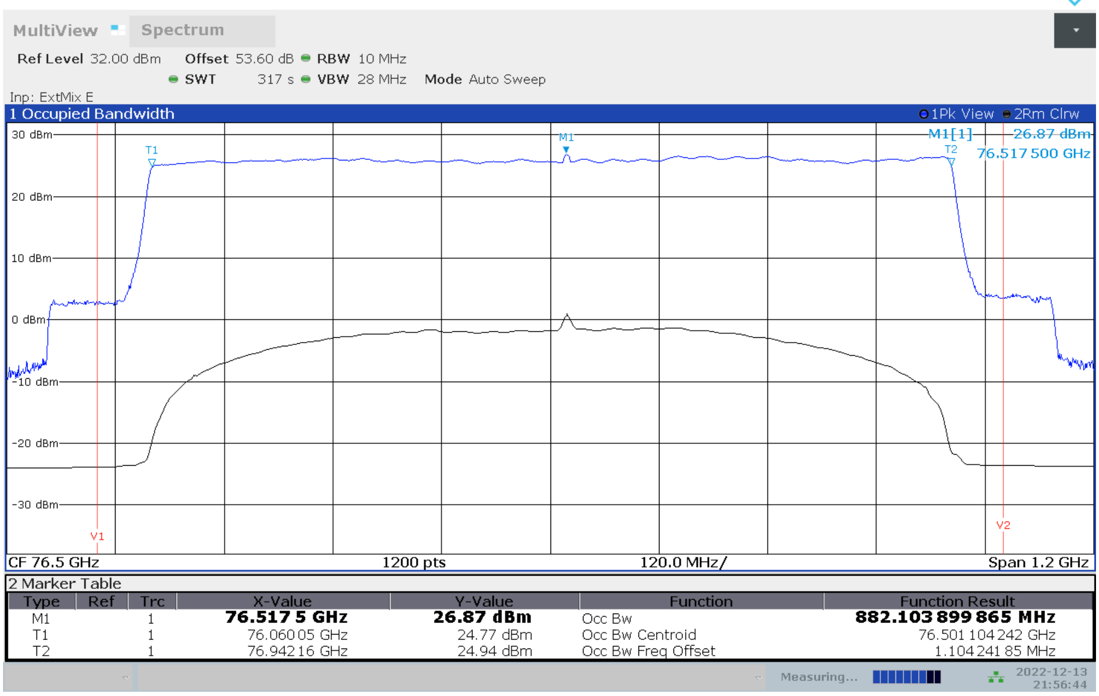
10:22:52 12/13/2022

Plot no. 43: 99% OBW, Peak detector, -20 °C, DMP12



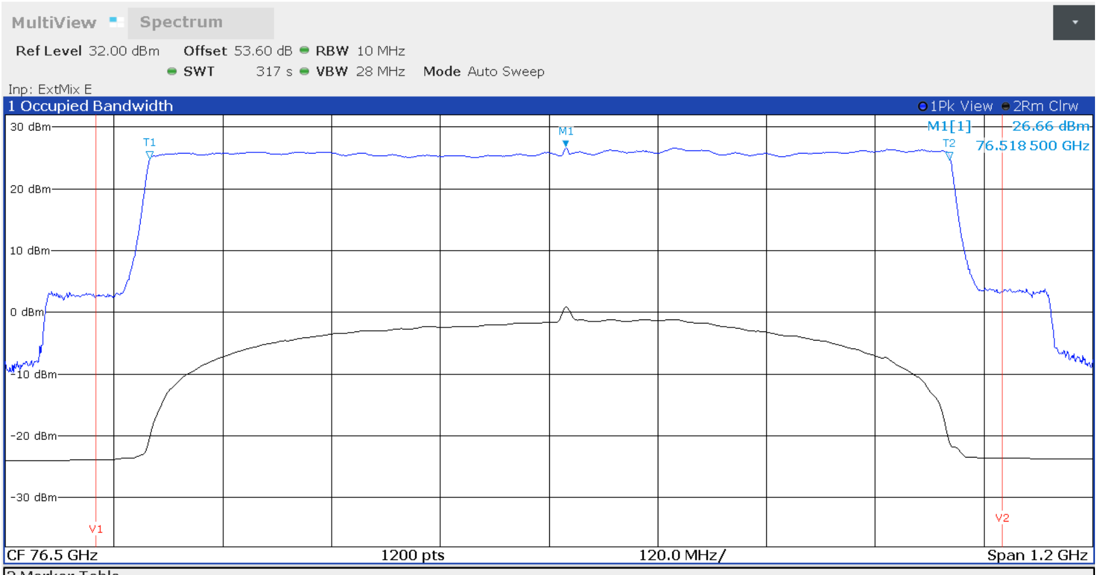
10:09:49 12/13/2022

Plot no. 44: 99% OBW, Peak detector, -30 °C, DMP12



09:56:45 12/13/2022

Plot no. 45: 99% OBW, Peak detector, -40 °C, DMP12



Type	Ref	Trc	X-Value	Y-Value	Function	Function Result
M1		1	**76.518 5 GHz**	**26.66 dBm**	Occ Bw	**882.439 174 142 MHz**
T1		1	76.059 57 GHz	24.79 dBm	Occ Bw Centroid	76.500 786 345 GHz
T2		1	76.942 01 GHz	24.64 dBm	Occ Bw Freq Offset	786.344 622 437 kHz

09:21:48 12/13/2022

7.4 Field strength of spurious radiation (§2.1053 & §95.3379)

Description

§2.1053 Measurements required: Field strength of spurious radiation.

(a) Measurements shall be made to detect spurious emissions that may be radiated directly from the cabinet, control circuits, power leads, or intermediate circuit elements under normal conditions of installation and operation. Curves or equivalent data shall be supplied showing the magnitude of each harmonic and other spurious emission. For this test, single sideband, independent sideband, and controlled carrier transmitters shall be modulated under the conditions specified in paragraph (c) of §2.1049, as appropriate. For equipment operating on frequencies below 890 MHz, an open field test is normally required, with the measuring instrument antenna located in the far-field at all test frequencies. In the event it is either impractical or impossible to make open field measurements (e.g. a broadcast transmitter installed in a building) measurements will be accepted of the equipment as installed. Such measurements must be accompanied by a description of the site where the measurements were made showing the location of any possible source of reflections which might distort the field strength measurements. Information submitted shall include the relative radiated power of each spurious emission with reference to the rated power output of the transmitter, assuming all emissions are radiated from halfwave dipole antennas.

Limits

§95.3379 76-81 GHz Band Radar Service unwanted emissions limits.

(a) The power density of any emissions outside the 76-81 GHz band shall consist solely of spurious emissions and shall not exceed the following:

(1) Radiated emissions below 40 GHz shall not exceed the field strength as shown in the following emissions table.

Frequency [MHz]	Field Strength [µV/m] / [dBµV/m]	Measurement distance [m]
0.009 – 0.490	2400/F[kHz]	300
0.490 – 1.705	24000/F[kHz]	30
1.705 – 30.0	30.0 / 29.5	30
30 – 88	100 / 40.0	3
88 – 216	150 / 43.5	3
216 – 960	200 / 46.0	3
960 – 40 000	500 / 54.0	3

(2) The power density of radiated emissions outside the 76-81 GHz band above 40.0 GHz shall not exceed the following, based on measurements employing an average detector with a 1 MHz RBW:

Frequency [GHz]	Power Density / EIRP	Measurement distance [m]
40 – 200	600 pW/cm² → -1.7 dBm	3
200 – 243	1000 pW/cm² → +0.5 dBm	3

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 C63.26, chapter D2: general considerations).

Calculation of the far field distance (Rayleigh distance):
The aperture dimensions of these horn antennas shall be small enough so that the measurement distance in meters is equal to or greater than the Rayleigh distance (i.e. $R_m = 2D^2 / \lambda$), where *D* is the largest linear dimension (i.e. width or height) of the antenna aperture in m and λ is the free-space wavelength in meters at the frequency of measurement.

Antenna type	Frequency range [GHz]	D [m]	Highest frequency in use [GHz]	Far field distance R_m [m]
20240-20	18.0 – 26.5	0.0520	26.5	0.478
22240-20	26.5 – 40.0	0.0342	40	0.312
23240-20	33.0 – 50.0	0.0280	50	0.261
24240-20	40.0 – 60.0	0.0230	60	0.212
25240-20	50.0 – 75.0	0.0185	75	0.171
26240-20	60.0 – 90.0	0.0150	90	0.135
27240-20	75.0 – 110	0.0124	110	0.113
28240-20	90.0 – 140	0.0100	140	0.093
29240-20	110 – 170	0.0085	170	0.082
30240-20	140 – 220	0.0068	220	0.068
32240-20	220 – 325	0.00446	243	0.032

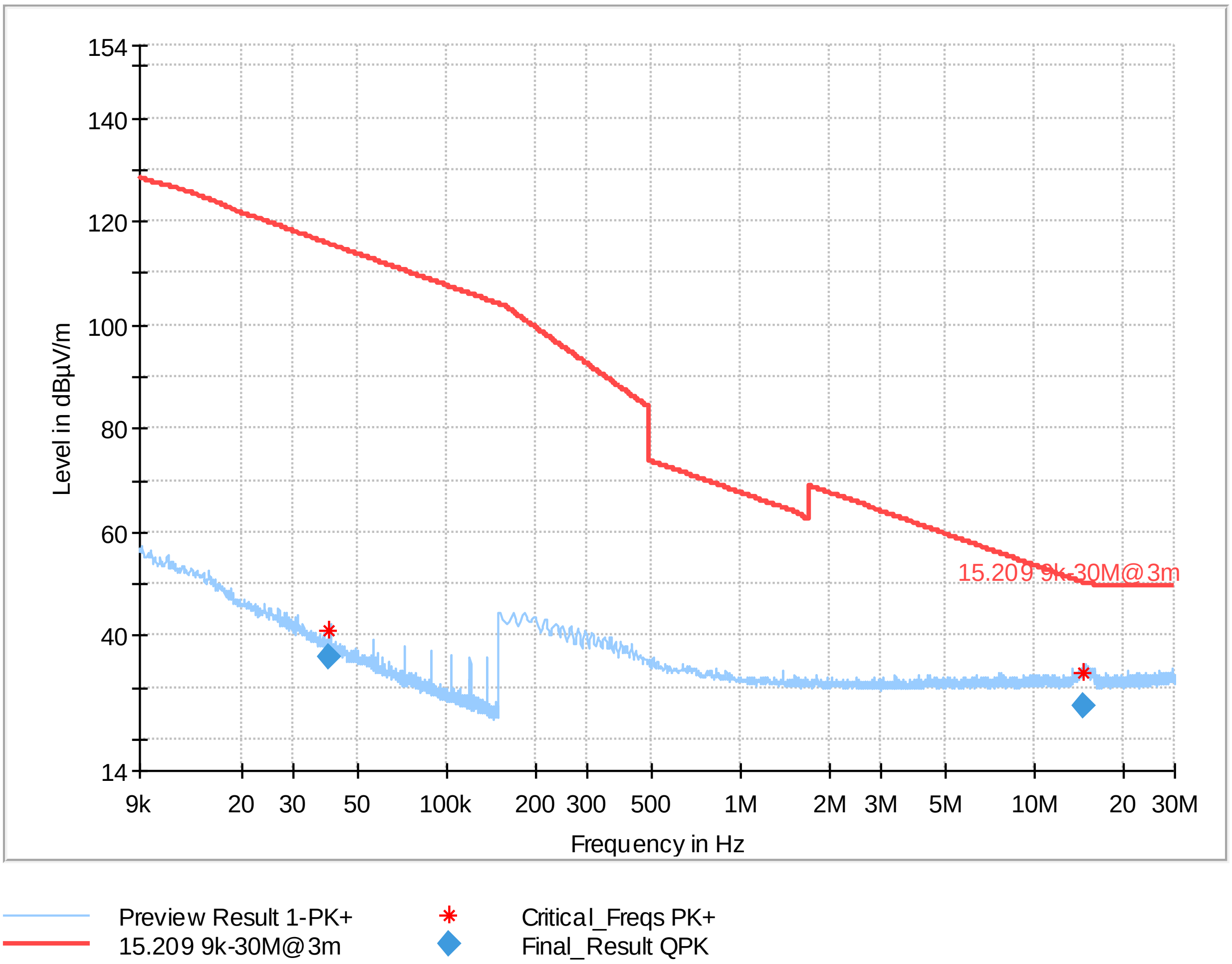
Used test distances
Up to 18 GHz: 3.00 m
18 to 40 GHz: 0.50 m
40 to 60 GHz: 1.00 m
60 to 84 GHz: 1.50 m
84 to 110 GHz: 0.50 m
110 to 170 GHz: 0.25 m
170 to 220 GHz: 0.25 m
220 to 231 GHz: 0.25 m

Test setup: 8.1 – 8.4 (in case of field strength measurements below 40 GHz: test distance correction factor of 20dB/decade is already considered in the plots / test result table)

Test results

Channel / Mode	Frequency [GHz]	Detector	Test distance [m]	Level [dBµV/dBm]	Limit [dBµV/dBm]	Margin [dB]
No critical peaks found. Please refer to plots.						

Plot no. 46: radiated emissions 9 kHz – 30 MHz, loop antenna, DMP06



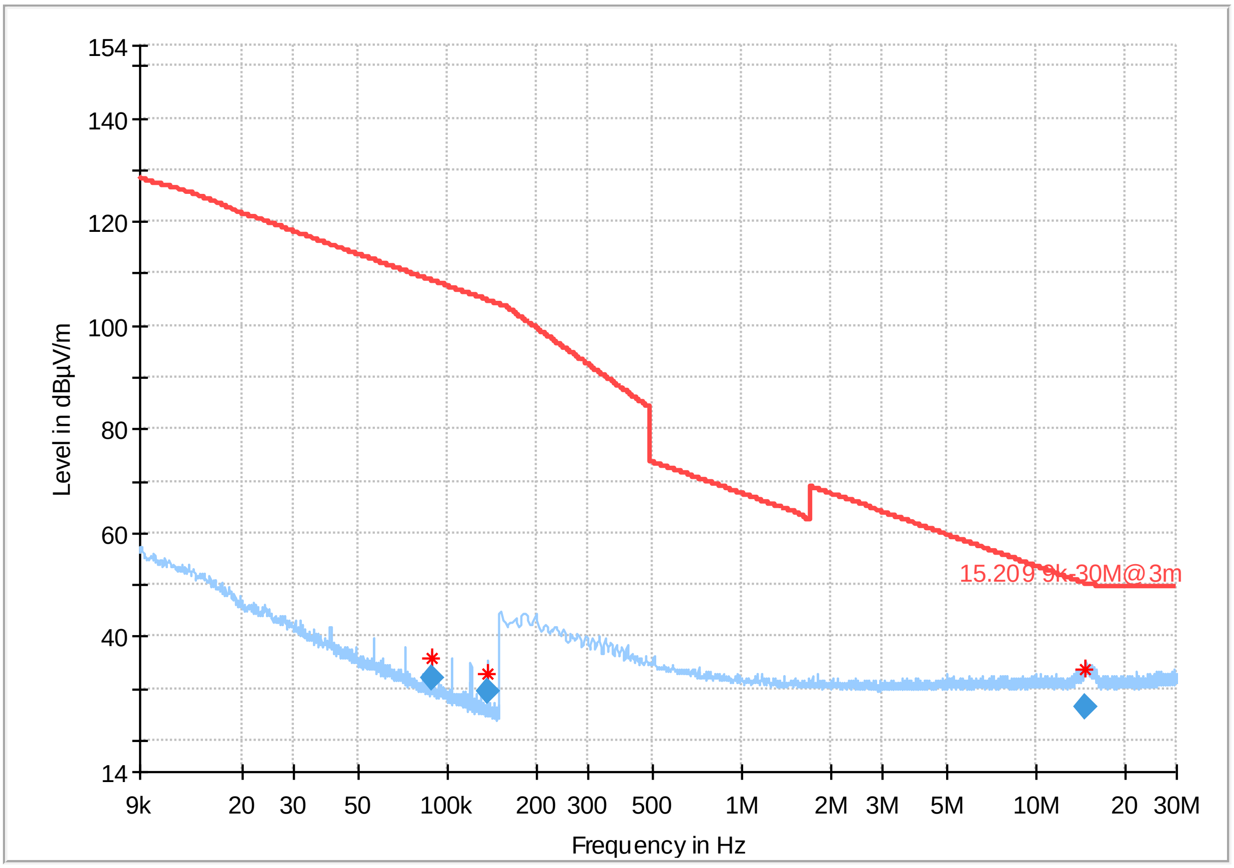
Final_Result

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Pol	Azimuth (deg)	Corr. (dB/m)
0.039950	35.75	115.57	79.82	100.0	0.200	H	105.0	20.7
14.766000	26.29	50.20	23.91	100.0	9.000	H	255.0	20.5

(continuation of the "Final_Result" table from column 15 ...)

Frequency (MHz)	Comment
0.039950	-
14.766000	-

Plot no. 47: radiated emissions 9 kHz – 30 MHz, loop antenna, DMP08



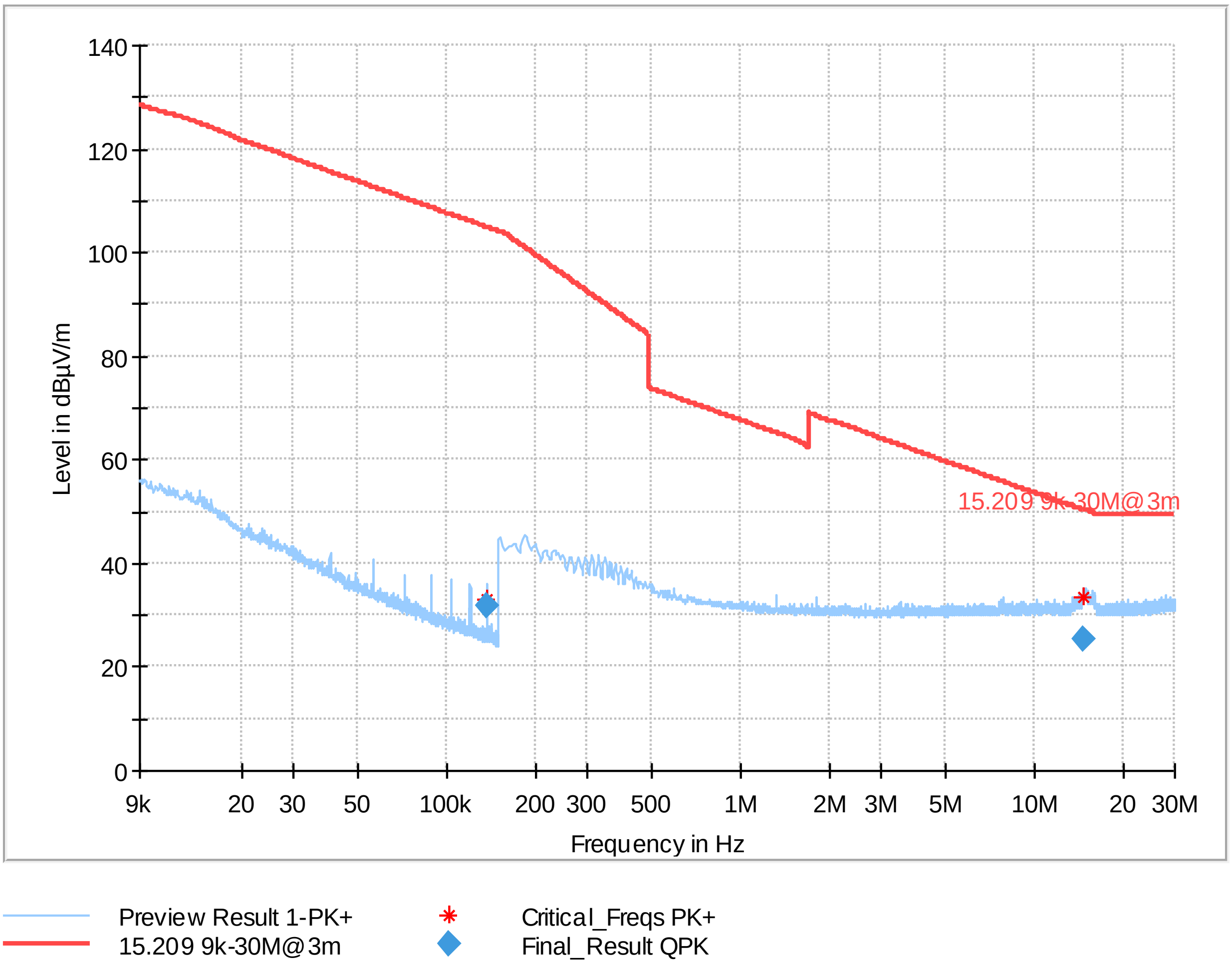
Final_Result

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Pol	Azimuth (deg)	Corr. (dB/m)
0.088000	32.25	108.72	76.47	100.0	0.200	H	240.0	20.5
0.136000	29.60	104.94	75.34	100.0	0.200	H	240.0	20.5
14.788500	26.30	50.19	23.89	100.0	9.000	H	285.0	20.5

(continuation of the "Final_Result" table from column 15 ...)

