DAkkS Deutsche Akkreditierungsstelle D-PL-21375-01-00

INGENIEURBÜRO LENHARDT

Bundesnetzagentur

BNetzA-CAB-21/21-21

Test Report

Test report no.: 23109276-35559-0
Date of issue: 2024-05-02

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

Applicant
Robert Bosch GmbH

Manufacturer
Robert Bosch GmbH

Test Item
CR5CBCC

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* *Head of Dept RF*	signature
Approved by (name, function, signature)	*Karsten Geraldy* *Lab manager RF*	signature

Applicant and Test item details	
Applicant	Robert Bosch GmbH Daimlerstrasse 6 71229, Leonberg, Germany Phone: (phone number) Fax: (fax number)
Manufacturer	Robert Bosch GmbH Daimlerstrasse 6 71229, Leonberg, Germany
Test item description	Corner Radar Gen 5 for Cars
Model/Type reference	CR5CBCC
FCC ID	NF3-CR5CBCC
Frequency	76.0 GHz to 77.0 GHz
Antenna	integrated patch antenna
Power supply	7.0 to 16.0 V DC
Temperature range	-40 °C to +85 °C

Disclaimer and Notes

The content of this report relates to the mentioned test sample(s) only.
IBL-Lab GmbH does not take samples. The samples used for testing are provided by the applicant.
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The last valid version is available at TAMSys®.
Signatures are done electronically, if signer does not match stated signer, it is signed per order.
Information supplied by the applicant can affect the validity of results. The data is marked accordingly.

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:
Decision rule based on simple acceptance without guard bands, binary statement, based on mutually agreed uncertainty tolerances with expansion factor k=2.

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: https://ib-lenhardt.com/ E-Mail: info@ib-lenhardt.com
Accreditation / Designation	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: • Attachment to the accreditation certificate D-PL-21375-01-00 ○ Electronics ○ Electromagnetic Compatibility ○ Radio ○ Electromagnetic Compatibility and Telecommunication (FCC requirements) ○ Telecommunication (TC) and Electromagnetic Compatibility (EMC) for Canadian Standards ○ Automotive EMC Website DAkkS: https://www.dakks.de/ The Deutsche Akkreditierungsstelle GmbH (DAkkS) is also a signatory to the ILAC Mutual Recognition Arrangement. • Designations ○ FCC Testing Laboratory Designation Number DE0024 ○ ISED ISED Company Number 27156 Testing Laboratory CAB Identifier DE0020 ○ Kraftfahrt-Bundesamt KBA-P 00120-23
Testing laboratory	**IBL-Lab GmbH** Heinrich-Hertz-Allee 7 66386 St. Ingbert / Germany Fon: +49 6894 38938-0 Fax: +49 6894 38938-99 URL: https://ib-lenhardt.com/ E-Mail: info@ib-lenhardt.com
Date of receipt of test samples	2024-04-08
Start – End of tests	2024-04-08 – 2024-04-22

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

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	+23 °C	+85 °C
Relative humidity	-/-	45 % r.h.	-/-
Power supply	7 V DC	13.4 V DC	16 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

Corner Radar Gen 5 for Cars

5.2 Description of test item

Model name*	CR5CBCC
Serial number*	597901052168810593531081082312621324207 5
PCB identifier*	1038202748
Hardware status*	0265B62574-01
Software status*	1037608560

*: 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*	~26.45 %
Antenna*	integrated patch antenna
Power supply*	7.0 to 16.0 V DC
Temperature range*	-40 °C to +85 °C

*: as declared by applicant

5.4 Additional information

Model differences	none
Additional application considerations to test a component or sub-assembly	none
Ancillaries tested with	none
Additional equipment used for testing	notebook with special test software and CAN-Bus adapter to setup test modes

5.1 Operating conditions