Frequency (MHz)	Comment
0.088000	-
0.136000	-
14.788500	-

Plot no. 48: radiated emissions 9 kHz – 30 MHz, loop antenna, DMP012



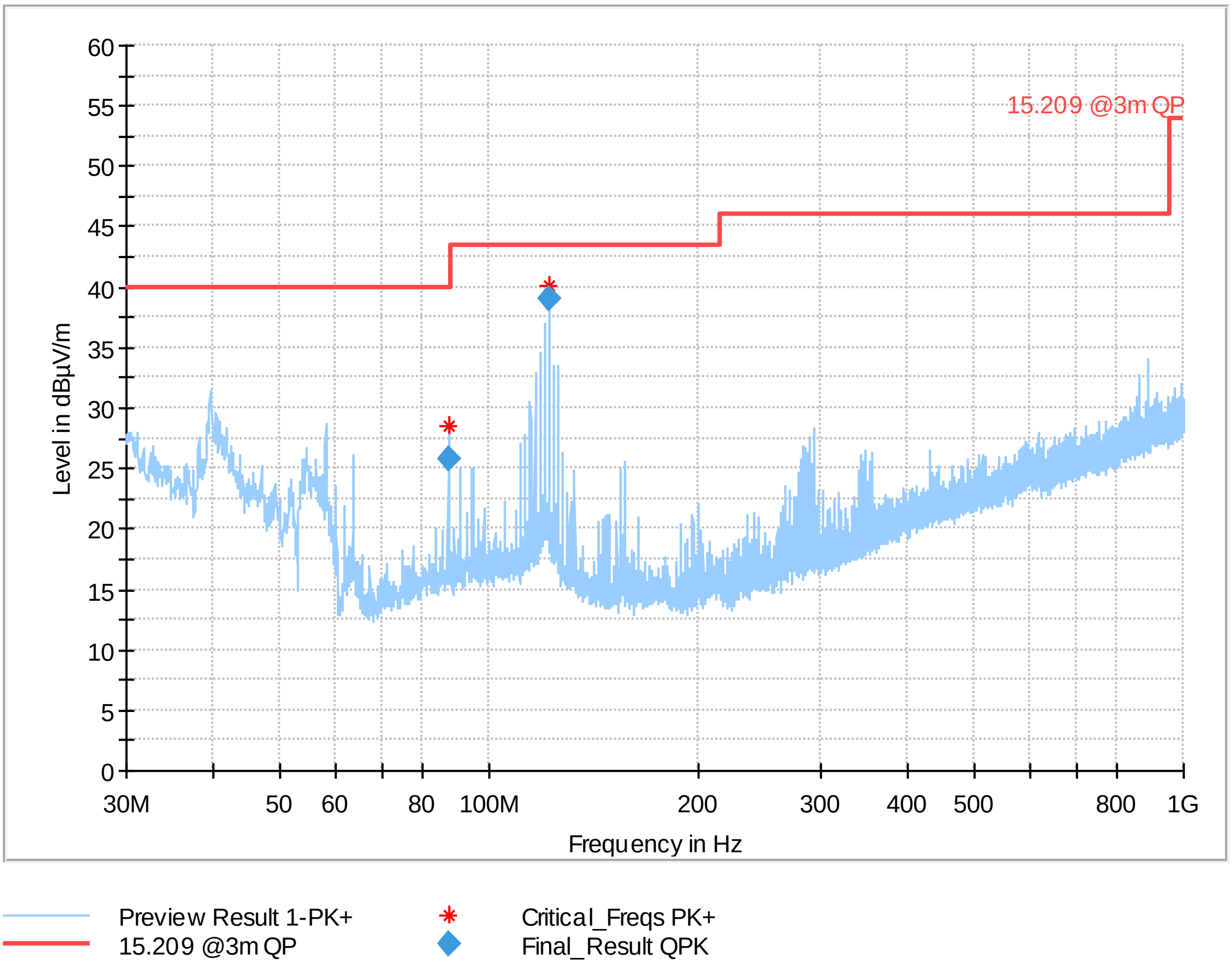
Final_Result

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Pol	Azimuth (deg)	Corr. (dB/m)
0.136000	31.87	104.94	73.07	100.0	0.200	H	-30.0	20.5
14.781750	25.54	50.19	24.65	100.0	9.000	H	150.0	20.5

(continuation of the "Final_Result" table from column 15 ...)

Frequency (MHz)	Comment
0.136000	-
14.781750	-

Plot no. 49: radiated emissions 30 MHz – 1 GHz, polarization vertical / horizontal, DMP06



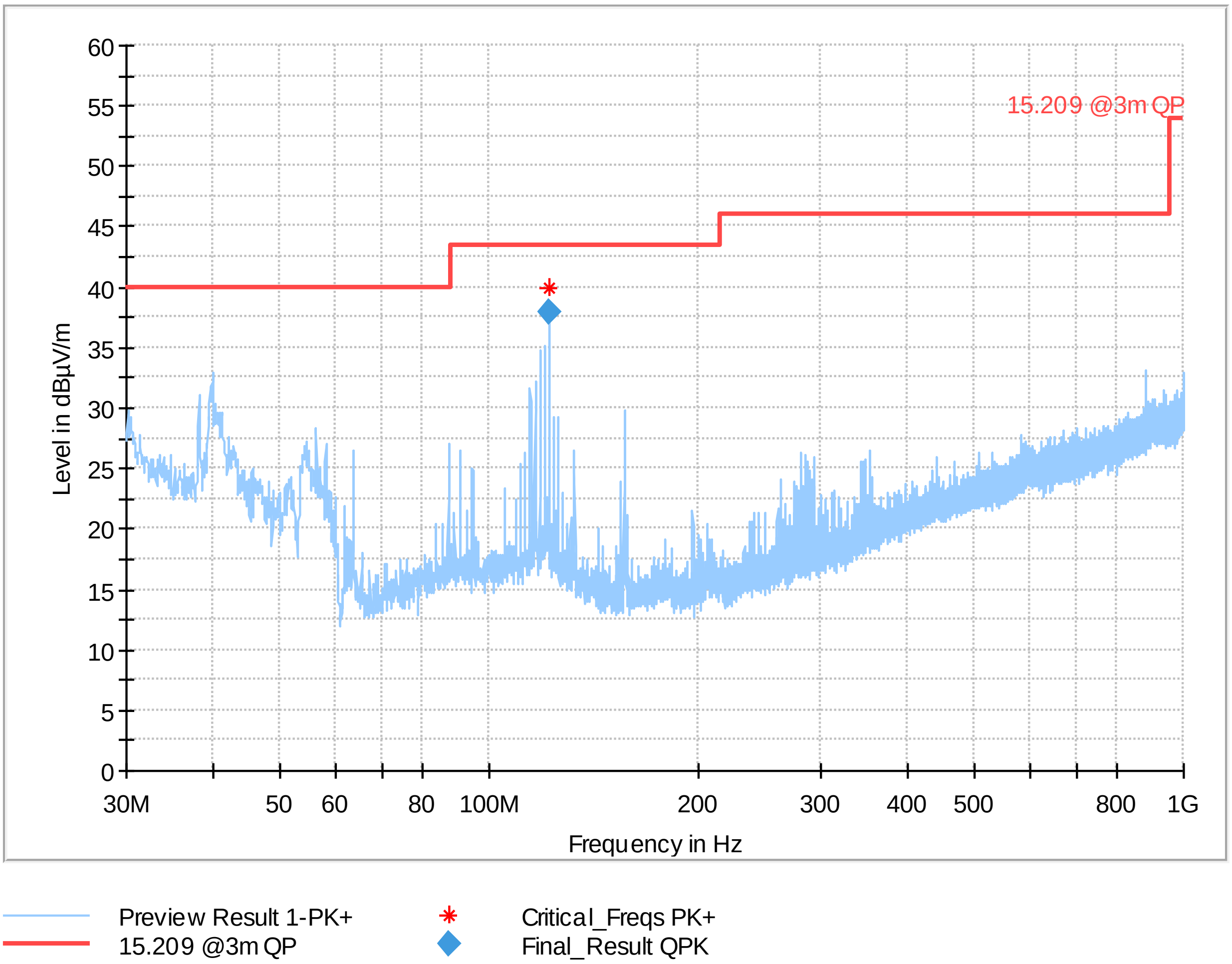
Final_Result

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)
87.278500	25.85	40.00	14.15	100.0	120.000	150.0	V	328.0
121.810500	39.00	43.50	4.50	100.0	120.000	301.0	H	71.0

(continuation of the "Final_Result" table from column 15 ...)

Frequency (MHz)	Corr. (dB/m)	Comment
87.278500	11.6	-
121.810500	12.4	-

Plot no. 50: radiated emissions 30 MHz – 1 GHz, polarization vertical / horizontal, DMP08



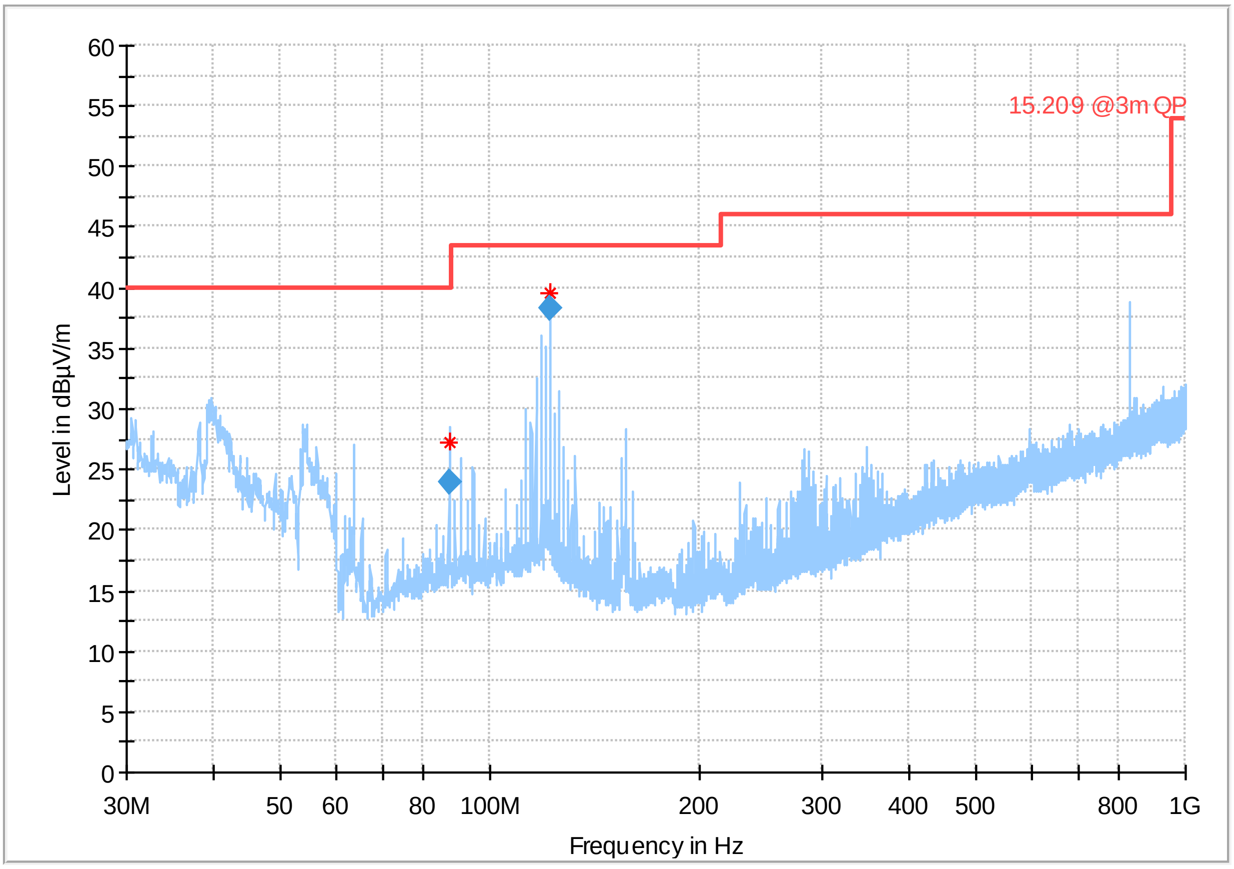
Final_Result

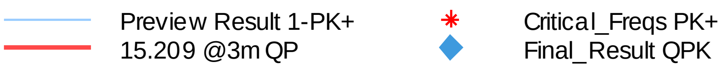
Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)
121.810500	37.97	43.50	5.53	100.0	120.000	279.0	H	241.0

(continuation of the "Final_Result" table from column 15 ...)

Frequency (MHz)	Corr. (dB/m)	Comment
121.810500	12.4	-

Plot no. 51: radiated emissions 30 MHz – 1 GHz, polarization vertical / horizontal, DMP12





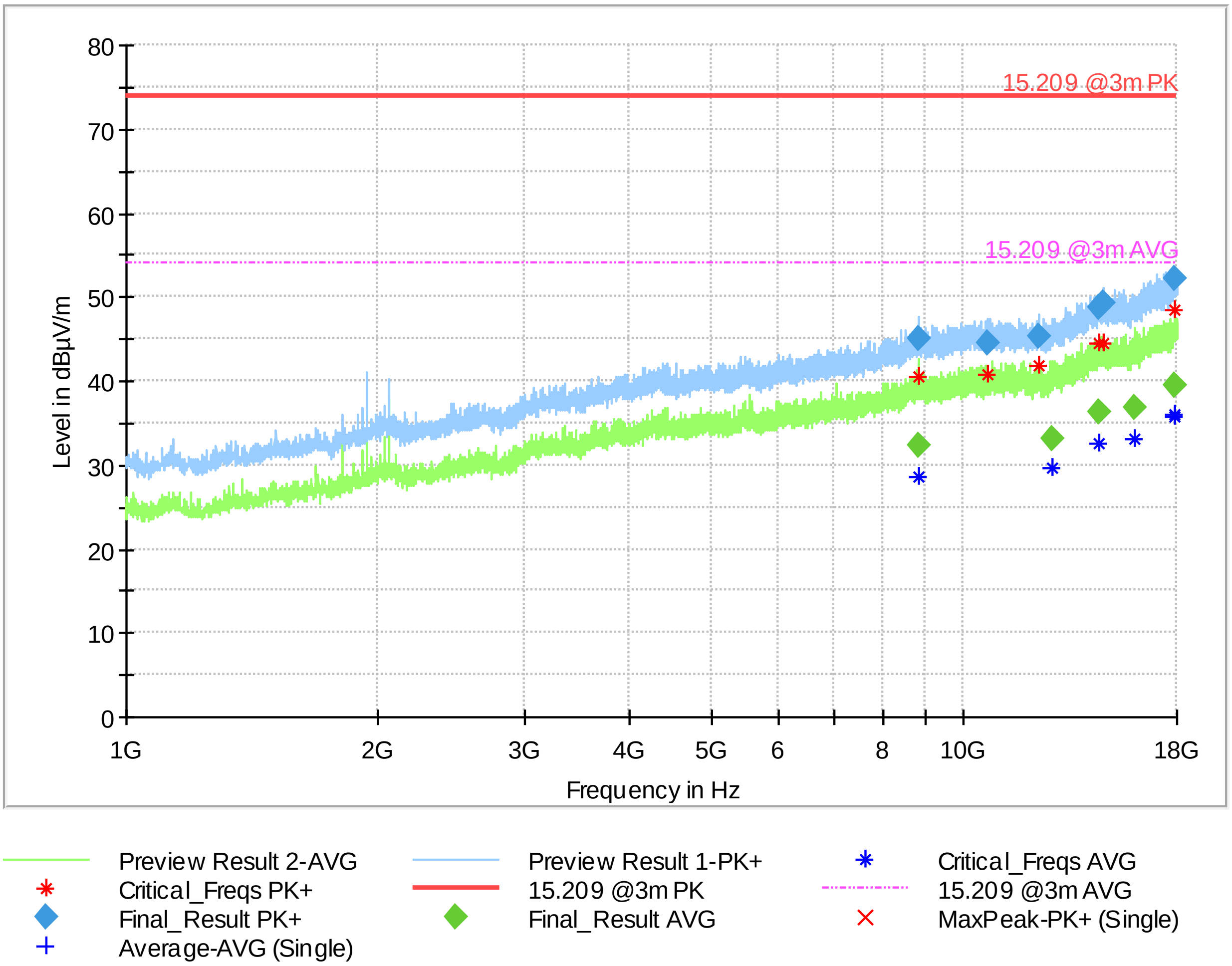
Final_Result

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)
87.278500	23.95	40.00	16.05	100.0	120.000	136.0	V	11.0
121.810500	38.28	43.50	5.22	100.0	120.000	279.0	H	77.0

(continuation of the "Final_Result" table from column 15 ...)

Frequency (MHz)	Corr. (dB/m)	Comment
87.278500	11.6	-
121.810500	12.4	-

Plot no. 52: radiated emissions 1 GHz – 18 GHz, polarization vertical / horizontal, DMP06



Final_Result

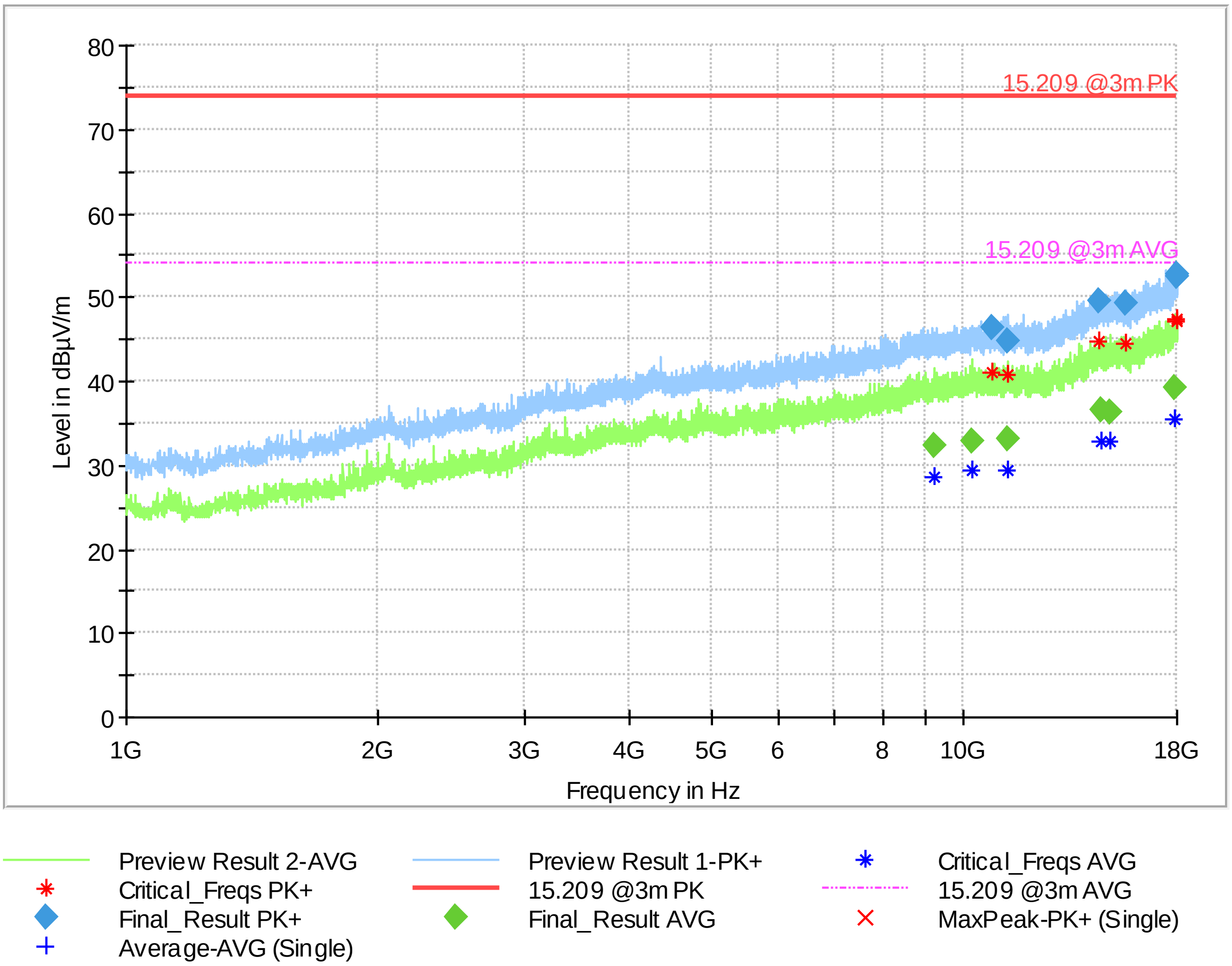
Frequency (MHz)	MaxPeak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol
8824.391667	44.95	---	74.00	29.05	100.0	1000.000	150.0	H
8827.091667	---	32.28	54.00	21.72	100.0	1000.000	150.0	H
10724.975000	44.38	---	74.00	29.62	100.0	1000.000	150.0	V
12323.963889	45.41	---	74.00	28.59	100.0	1000.000	150.0	V
12791.944444	---	33.22	54.00	20.78	100.0	1000.000	150.0	V
14513.486111	---	36.26	54.00	17.74	100.0	1000.000	150.0	V
14551.938889	48.75	---	74.00	25.25	100.0	1000.000	150.0	H
14683.291667	49.40	---	74.00	24.60	100.0	1000.000	150.0	V
16059.316667	---	36.73	54.00	17.27	100.0	1000.000	150.0	V
17915.825000	52.11	---	74.00	21.89	100.0	1000.000	150.0	V
17929.272222	---	39.46	54.00	14.54	100.0	1000.000	150.0	V
17929.347222	---	39.49	54.00	14.51	100.0	1000.000	150.0	V

(continuation of the "Final_Result" table from column 14 ...)

Frequency (MHz)	Azimuth (deg)	Elevation (deg)	Corr. (dB/m)	Comment
8824.391667	207.0	95.0	12.1	-
8827.091667	205.0	91.0	12.1	-
10724.975000	285.0	35.0	15.2	-
12323.963889	86.0	6.0	14.4	-

12791.944444	**151.0**	**-6.0**	**14.8**	**-**
14513.486111	**205.0**	**88.0**	**18.0**	**-**
14551.938889	**105.0**	**30.0**	**18.0**	**-**
14683.291667	**331.0**	**95.0**	**17.9**	**-**
16059.316667	**8.0**	**88.0**	**17.8**	**-**
17915.825000	**106.0**	**-10.0**	**22.3**	**-**
17929.272222	**175.0**	**85.0**	**22.4**	**-**
17929.347222	**173.0**	**101.0**	**22.4**	**-**

Plot no. 53: radiated emissions 1 GHz – 18 GHz, polarization vertical / horizontal, DMP08



Final_Result

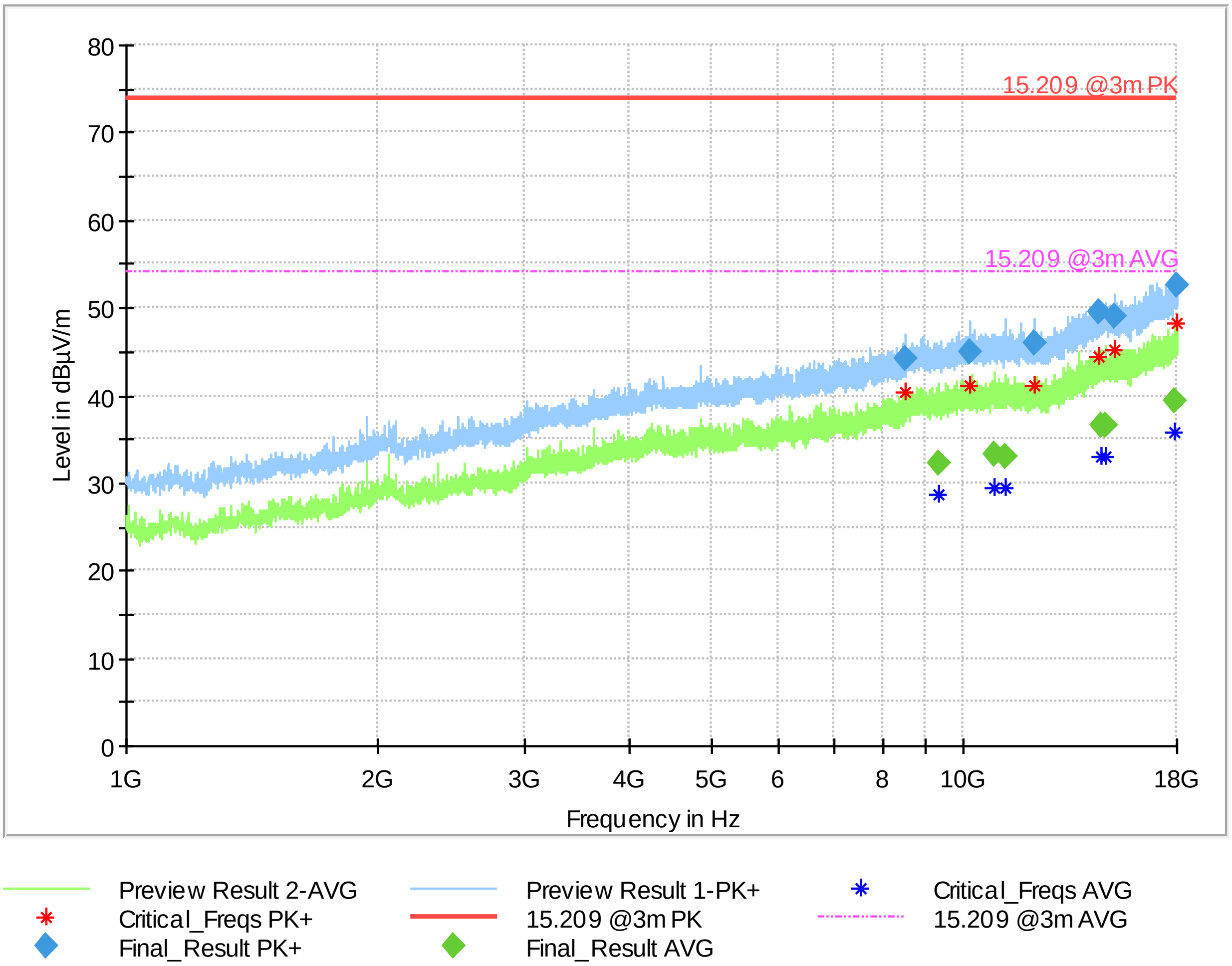
Frequency (MHz)	MaxPeak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol
9220.400000	---	32.20	54.00	21.80	100.0	1000.000	150.0	V
10272.166667	---	32.98	54.00	21.02	100.0	1000.000	150.0	V
10857.841667	46.32	---	74.00	27.68	100.0	1000.000	150.0	H
11291.147222	---	33.07	54.00	20.93	100.0	1000.000	150.0	V
11315.777778	44.81	---	74.00	29.19	100.0	1000.000	150.0	H
14539.961111	49.42	---	74.00	24.58	100.0	1000.000	150.0	V
14590.286111	---	36.55	54.00	17.45	100.0	1000.000	150.0	V
14966.188889	---	36.32	54.00	17.68	100.0	1000.000	150.0	V
15643.791667	49.17	---	74.00	24.84	100.0	1000.000	150.0	V
17881.988889	---	39.20	54.00	14.80	100.0	1000.000	150.0	V
17968.352778	52.59	---	74.00	21.41	100.0	1000.000	150.0	H
17969.252778	52.35	---	74.00	21.65	100.0	1000.000	150.0	H

(continuation of the "Final_Result" table from column 14 ...)

Frequency (MHz)	Azimuth (deg)	Elevation (deg)	Corr. (dB/m)	Comment
9220.400000	226.0	80.0	12.8	-
10272.166667	205.0	7.0	15.1	-
10857.841667	306.0	39.0	15.4	-
11291.147222	182.0	44.0	15.4	-
11315.777778	284.0	35.0	15.2	-

14539.961111	**240.0**	**39.0**	**18.0**	**-**
14590.286111	**310.0**	**105.0**	**18.0**	**-**
14966.188889	**6.0**	**50.0**	**17.8**	**-**
15643.791667	**327.0**	**30.0**	**17.6**	**-**
17881.988889	**203.0**	**102.0**	**22.1**	**-**
17968.352778	**130.0**	**-6.0**	**22.6**	**-**
17969.252778	**132.0**	**-2.0**	**22.6**	**-**

Plot no. 54: radiated emissions 1 GHz – 18 GHz, polarization vertical / horizontal, DMP12



Final_Result

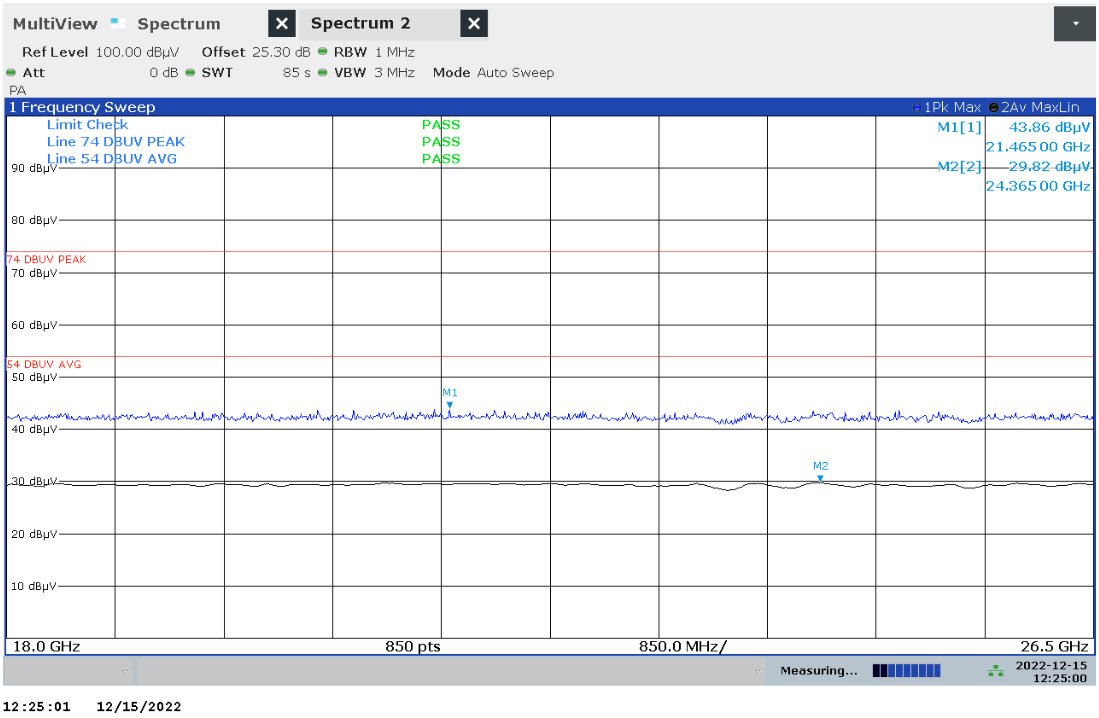
Frequency (MHz)	MaxPeak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol
8517.313889	44.08	---	74.00	29.92	100.0	1000.000	150.0	H
9345.216667	---	32.25	54.00	21.75	100.0	1000.000	150.0	V
10210.972222	44.83	---	74.00	29.17	100.0	1000.000	150.0	H
10895.500000	---	33.19	54.00	20.81	100.0	1000.000	150.0	H
11263.833333	---	33.12	54.00	20.88	100.0	1000.000	150.0	H
12171.444444	46.09	---	74.00	27.91	100.0	1000.000	150.0	H
14550.844444	49.64	---	74.00	24.36	100.0	1000.000	150.0	H
14591.036111	---	36.51	54.00	17.49	100.0	1000.000	150.0	V
14788.469444	---	36.57	54.00	17.43	100.0	1000.000	150.0	V
15140.222222	49.04	---	74.00	24.96	100.0	1000.000	150.0	V
17925.000000	---	39.35	54.00	14.65	100.0	1000.000	150.0	H
17997.091667	52.58	---	74.00	21.42	100.0	1000.000	150.0	H

(continuation of the "Final_Result" table from column 14 ...)

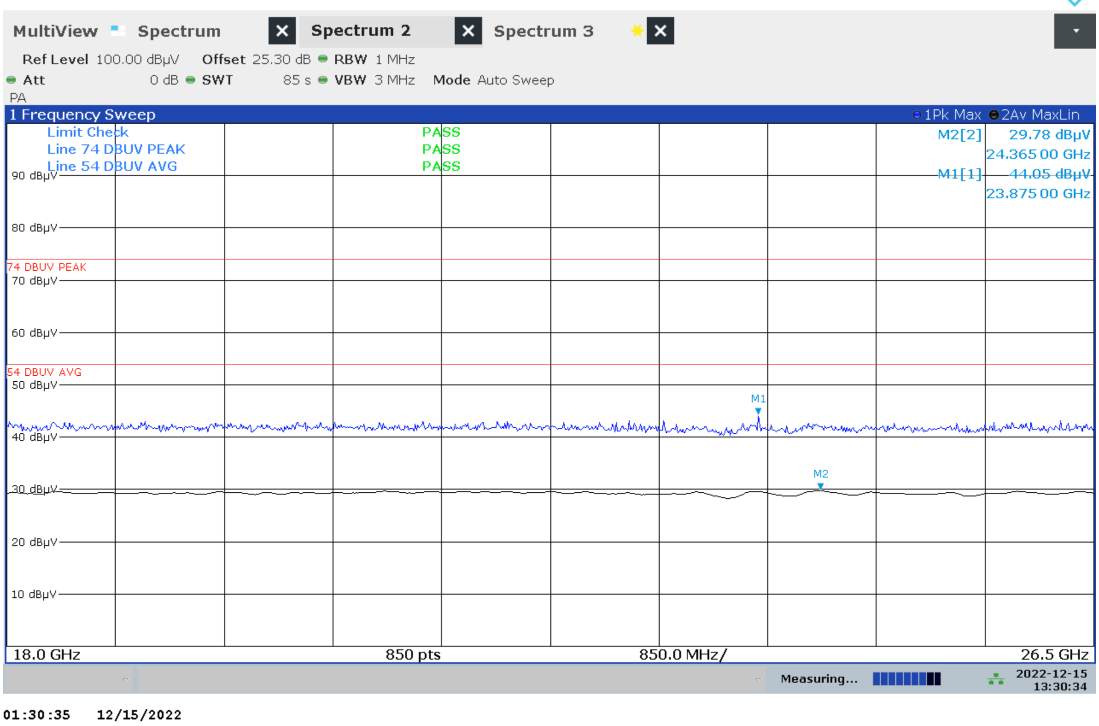
Frequency (MHz)	Azimuth (deg)	Elevation (deg)	Corr. (dB/m)	Comment
8517.313889	97.0	3.0	10.8	-
9345.216667	146.0	105.0	13.2	-
10210.972222	9.0	92.0	15.1	-
10895.500000	17.0	89.0	15.4	-
11263.833333	104.0	35.0	15.3	-

12171.444444	8.0	55.0	14.8	-
14550.844444	258.0	-2.0	18.0	-
14591.036111	101.0	30.0	18.0	-
14788.469444	350.0	60.0	17.8	-
15140.222222	211.0	-2.0	17.8	-
17925.000000	310.0	75.0	22.3	-
17997.091667	266.0	60.0	22.7	-

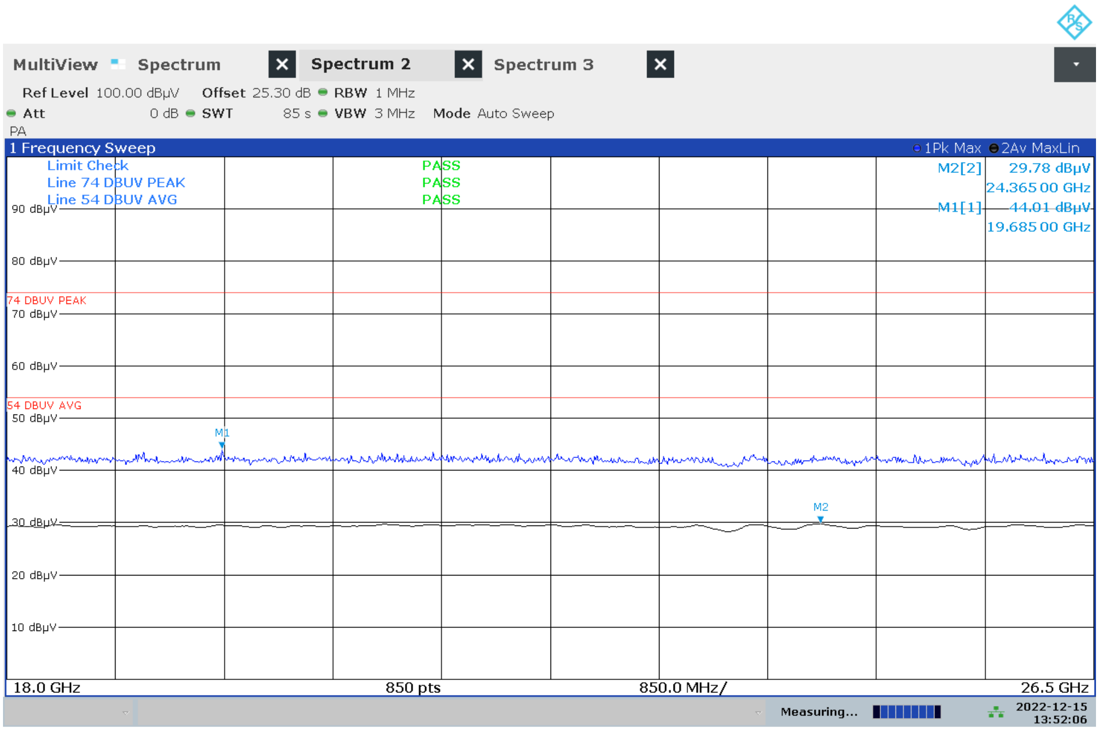
Plot no. 55: radiated emissions 18 GHz – 26.5 GHz, DMP06, polarization vertical / horizontal



Plot no. 56: radiated emissions 18 GHz – 26.5 GHz, DMP08, polarization vertical / horizontal

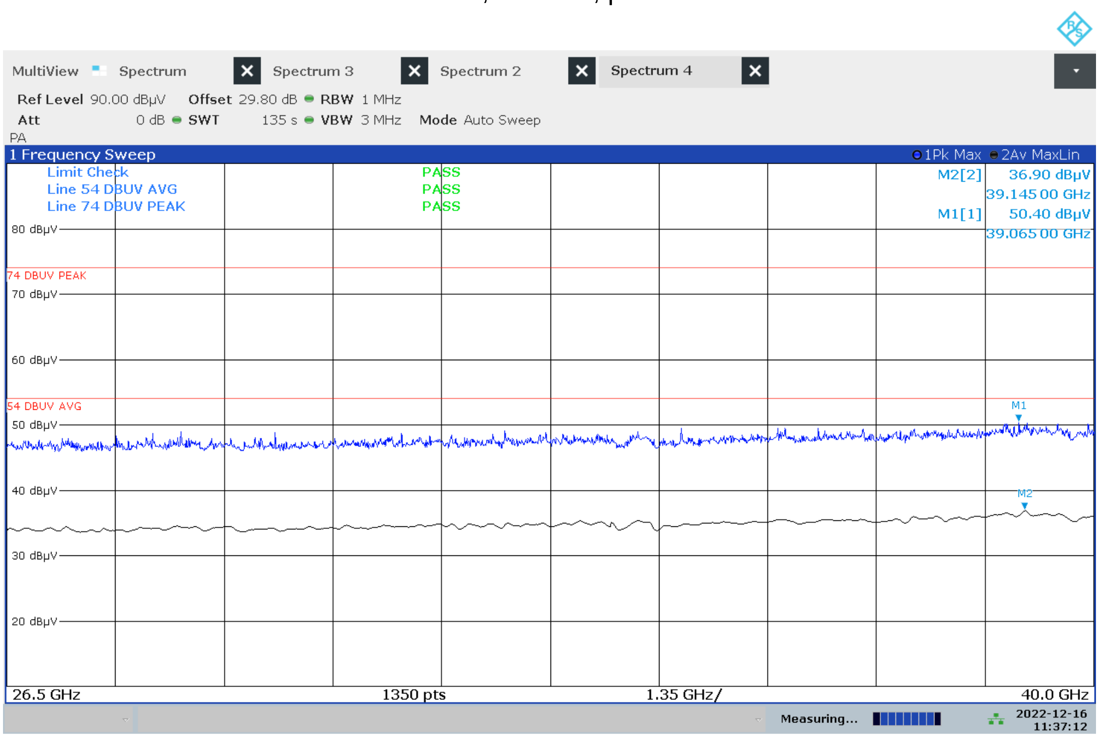


Plot no. 57: radiated emissions 18 GHz – 26.5 GHz, DMP 12, polarization vertical / horizontal



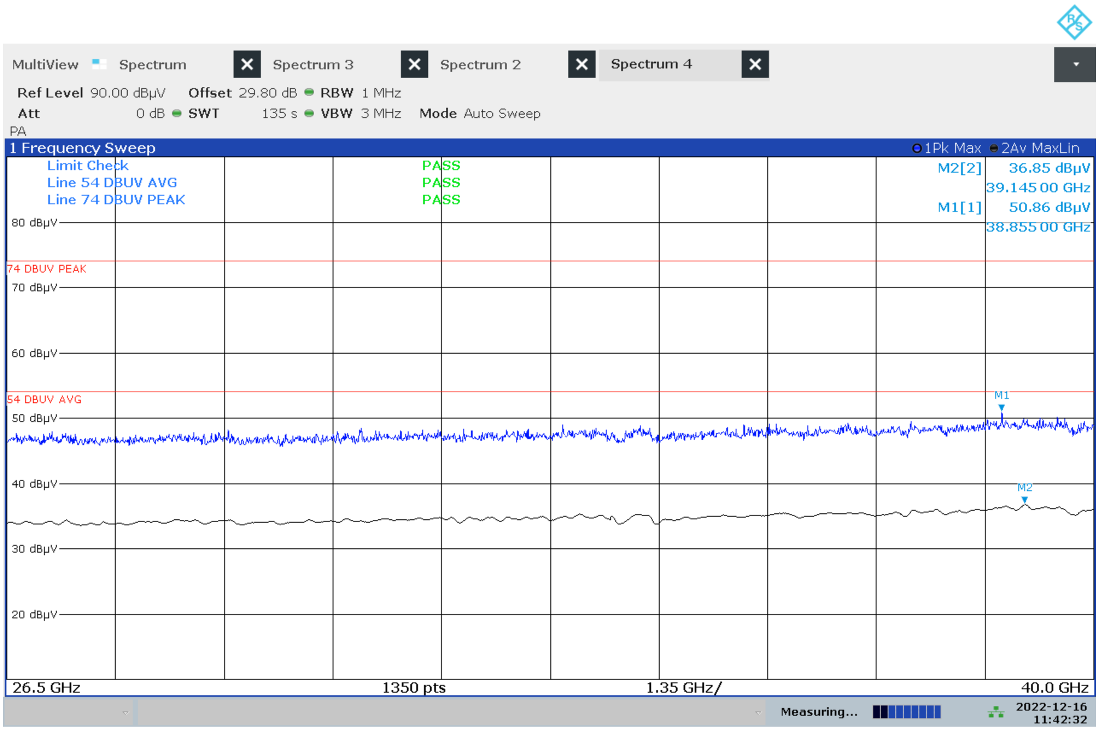
01:52:06 12/15/2022

Plot no. 58: radiated emissions 26.5 GHz – 40 GHz, DMP 06, polarization vertical / horizontal



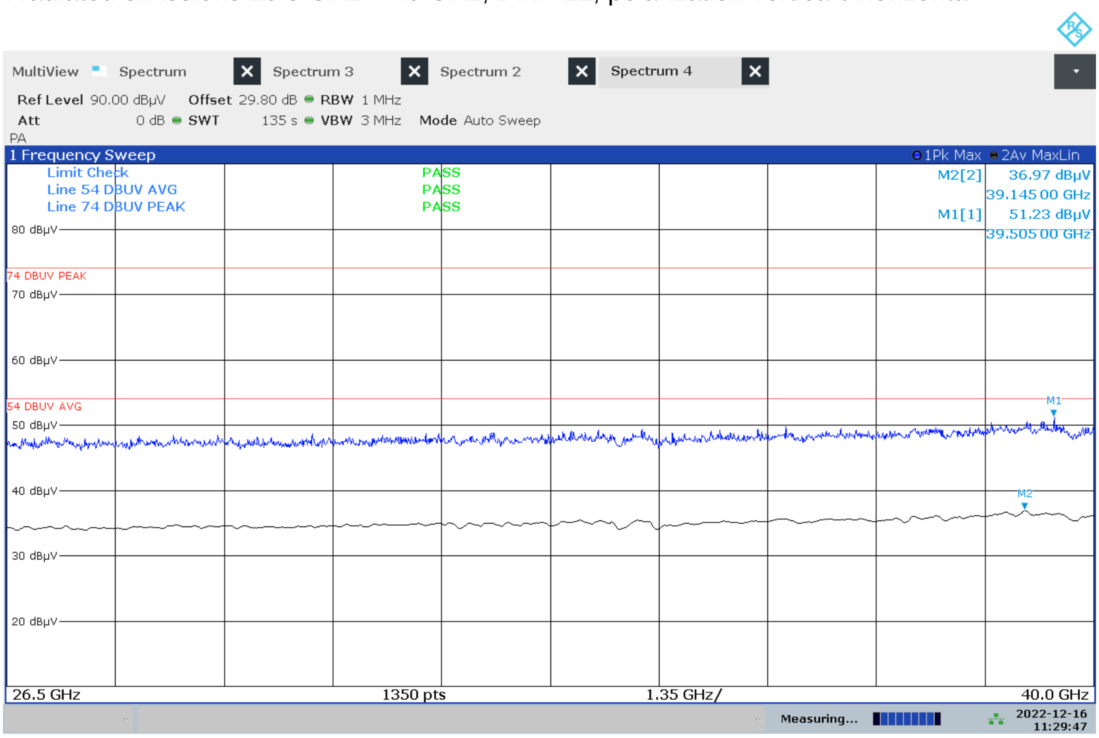
11:37:12 12/16/2022

Plot no. 59: radiated emissions 26.5 GHz – 40 GHz, DMP 08, polarization vertical / horizontal



11:42:33 12/16/2022

Plot no. 60: radiated emissions 26.5 GHz – 40 GHz, DMP 12, polarization vertical / horizontal

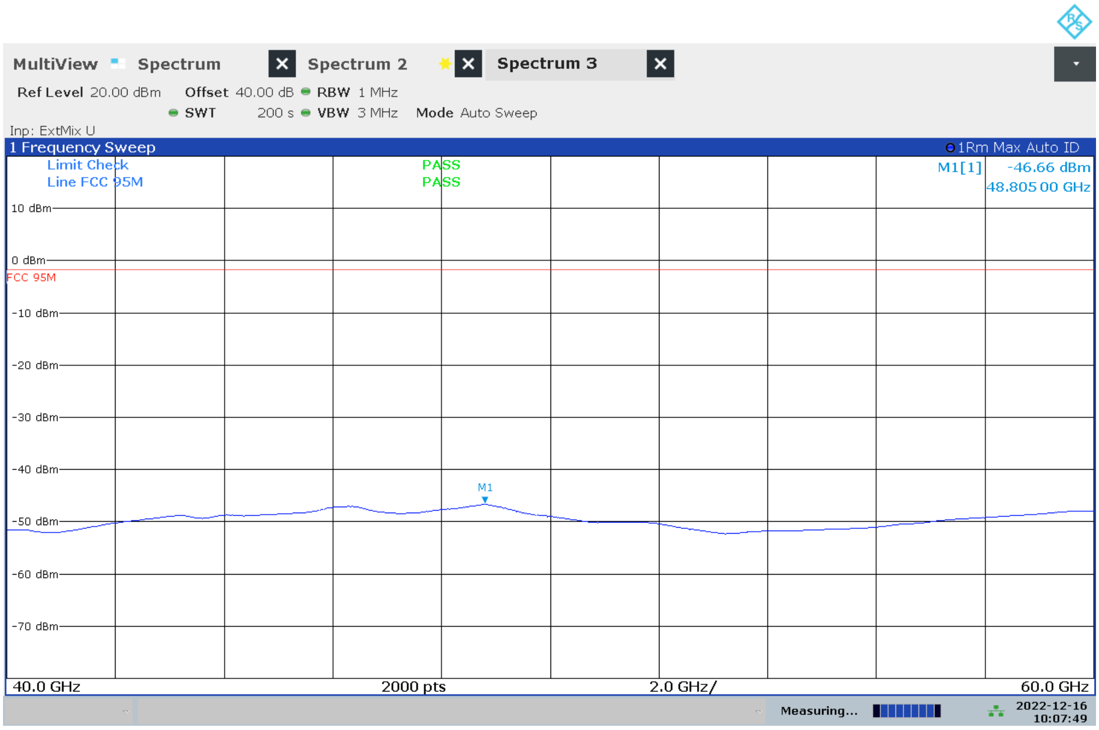


11:29:47 12/16/2022

Plot no. 61: radiated emissions 40 GHz – 60 GHz, DMP 06, polarization vertical / horizontal

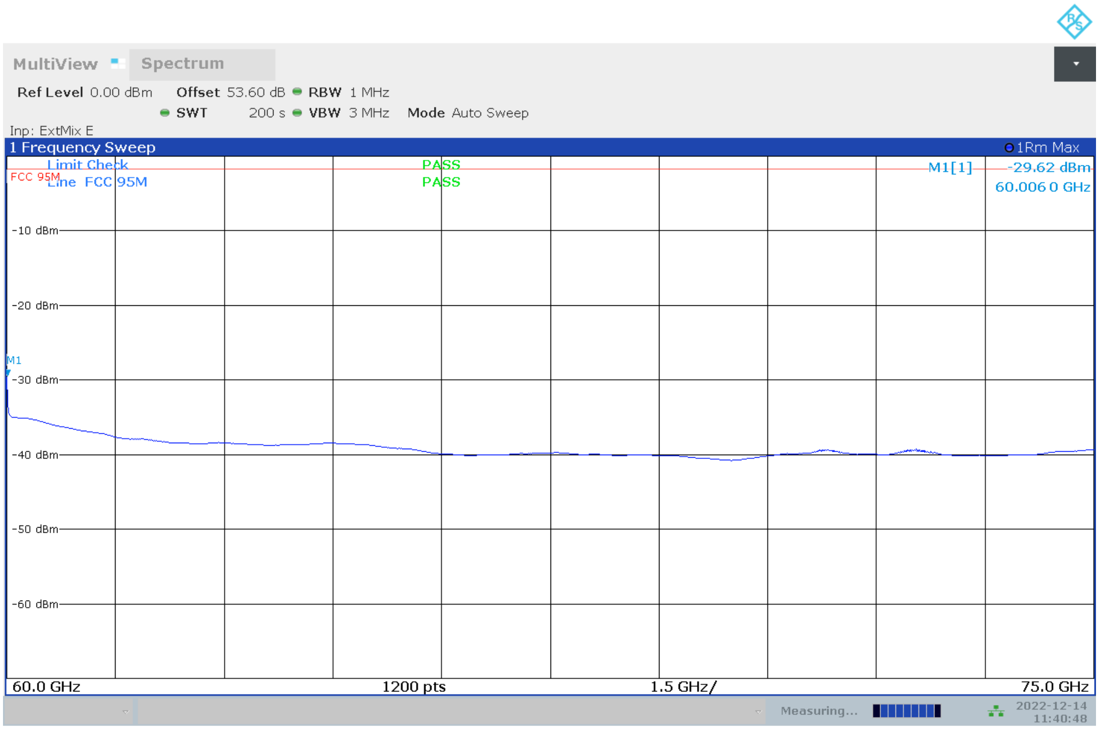
Plot no. 62: radiated emissions 40 GHz – 60 GHz, DMP 08, polarization vertical / horizontal

Plot no. 63: radiated emissions 40 GHz – 60 GHz, DMP 12, polarization vertical / horizontal



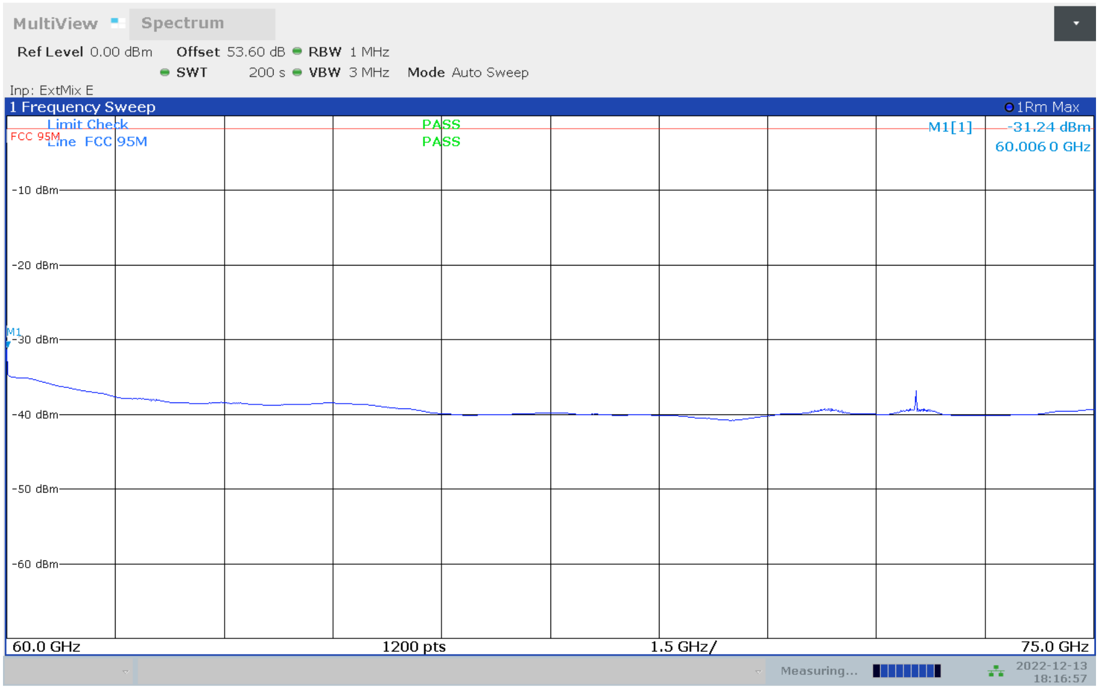
10:07:49 12/16/2022

Plot no. 64: radiated emissions 60 GHz – 75 GHz, DMP 06, polarization vertical / horizontal



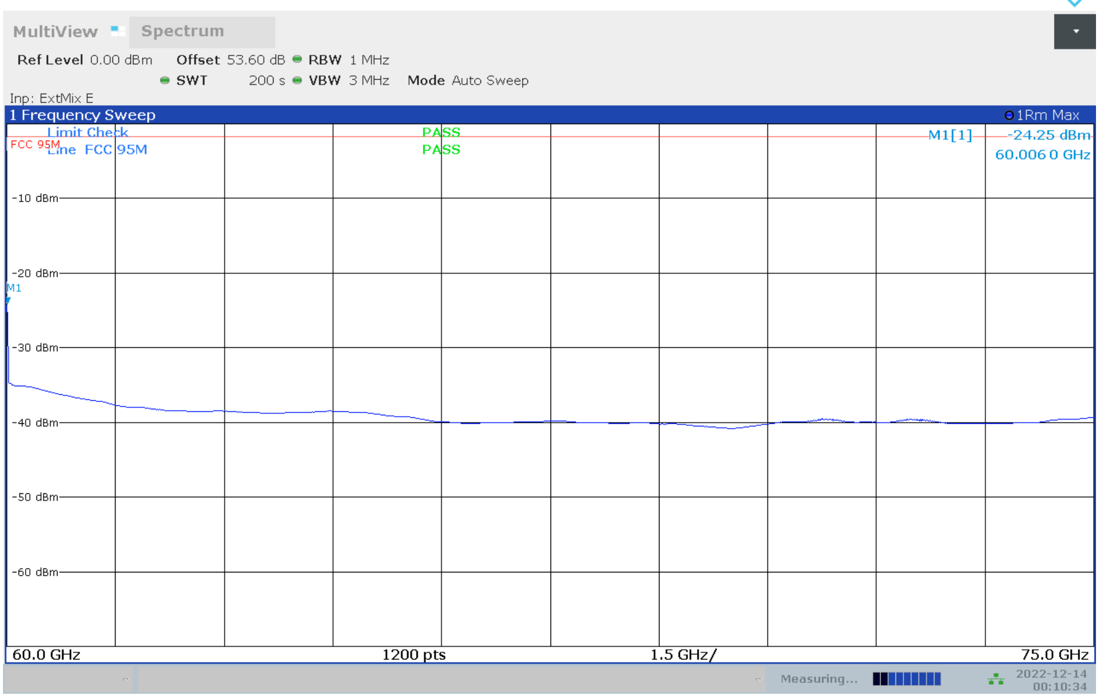
11:40:48 12/14/2022

Plot no. 65: radiated emissions 60 GHz – 75 GHz, DMP 08, polarization vertical / horizontal



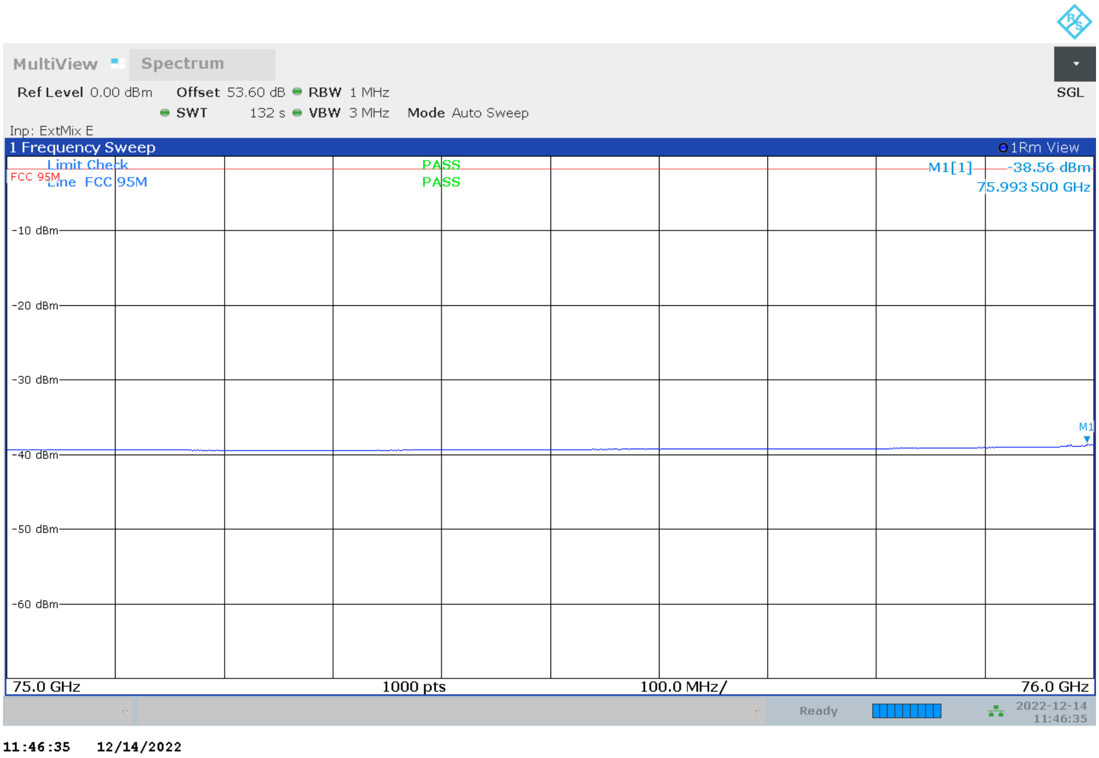
06:16:58 12/13/2022

Plot no. 66: radiated emissions 60 GHz – 75 GHz, DMP 12, polarization vertical / horizontal

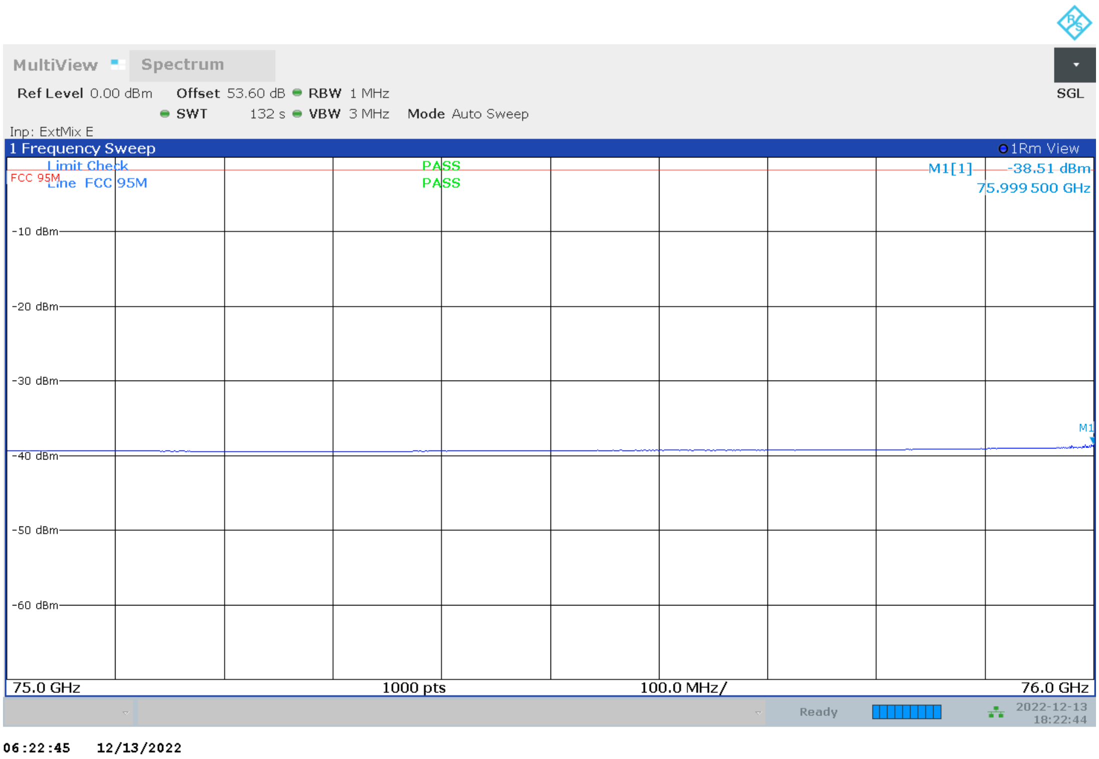


12:10:35 12/14/2022

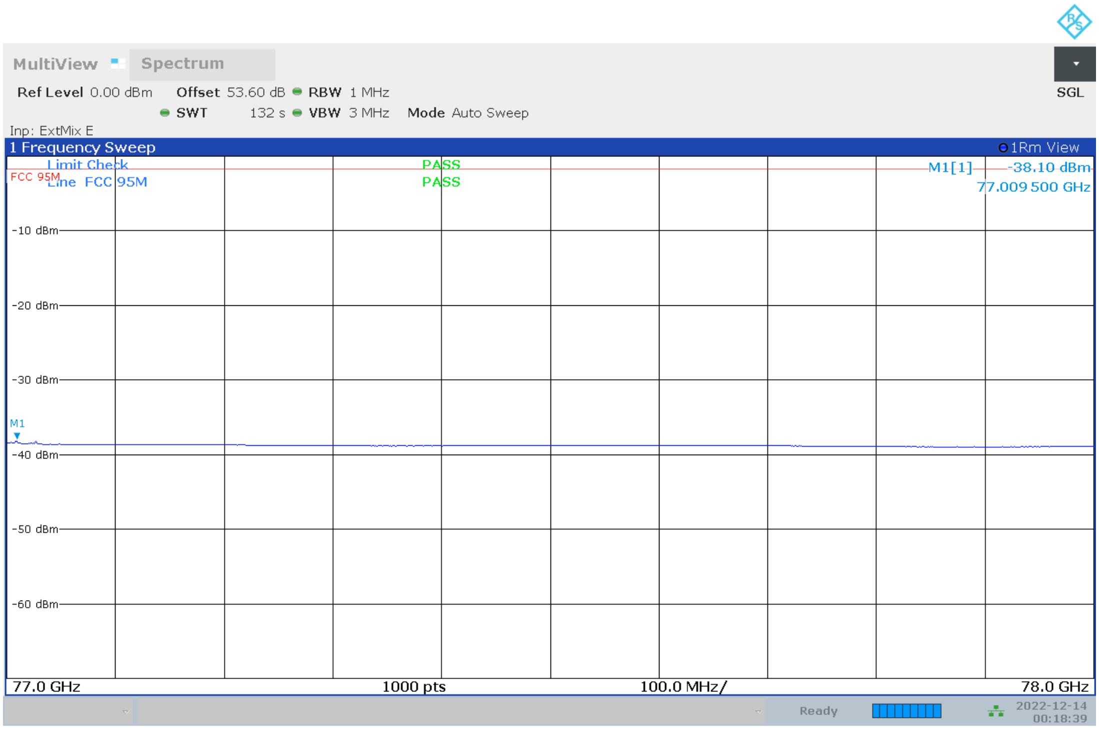
Plot no. 67: radiated emissions, Band edge Low, DMP 06, polarization vertical / horizontal



Plot no. 68: radiated emissions, Band edge Low, DMP 08, polarization vertical / horizontal

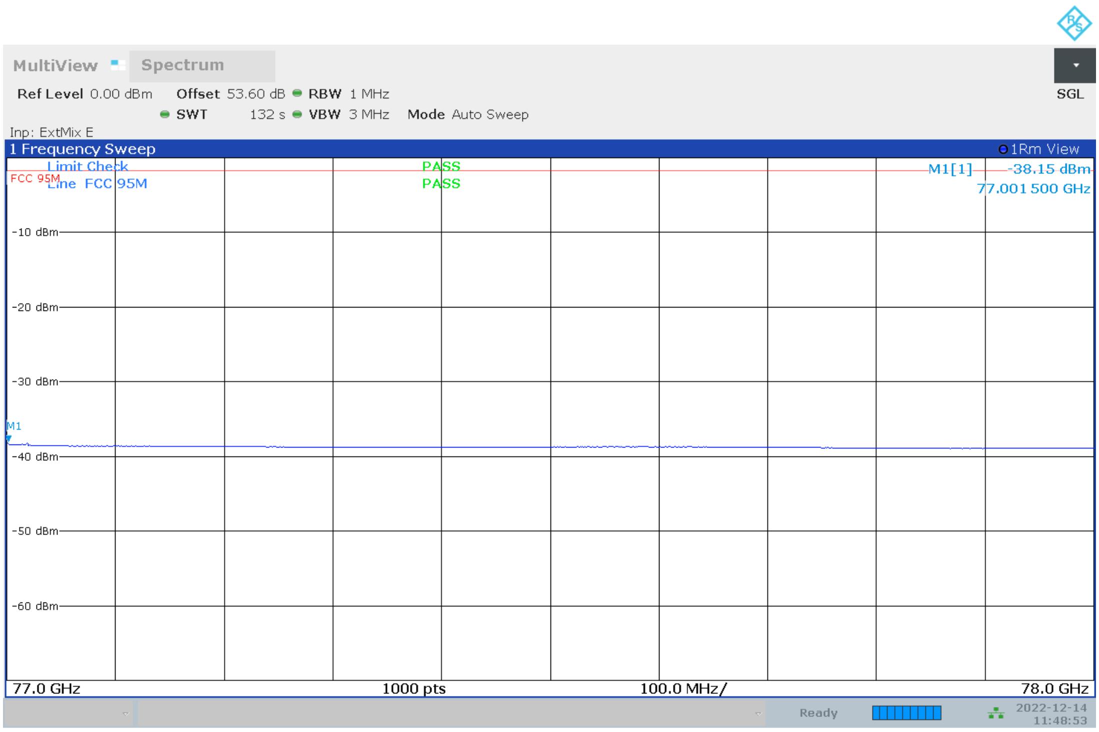


Plot no. 69: radiated emissions, Band edge Low, DMP 12, polarization vertical / horizontal



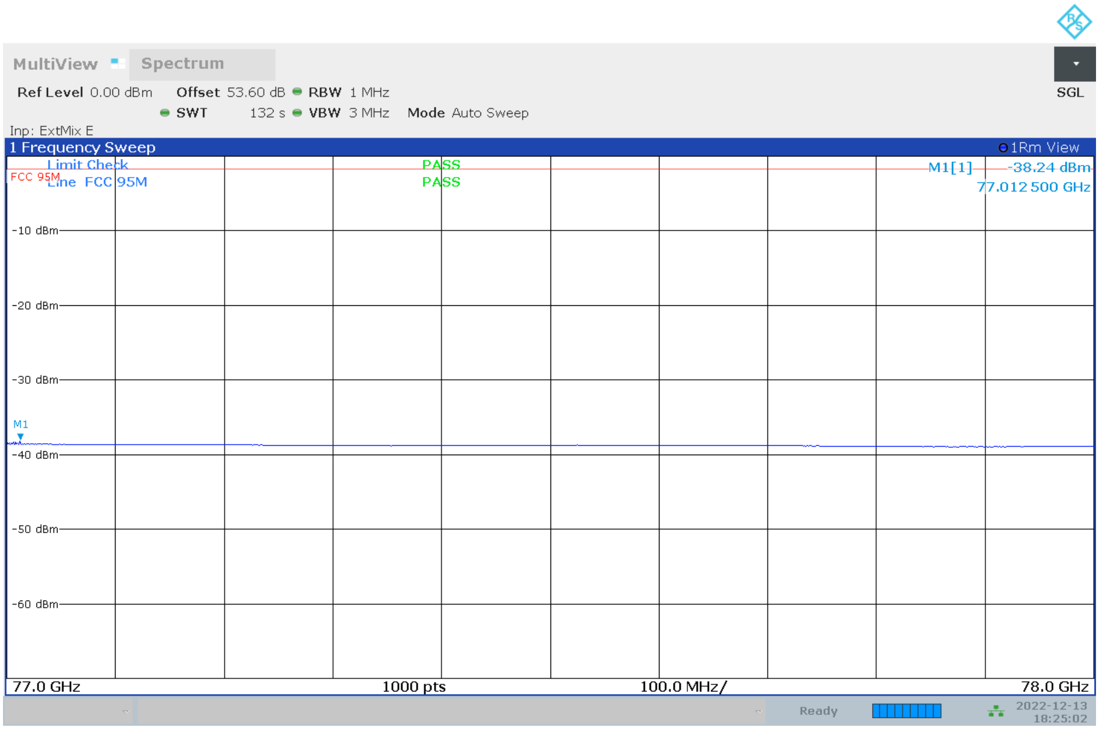
12:18:40 12/14/2022

Plot no. 70: radiated emissions, Band edge High, DMP 06, polarization vertical / horizontal



11:48:53 12/14/2022

Plot no. 71: radiated emissions, Band edge High, DMP 08, polarization vertical / horizontal



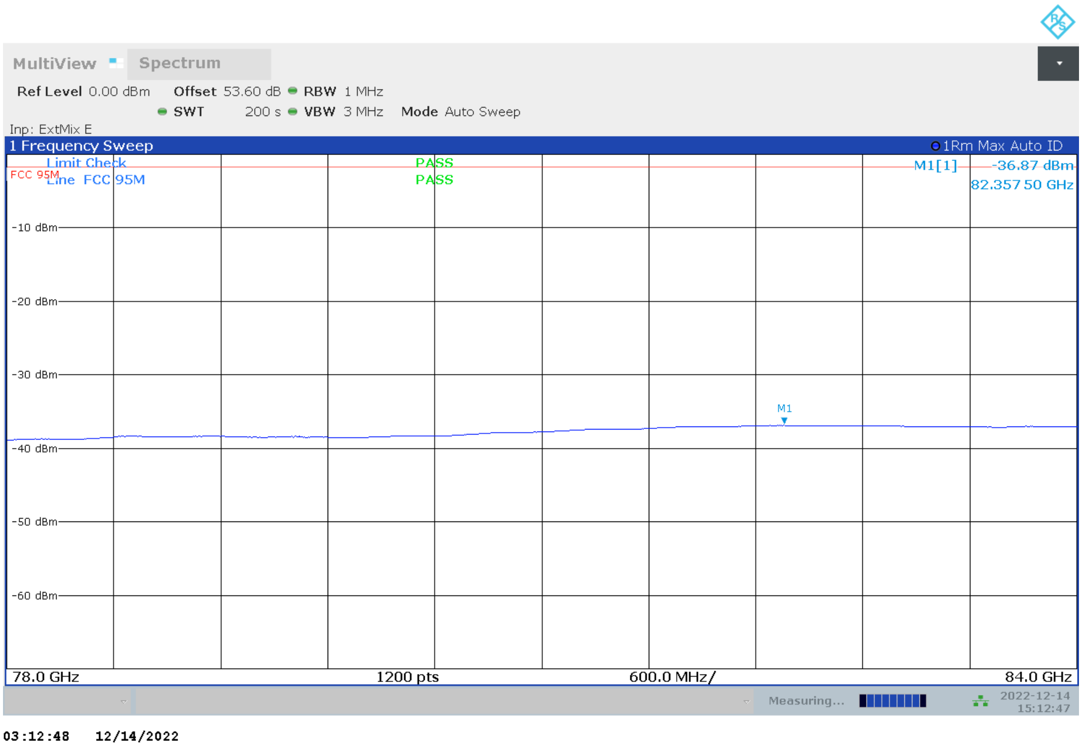
06:25:03 12/13/2022

Plot no. 72: radiated emissions, Band edge High, DMP 12, polarization vertical / horizontal

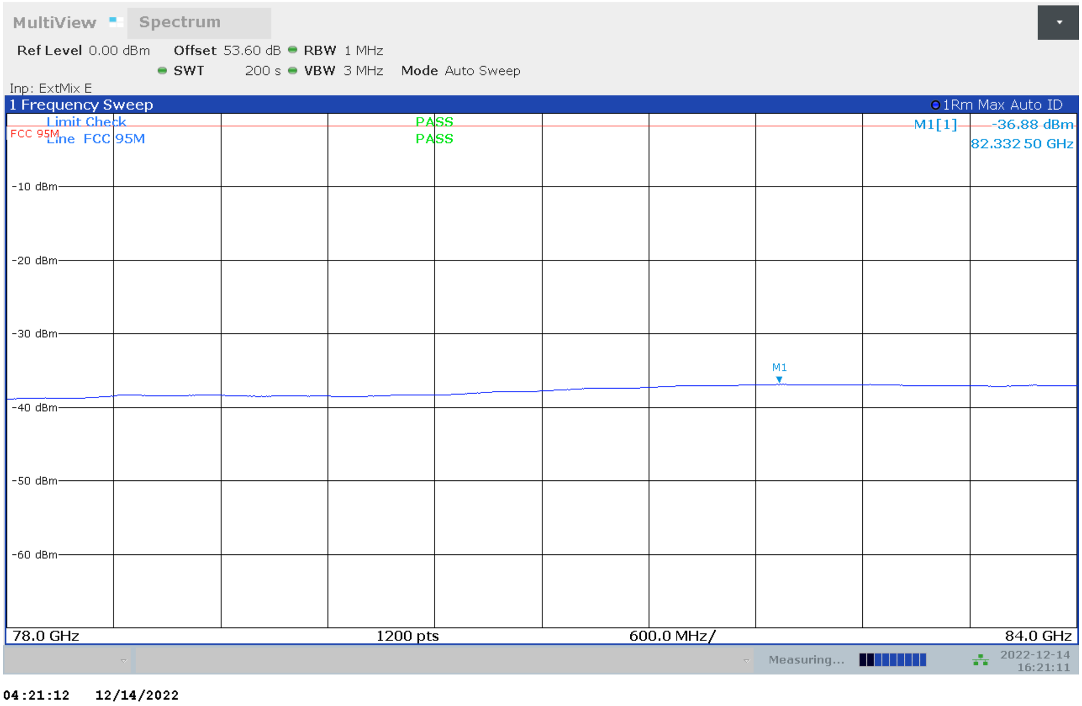
12:18:40 12/14/2022

Plot no. 73: radiated emissions 78 GHz – 84 GHz, DMP 06, polarization vertical / horizontal

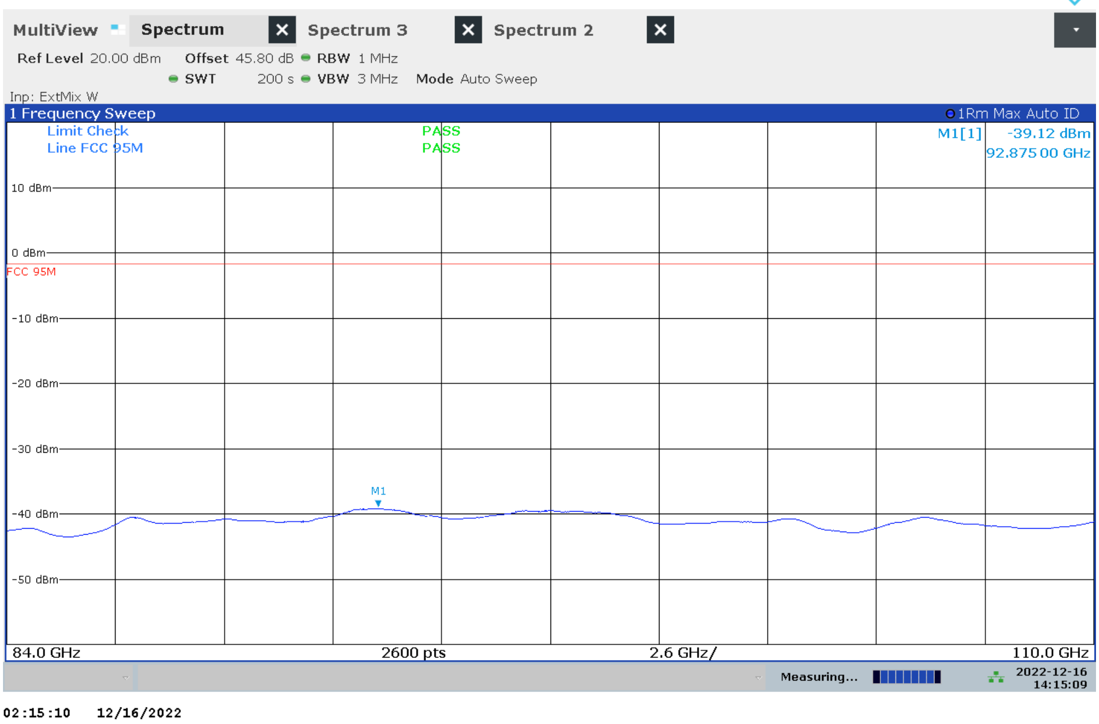
Plot no. 74: radiated emissions 78 GHz – 84 GHz, DMP 08, polarization vertical / horizontal



Plot no. 75: radiated emissions 78 GHz – 84 GHz, DMP 12, polarization vertical / horizontal

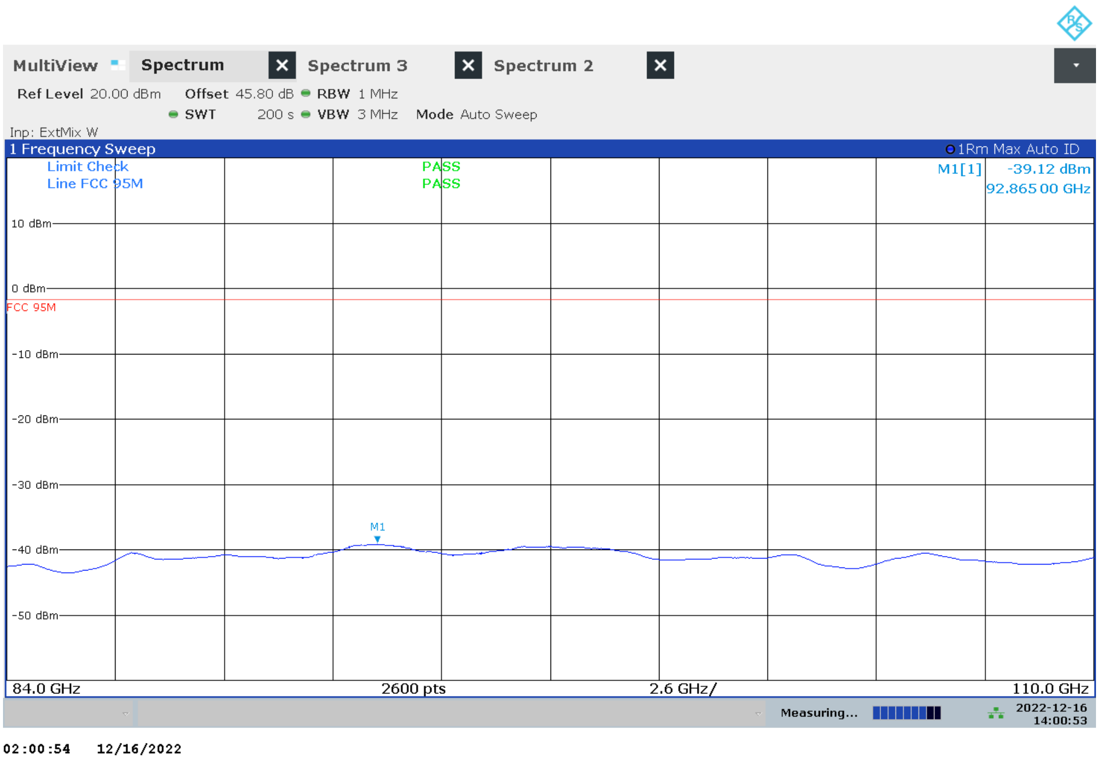


Plot no. 76: radiated emissions 84 GHz – 110 GHz, DMP 06, polarization vertical / horizontal

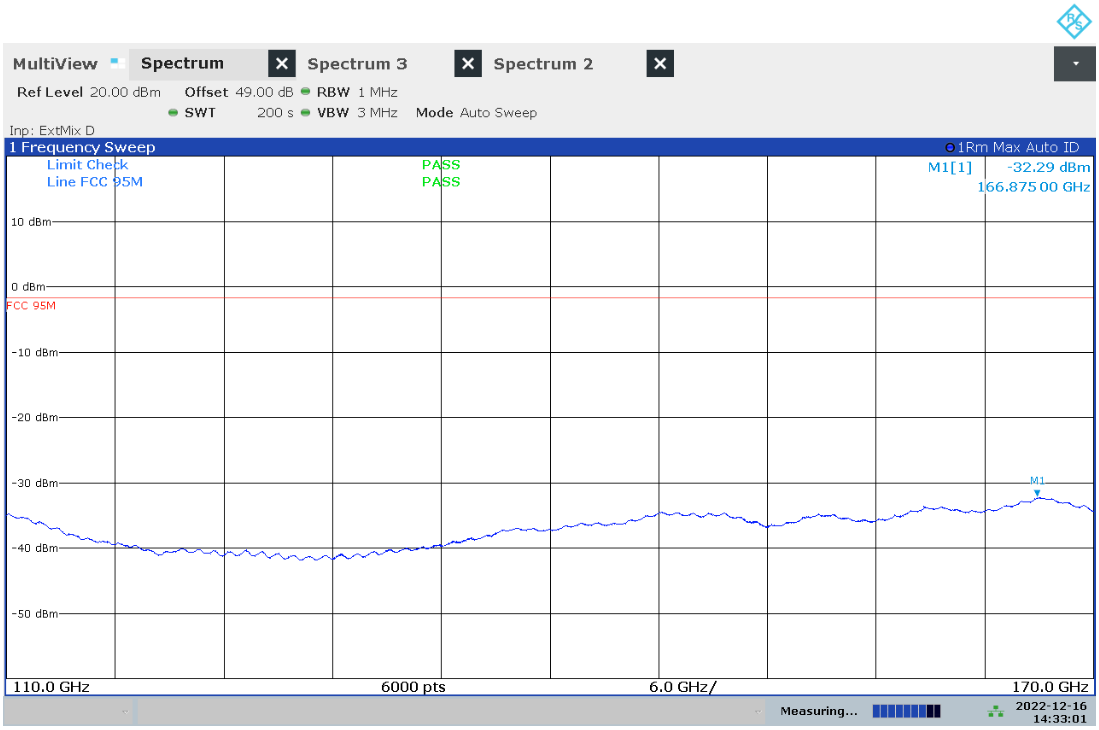


Plot no. 77: radiated emissions 84 GHz – 110 GHz, DMP 08, polarization vertical / horizontal

Plot no. 78: radiated emissions 84 GHz – 110 GHz, DMP 12, polarization vertical / horizontal

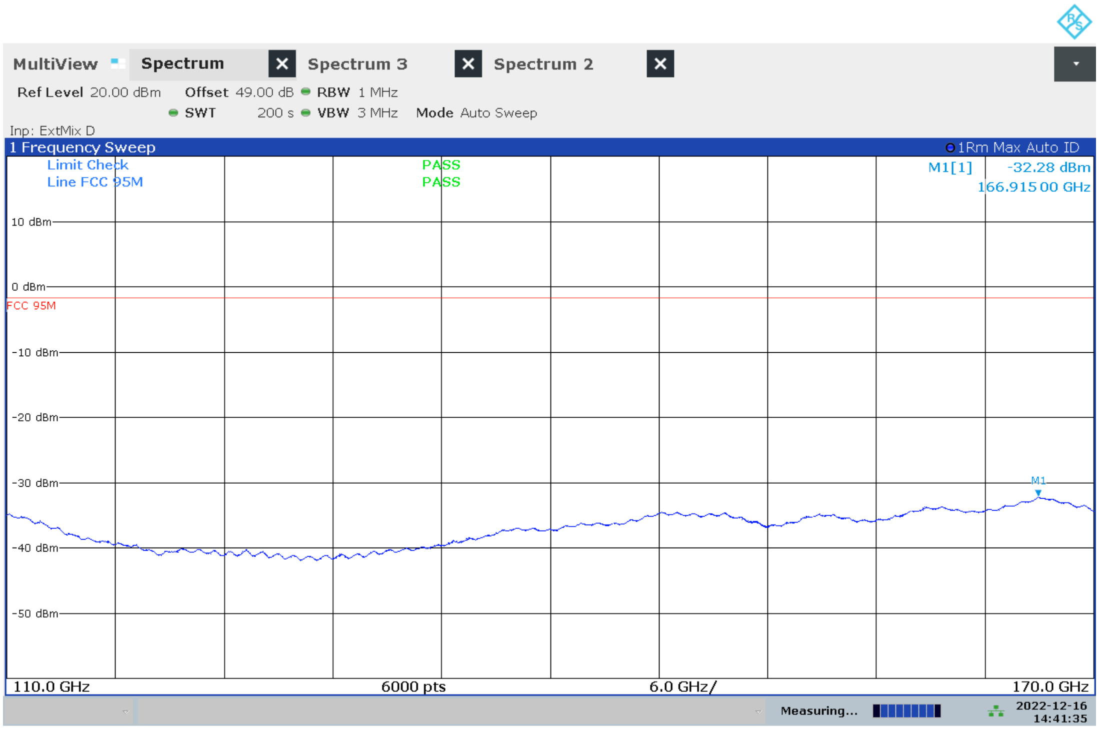


Plot no. 79: radiated emissions 110 GHz – 170 GHz, DMP 06, polarization vertical / horizontal



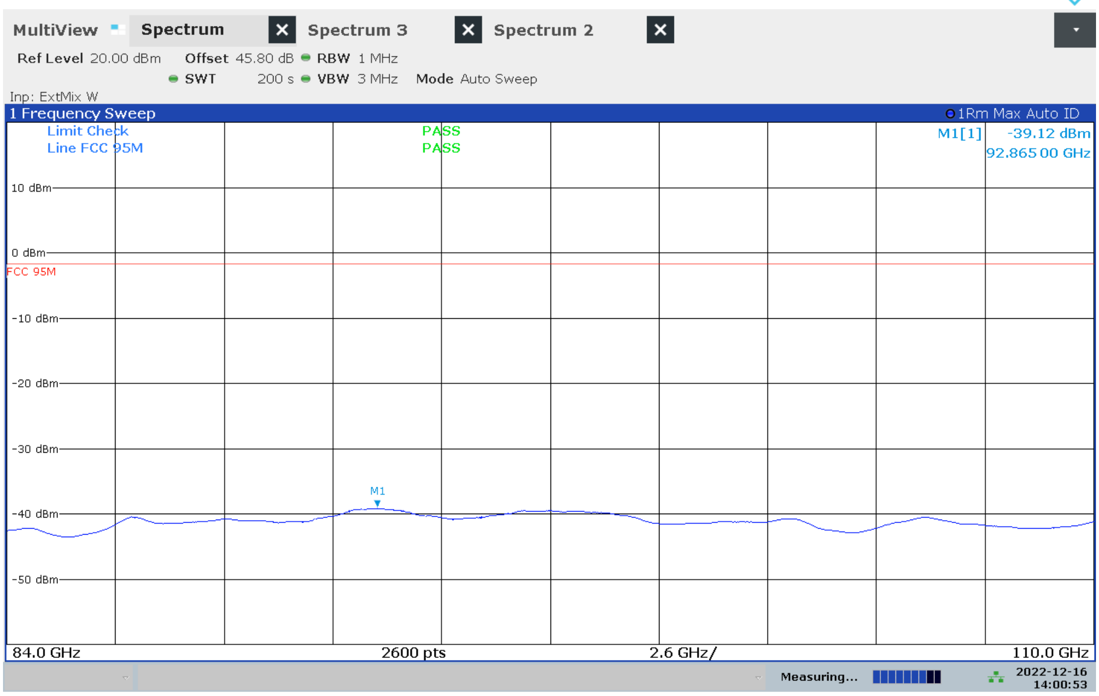
02:33:01 12/16/2022

Plot no. 80: radiated emissions 110 GHz – 170 GHz, DMP 08, polarization vertical / horizontal



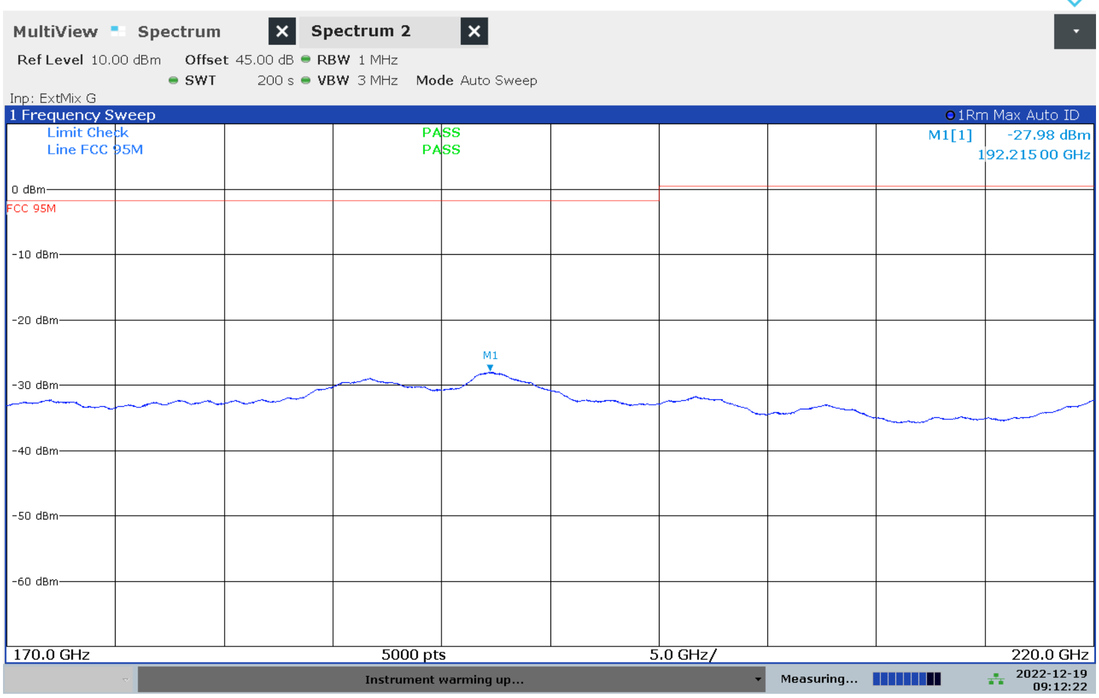
02:41:35 12/16/2022

Plot no. 81: radiated emissions 110 GHz – 170 GHz, DMP 12, polarization vertical / horizontal



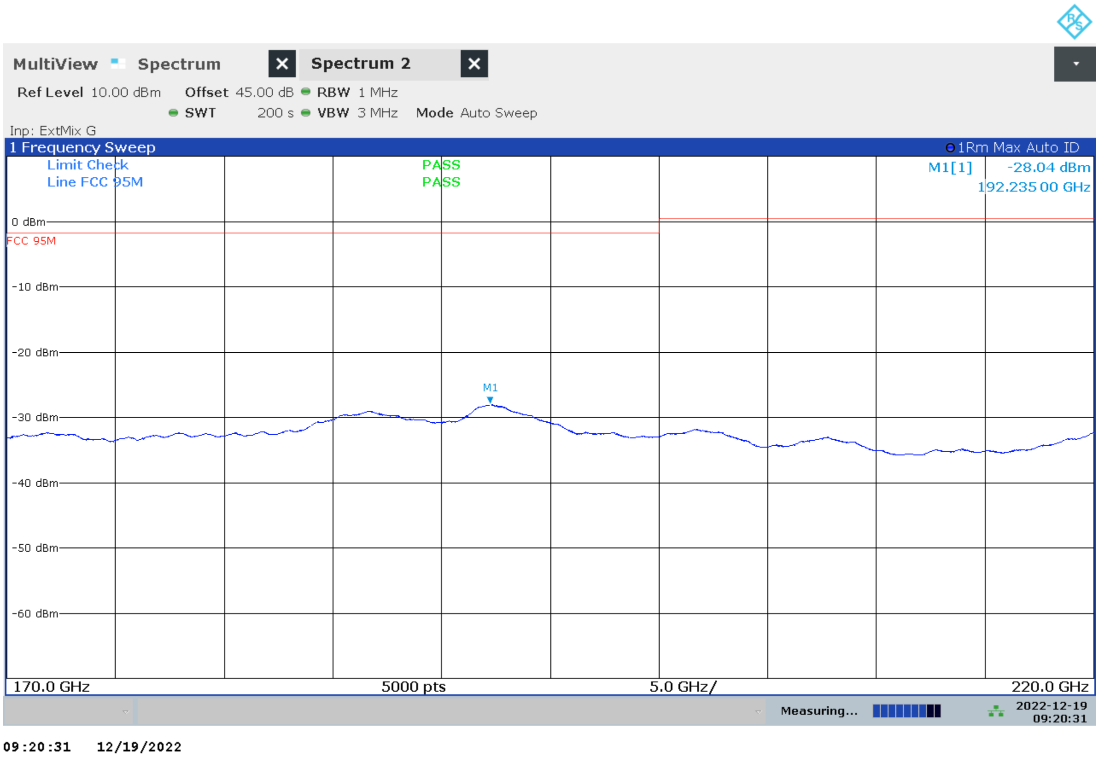
02:00:54 12/16/2022

Plot no. 82: radiated emissions 170 GHz – 220 GHz, DMP 06, polarization vertical / horizontal

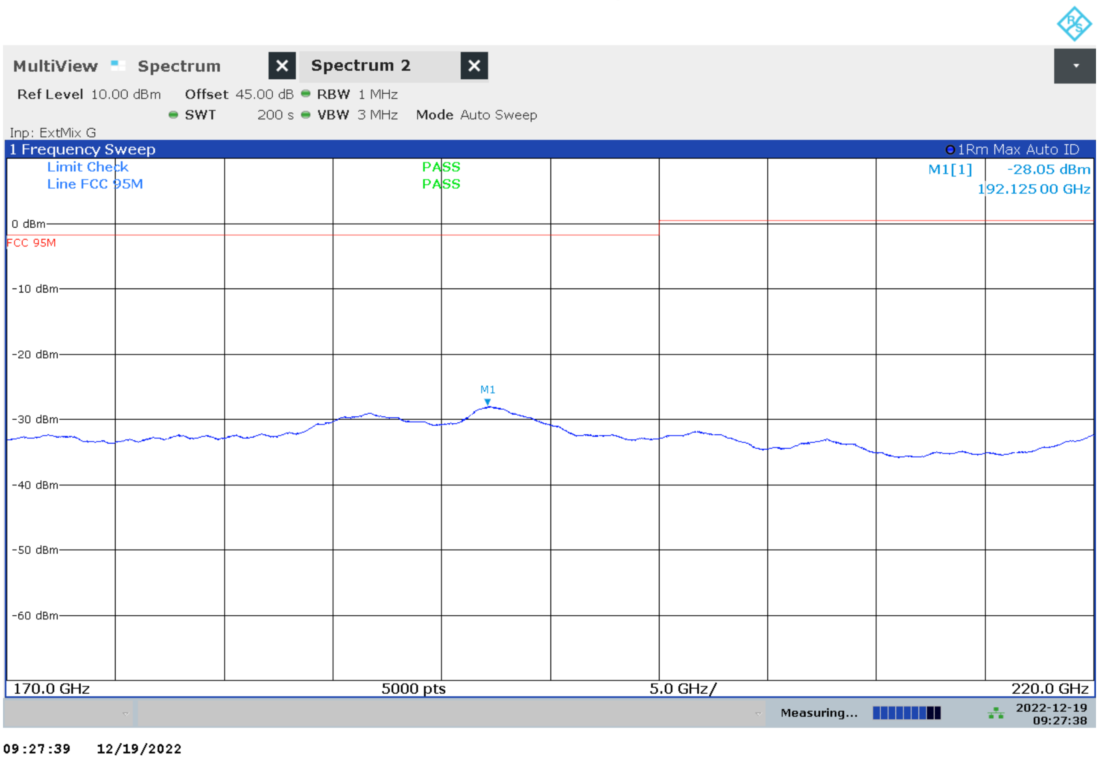


09:12:22 12/19/2022

Plot no. 83: radiated emissions 170 GHz – 220 GHz, DMP 08, polarization vertical / horizontal



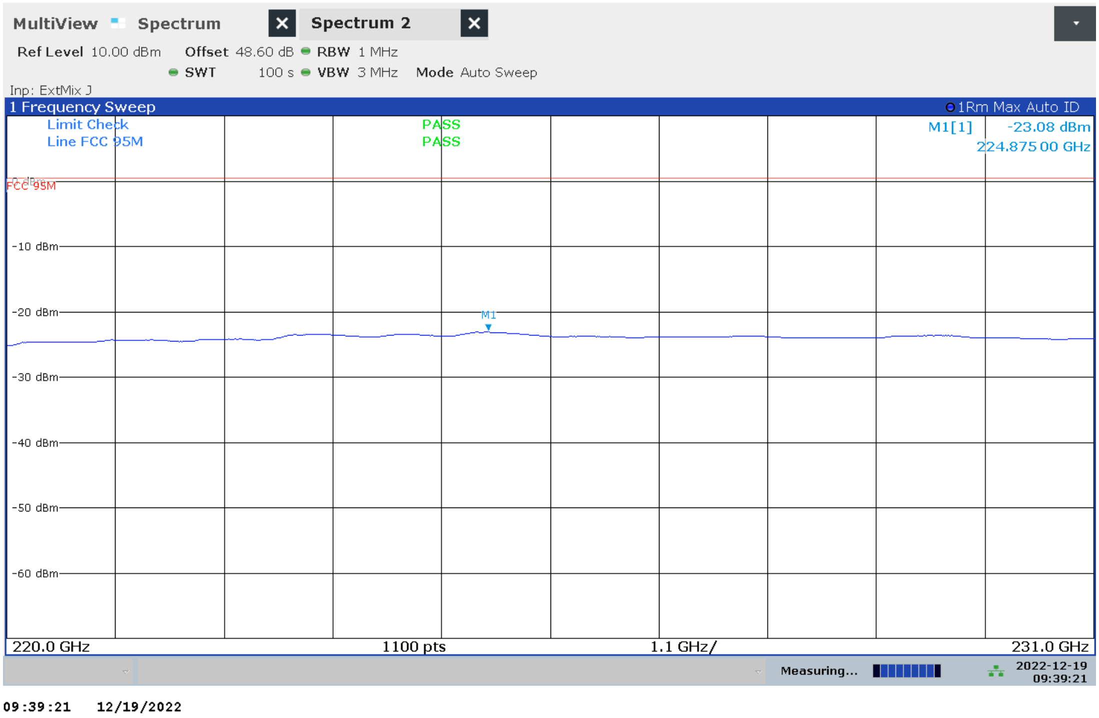
Plot no. 84: radiated emissions 170 GHz – 220 GHz, DMP 12, polarization vertical / horizontal



Plot no. 85: radiated emissions 220 GHz – 231 GHz, DMP 06, polarization vertical / horizontal

Plot no. 86: radiated emissions 220 GHz – 231 GHz, DMP 08, polarization vertical / horizontal

Plot no. 87: radiated emissions 220 GHz – 231 GHz, DMP 12, polarization vertical / horizontal



8 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. Cyclic chamber inspections and range calibrations are performed. Where possible, RF generating and signalling equipment as well as measuring receivers and analysers are connected to an external high-precision 10 MHz reference (GPS-based or rubidium frequency standard).

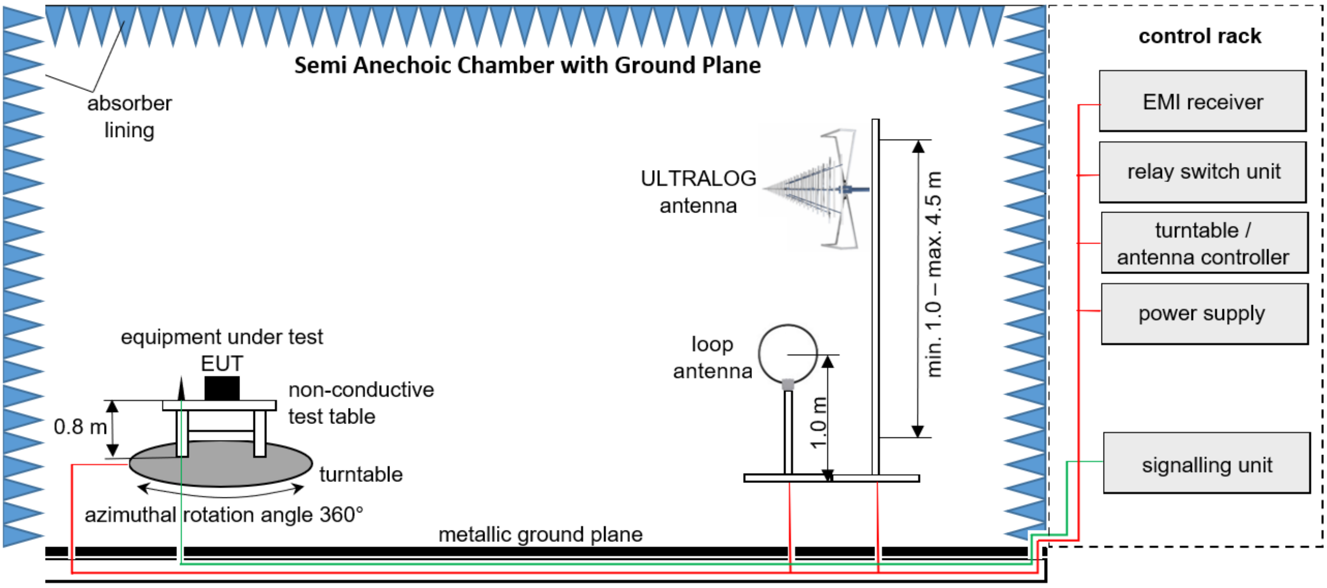
In order to simplify the identification of the equipment used at some special tests, some items of test equipment and ancillaries can be provided with an identifier or number in the equipment list below (Lab/Item).

Kind of calibration (abbreviations):

C = calibrated
CM = cyclic maintenance
NR = not required
L = locked

8.1 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 C63.26-2015, 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 at 3 m; loop antenna at 3 m
EMC32 software version: 11.20.00

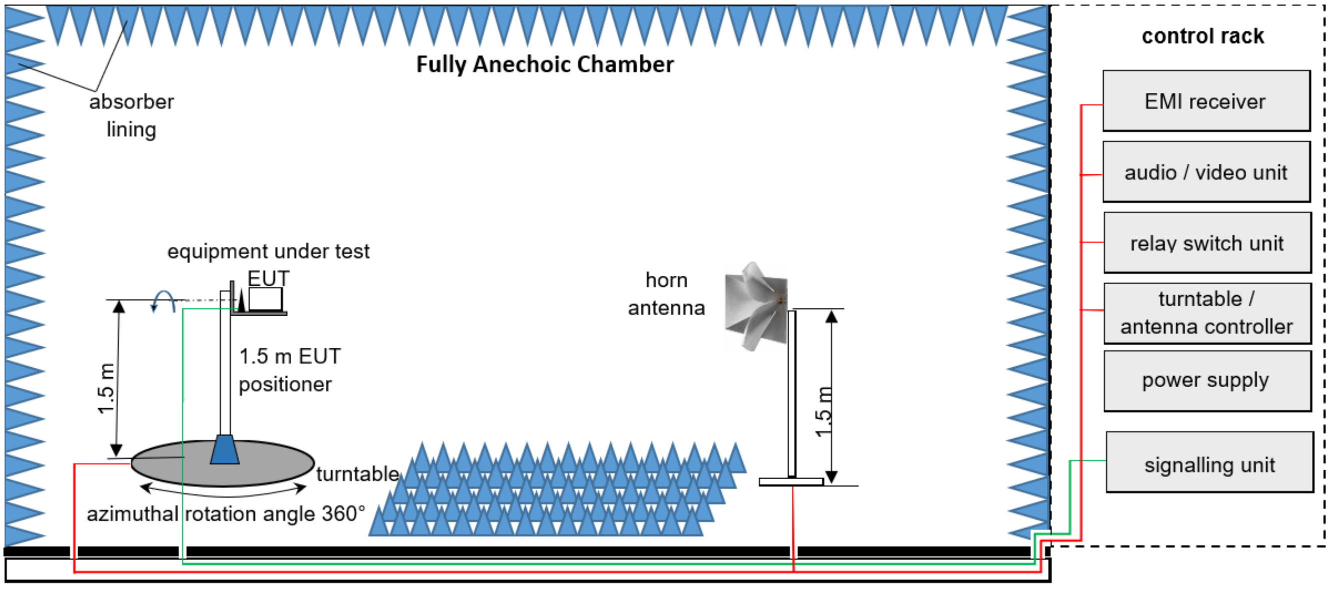
FS = UR + CL + AF
(FS-field strength; UR-voltage at the receiver; CL-loss of the cable; AF-antenna factor)

<u>*Example calculation:*</u>
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	NR	–
2	Test table	innco systems GmbH	PT1208-080-RH	-	LAB000306	NR	–
3	Power Supply	Chroma	61604	616040005416	LAB000285	NR	–
4	Positioner	maturo GmbH	TD 1.5-10KG		LAB000258	NR	–
5	Compressed Air	Implotex	1-850-30	-	LAB000256	NR	–
6	EMI Test Receiver	Rohde & Schwarz	ESW26	101481	LAB000236	C	2022-07-07 → 12M → 2023-07-07
7	Semi/Fully Anechoic Chamber (SFAC)	Albatross Projects GmbH	Babylon 5 (SAC 5)	20168.PRB	LAB000235	NR	–
8	Measurement Software	Rohde & Schwarz	EMC32 V11.20		LAB000226	NR	–
9	Turntable	maturo GmbH	TT2.0-2t	TT2.0-2t/921	LAB000225	NR	–
10	Antenna Mast	maturo GmbH	CAM4.0-P	CAM4.0-P/316	LAB000224	NR	–
11	Antenna Mast	maturo GmbH	BAM4.5-P	BAM4.5-P/272	LAB000223	NR	–
12	Controller	maturo GmbH	FCU 3.0	10082	LAB000222	NR	–
13	Power Supply	Elektro-Automatik GmbH & Co. KG	EA-PS 2042-10 B	2878350292	LAB000191	NR	–
14	Pre-Amplifier	Schwarzbeck Mess-Elektronik OHG	BBV 9718 C	84	LAB000169	NR	–
15	Antenna	Rohde & Schwarz	HF907	102899	LAB000151	C	2020-04-23 → 36M → 2023-04-23
16	Antenna	Rohde & Schwarz	HL562E	102005	LAB000150	C	2020-07-05 → 36M → 2023-07-05
17	Open Switch and Control Platform	Rohde & Schwarz	OSP200 Base Unit 2HU	101748	LAB000149	NR	–
18	Antenna	Rohde & Schwarz	HF907	102898	LAB000124	C	2020-04-23 → 36M → 2023-04-23
19	Antenna	Rohde & Schwarz	HL562E	102001	LAB000123	C	2020-07-05 → 36M → 2023-07-05
20	Antenna	Rohde & Schwarz	HFH2-Z2E - Active Loop Antenna	100954	LAB000108	C	2020-03-25 → 36M → 2023-03-25

8.2 Fully Anechoic Chamber



Measurement distance: horn antenna at 3 m
EMC32 software version: 11.20.00

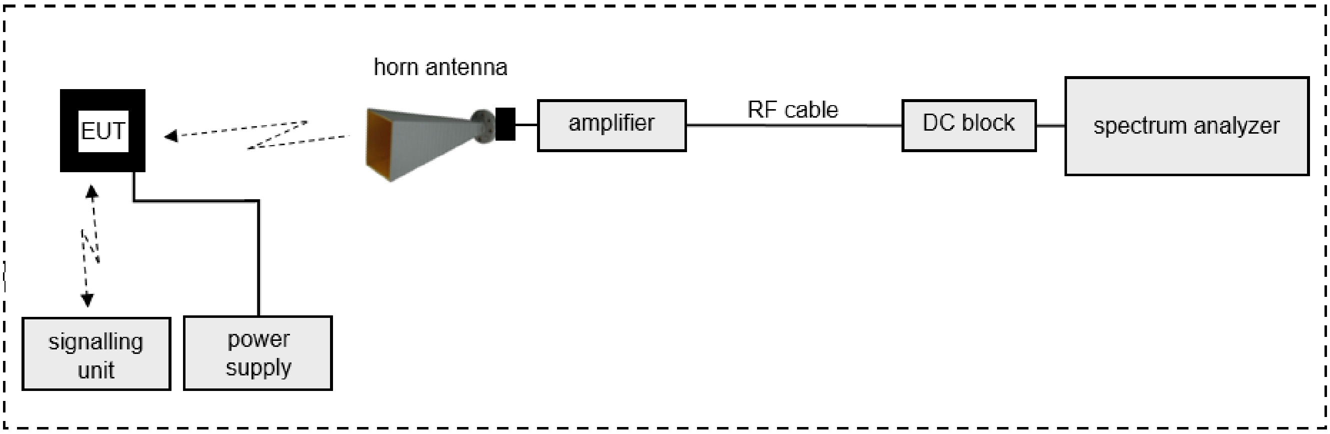
FS = UR + CA + AF
(FS-field strength; UR-voltage at the receiver; CA-loss of the signal path; AF-antenna factor)

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

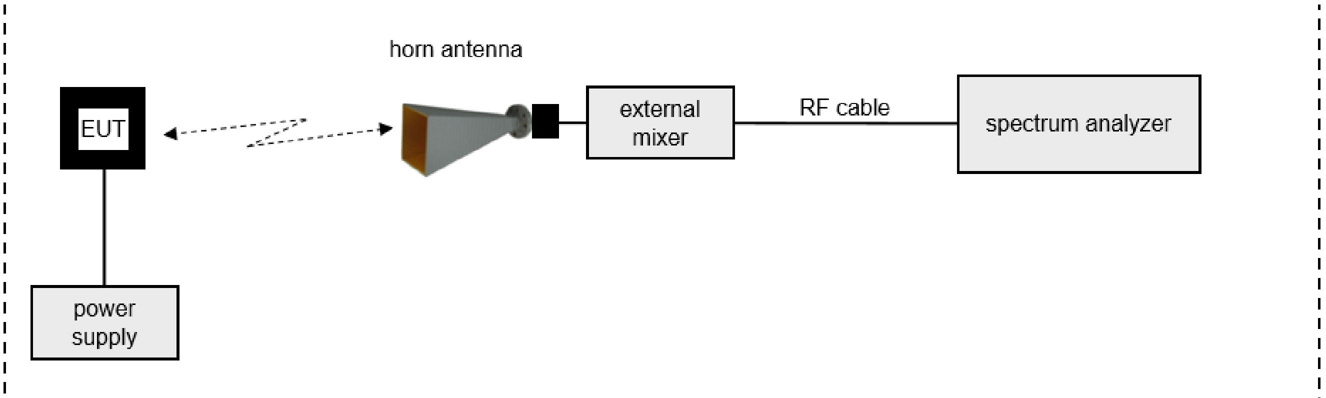
List of test equipment used:

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	NR	–
2	Test table	innco systems GmbH	PT1208-080-RH	-	LAB000306	NR	–
3	Power Supply	Chroma	61604	616040005416	LAB000285	NR	–
4	Positioner	maturo GmbH	TD 1.5-10KG		LAB000258	NR	–
5	Compressed Air	Implotex	1-850-30	-	LAB000256	NR	–
6	EMI Test Receiver	Rohde & Schwarz	ESW26	101481	LAB000236	C	2022-07-07 → 12M → 2023-07-07
7	Semi/Fully Anechoic Chamber (SFAC)	Albatross Projects GmbH	Babylon 5 (SAC 5)	20168.PRB	LAB000235	NR	–
8	Measurement Software	Rohde & Schwarz	EMC32 V11.20		LAB000226	NR	–
9	Turntable	maturo GmbH	TT2.0-2t	TT2.0-2t/921	LAB000225	NR	–
10	Antenna Mast	maturo GmbH	CAM4.0-P	CAM4.0-P/316	LAB000224	NR	–
11	Antenna Mast	maturo GmbH	BAM4.5-P	BAM4.5-P/272	LAB000223	NR	–
12	Controller	maturo GmbH	FCU 3.0	10082	LAB000222	NR	–
13	Power Supply	Elektro-Automatik GmbH & Co. KG	EA-PS 2042-10 B	2878350292	LAB000191	NR	–
14	Pre-Amplifier	Schwarzbeck Mess-Elektronik OHG	BBV 9718 C	84	LAB000169	NR	–
15	Antenna	Rohde & Schwarz	HF907	102899	LAB000151	C	2020-04-23 → 36M → 2023-04-23
16	Antenna	Rohde & Schwarz	HL562E	102005	LAB000150	C	2020-07-05 → 36M → 2023-07-05
17	Open Switch and Control Platform	Rohde & Schwarz	OSP200 Base Unit 2HU	101748	LAB000149	NR	–
18	Antenna	Rohde & Schwarz	HF907	102898	LAB000124	C	2020-04-23 → 36M → 2023-04-23
19	Antenna	Rohde & Schwarz	HL562E	102001	LAB000123	C	2020-07-05 → 36M → 2023-07-05
20	Antenna	Rohde & Schwarz	HFH2-Z2E - Active Loop Antenna	100954	LAB000108	C	2020-03-25 → 36M → 2023-03-25

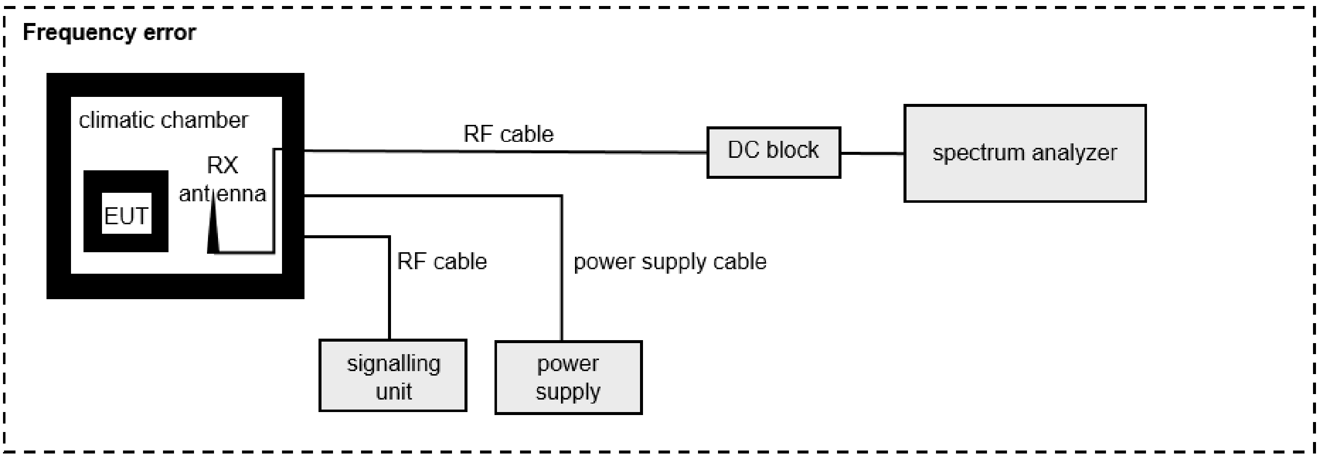
8.3 Radiated measurements > 18 GHz



8.4 Radiated measurements > 50 GHz



8.5 Radiated measurements under extreme conditions



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

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

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

List of test equipment used:

No.	Equipment	Manufacturer	Type	Serial No.	IBL No.	Kind of Calibration	Calibration
1	Test table	innco systems GmbH	PT0707-RH light	-	LAB000303	NR	–
2	Power Supply	Elektro-Automatik GmbH & Co. KG	EA-PS 2042-10 B	2878350255	LAB000189	NR	–
3	WG-Coax-Adapter	Flann Microwave Ltd	23373-TF30 UG383/U	273385	LAB000185	CM	2020-07-01 → 36M → 2023-07-01
4	WG-Coax-Adapter	Flann Microwave Ltd	22093-TF30 UG599/U	273263	LAB000183	CM	2020-07-01 → 36M → 2023-07-01
5	WG-Coax-Adapter	Flann Microwave Ltd	20093-TF30 UBR220	273374	LAB000181	CM	2020-07-01 → 36M → 2023-07-01
6	Antenna	Flann Microwave Ltd	30240-20	273390	LAB000178	CM	2020-08-01 → 36M → 2023-08-01
7	Coaxial Cable	Huber & Suhner	SF101/1.0m	503990/1	LAB000164	CM	2022-05-31 → 12M → 2023-05-31
8	Coaxial Cable	Rosenberger	LU7-022-1000	34	LAB000154	NR	–
9	Coaxial Cable	Rosenberger	LU7-022-1000	33	LAB000153	NR	–
10	Antenna	Flann Microwave Ltd	32240-20	273469	LAB000152	CM	2020-08-01 → 36M → 2023-08-01
11	Antenna	Flann Microwave Ltd	29240-20	273382	LAB000139	CM	2020-08-01 → 36M → 2023-08-01
12	Antenna	Flann Microwave Ltd	27240-20	273367	LAB000137	CM	2020-08-01 → 36M → 2023-08-01
13	Antenna	Flann Microwave Ltd	26240-20	273417	LAB000135	CM	2020-08-01 → 36M → 2023-08-01
14	Antenna	Flann Microwave Ltd	25240-20	272860	LAB000133	CM	2020-07-01 → 36M → 2023-07-01
15	Antenna	Flann Microwave Ltd	23240-20	273430	LAB000132	CM	2020-07-01 → 36M → 2023-07-01
16	Antenna	Flann Microwave Ltd	22240-20	270448	LAB000130	K	2020-06-29 → 36M → 2023-06-29
17	Antenna	Flann Microwave Ltd	20240-20	266403	LAB000128	K	2020-06-29 → 36M → 2023-06-29
18	Harmonic Mixer	Rohde & Schwarz	FS-Z170	100996	LAB000126	K	2022-04-12 → 12M → 2023-04-12
19	Harmonic Mixer	Rohde & Schwarz	FS-Z325	101015	LAB000117	K	2022-04-12 → 12M → 2023-04-12
20	Harmonic Mixer	Rohde & Schwarz	FS-Z220	101039	LAB000116	K	2022-03-28 → 12M → 2023-03-28
21	Harmonic Mixer	Rohde & Schwarz	FS-Z110	102000	LAB000114	K	2022-04-14 → 12M → 2023-04-14
22	Harmonic Mixer	Rohde & Schwarz	FS-Z090	102020	LAB000113	K	2022-04-05 → 12M → 2023-04-05
23	Harmonic Mixer	Rohde & Schwarz	FS-Z075	102015	LAB000112	K	2022-04-20 → 12M → 2023-04-20
24	Spectrum Analyser	Rohde & Schwarz	FSW50	101450	LAB000111	K	2022-07-28 → 12M → 2023-07-28
25	Climatic Chamber	CTS GmbH	T-65/50	204002	LAB000110	CM	2022-05-11 → 12M → 2023-05-11
26	Antenna Mast	Schwarzbeck Mess-Elektronik OHG	AM 9104	99	LAB000109	NR	–

9 Measurement procedures

9.1 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.

Distance correction (extrapolation)

- When performing measurements on test distances other than defined in the rules, the results shall be extrapolated to the specified distance by conservatively presuming that the field strength decays at 40 dB/decade of distance in the region closer than λ in m divided by 2π (i.e., λ/2π), and at 20 dB/decade of distance beyond that, using the measurement of a single point at the radial angle that produces the maximum emission.
  This correction is already included in the limit line of corresponding measurement plots.

Detailed requirements can be found in e.g. ANSI C63.4 / C63.26

9.2 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.

Distance correction (extrapolation)

- When performing measurements on test distances other than defined in the rules, the results shall be extrapolated to the specified distance by conservatively presuming that the field strength decays at 20 dB/decade of distance beyond the region λ in m divided by 2π (i.e., λ/2π), using the measurement of a single point at the radial angle that produces the maximum emission.
  This correction is already included in the corresponding measurement plots.

Detailed requirements can be found in e.g. ANSI C63.4 / C63.26

9.3 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.

Distance correction (extrapolation)

- When performing measurements on test distances other than defined in the rules, the results shall be extrapolated to the specified distance by conservatively presuming that the field strength decays at 20 dB/decade of distance beyond the region λ in m divided by 2π (i.e., λ/2π), using the measurement of a single point at the radial angle that produces the maximum emission.
  This correction is already included in the corresponding measurement plots.

Detailed requirements can be found in e.g. ANSI C63.4 / C63.26

9.4 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 (far field 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 / C63.26).
- 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.

Distance correction (extrapolation)

- When performing measurements on test distances other than defined in the rules, the results shall be extrapolated to the specified distance by conservatively presuming that the field strength decays at 20 dB/decade of distance beyond the region λ in m divided by 2π (i.e., λ/2π), using the measurement of a single point at the radial angle that produces the maximum emission.
  This correction is already included in the corresponding measurement plots.

Detailed requirements can be found in e.g. ANSI C63.4 / C63.26

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-4/01 m:2013. The true value is located in the corresponding interval with a probability of 95 %.

Annex 1 EUT Photographs, external

Photo No. 1:

Photo No. 2:

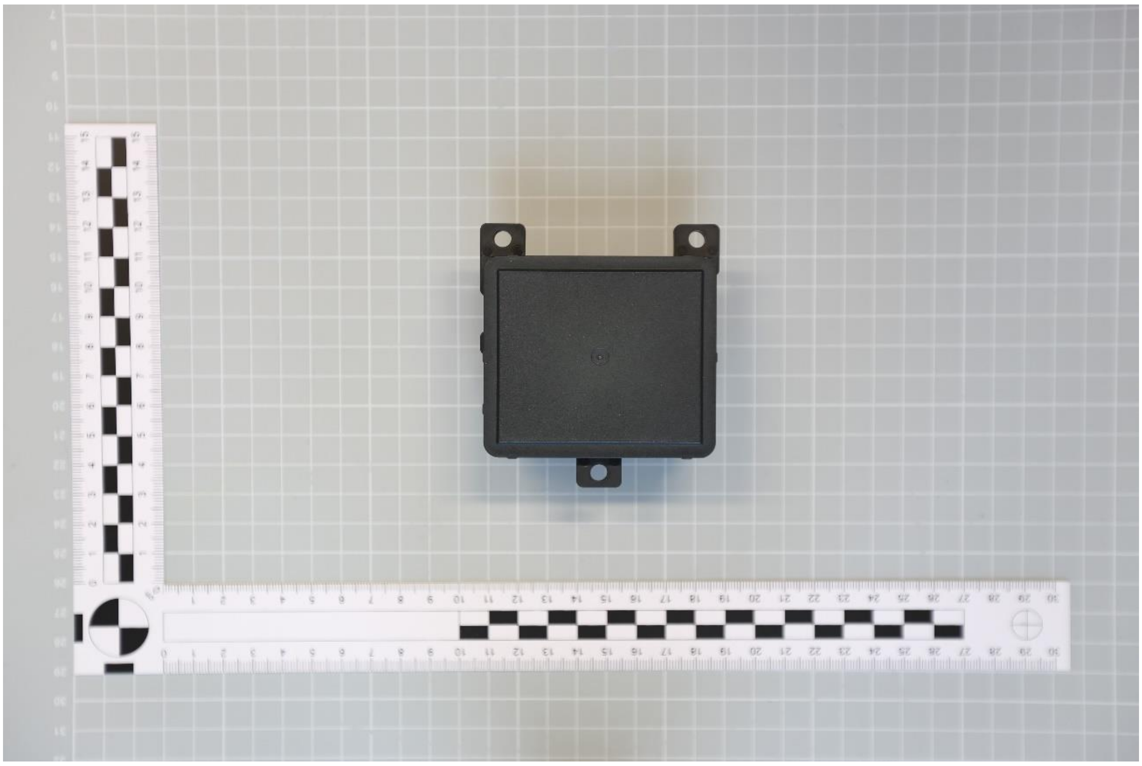


Photo No. 3:

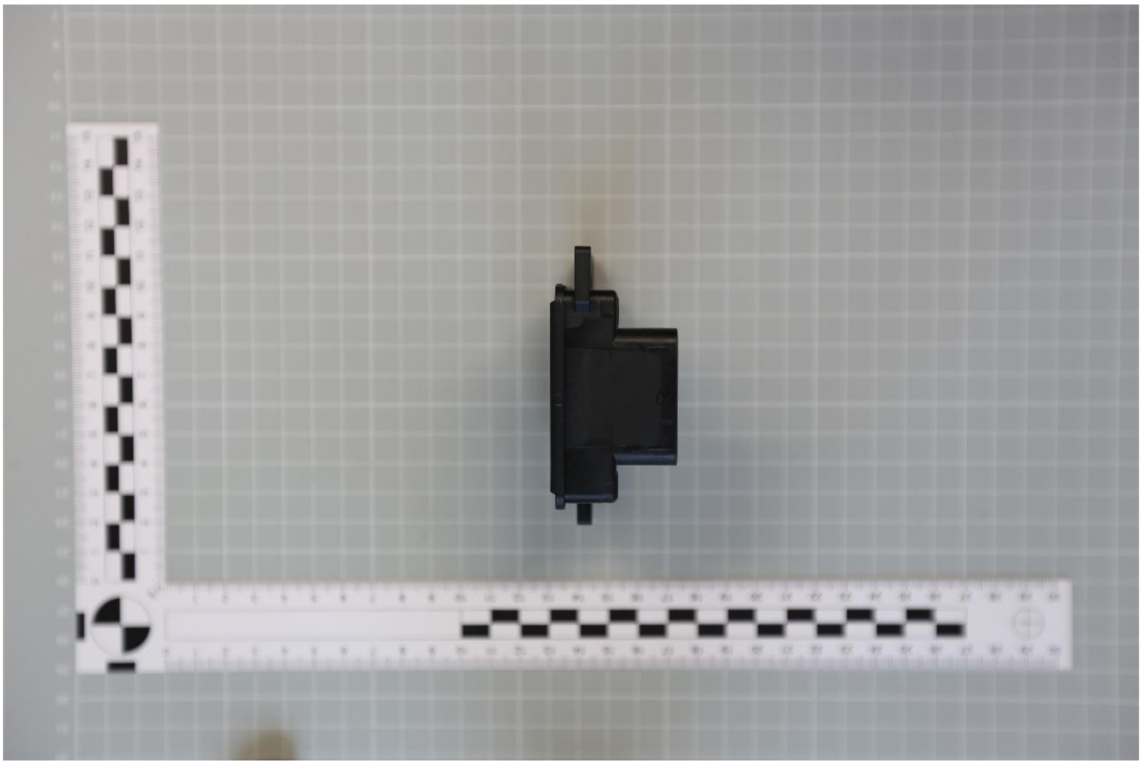


Photo No. 4:

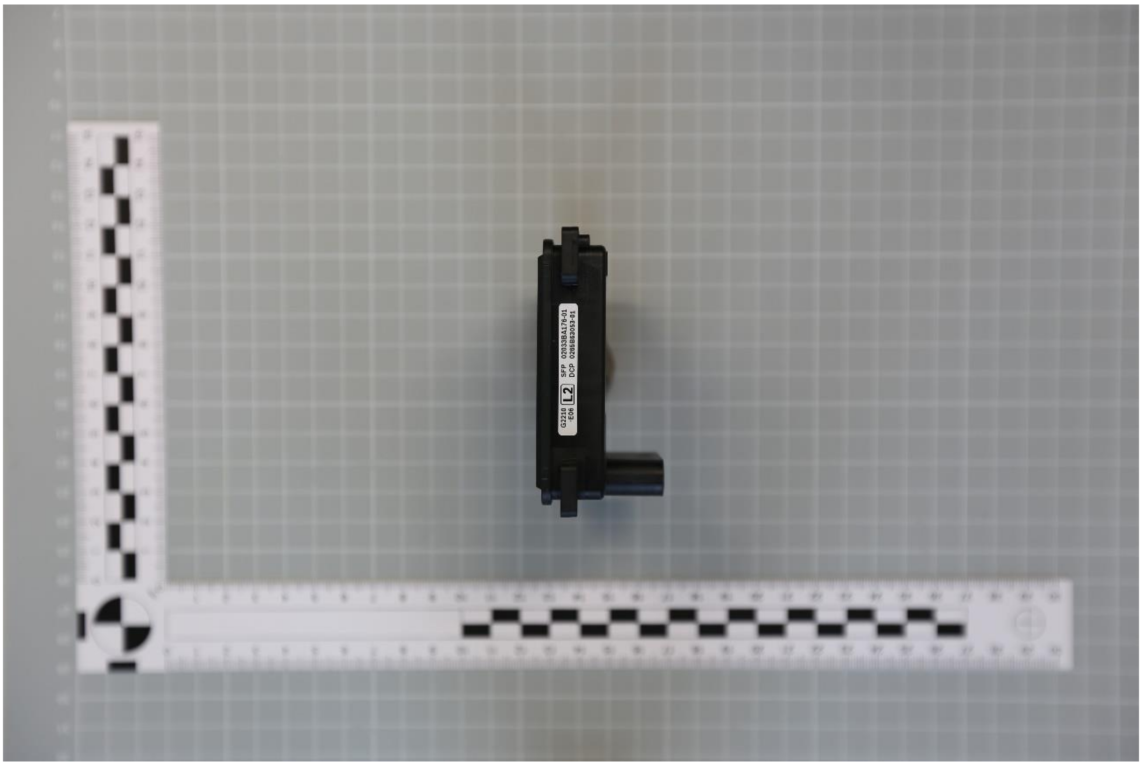


Photo No. 5:

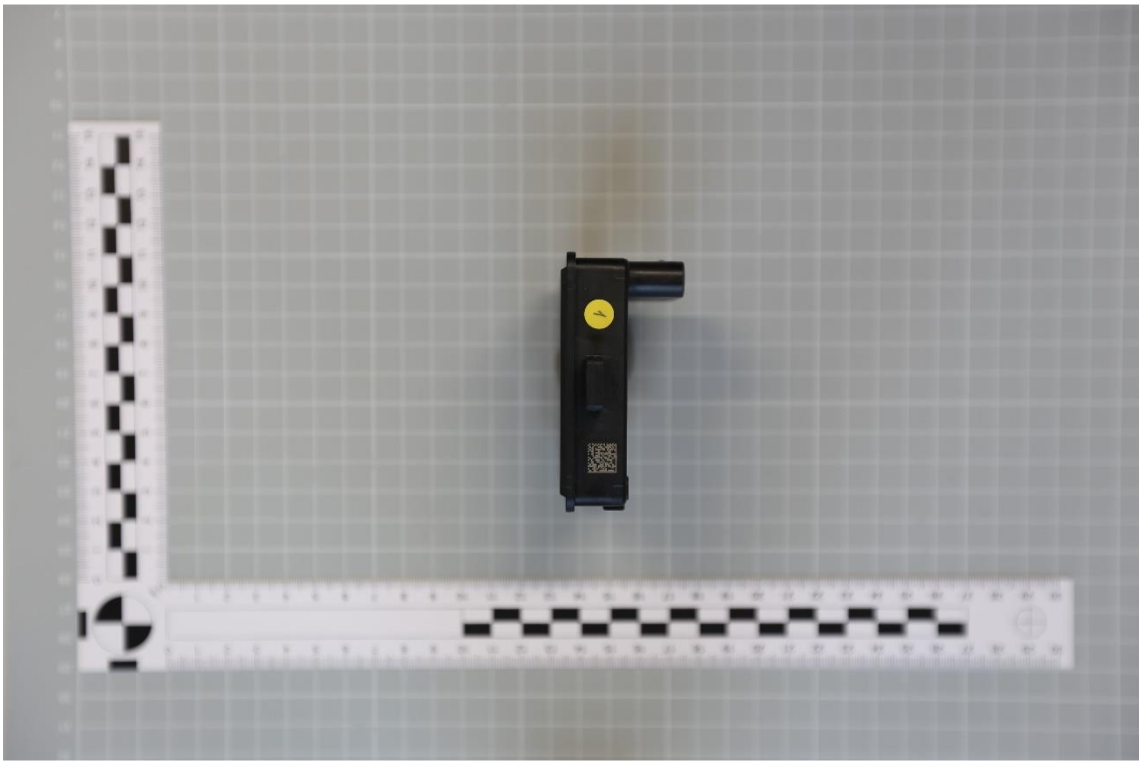
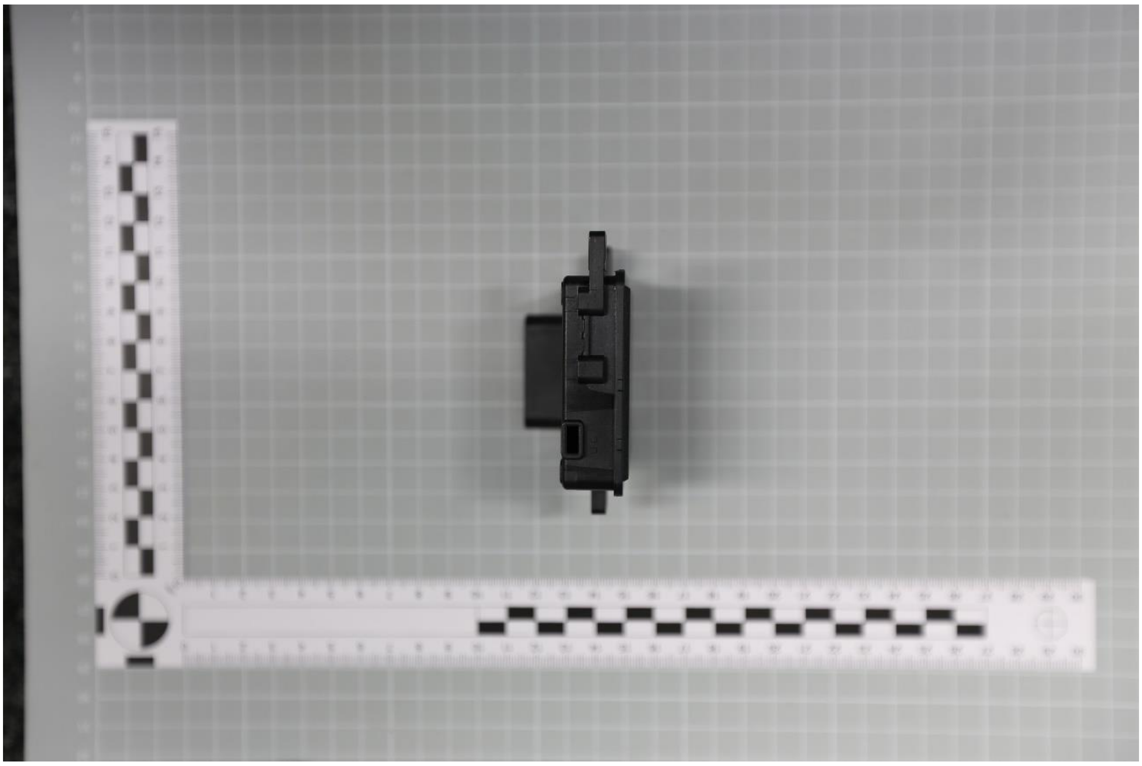


Photo No. 6:



Annex 2 EUT Photographs, internal

Photo No. 7:

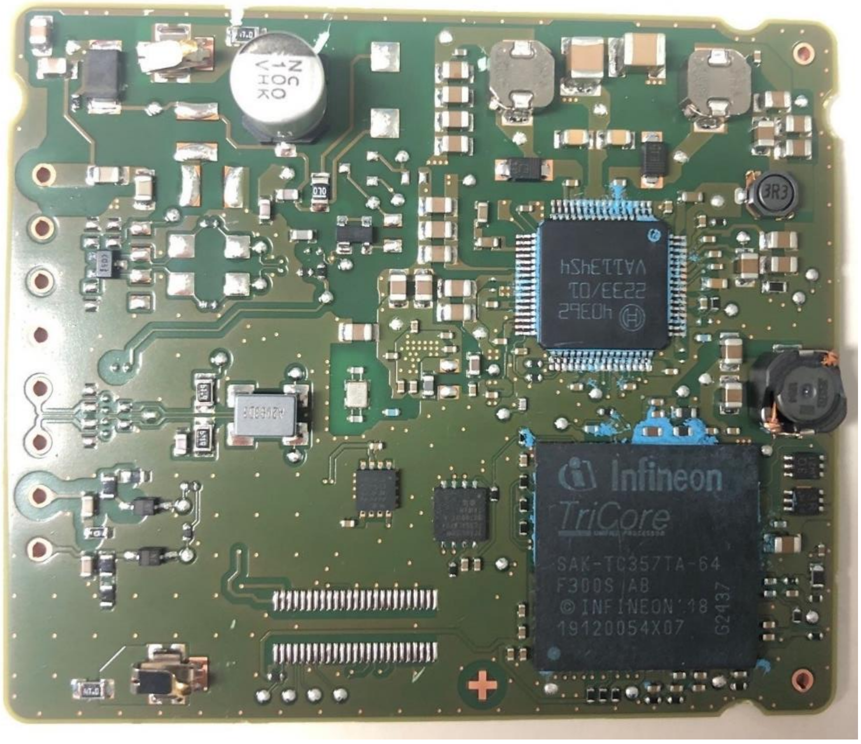
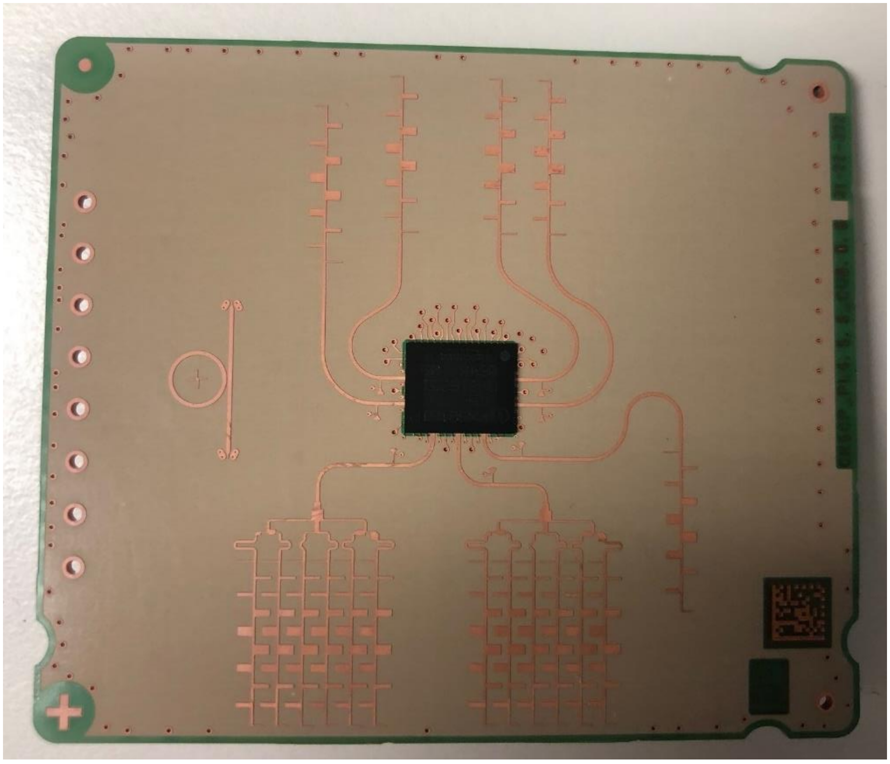


Photo No. 8:



Note: Internal photographs provided by customer

Annex 3 Test Setup Photographs

Photo No. 9:

Photo No. 10:

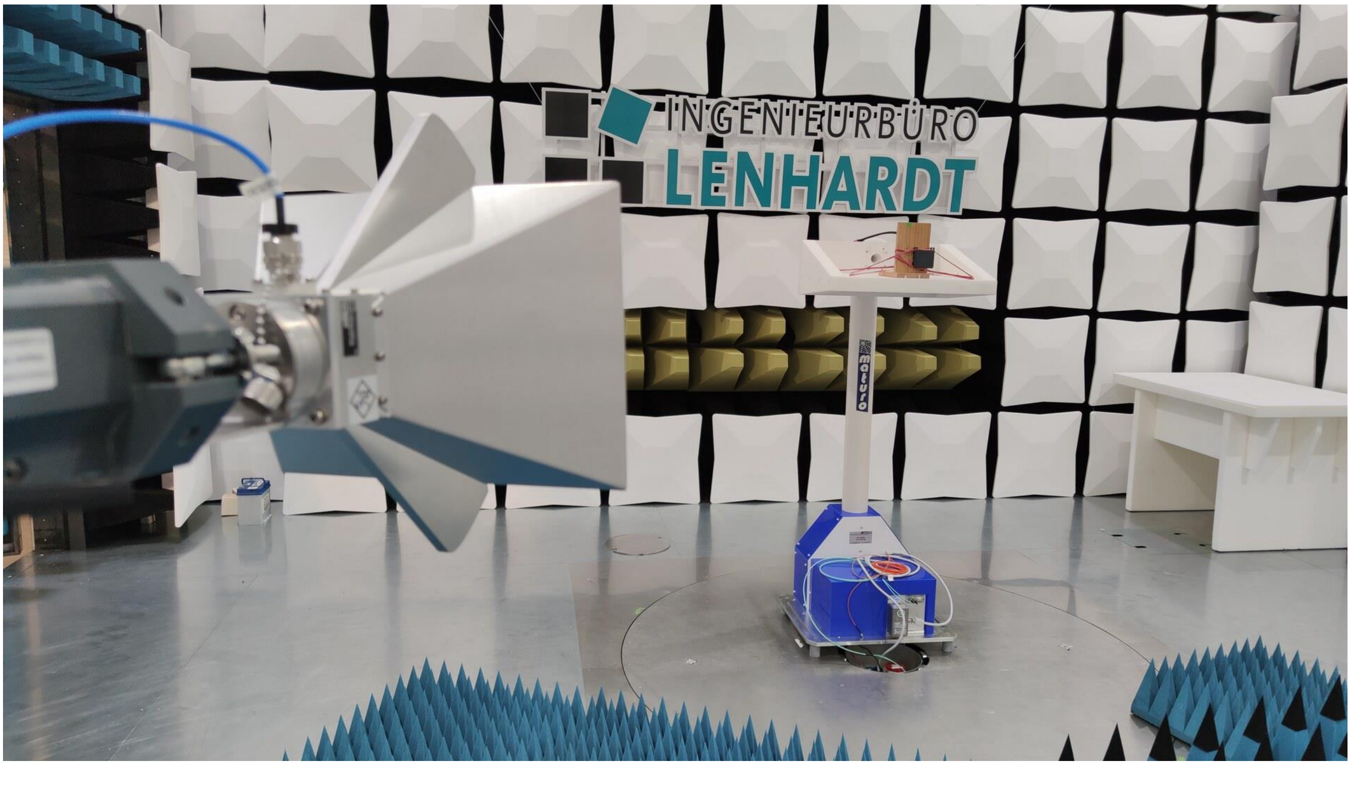


Photo No. 11:

Photo No. 12: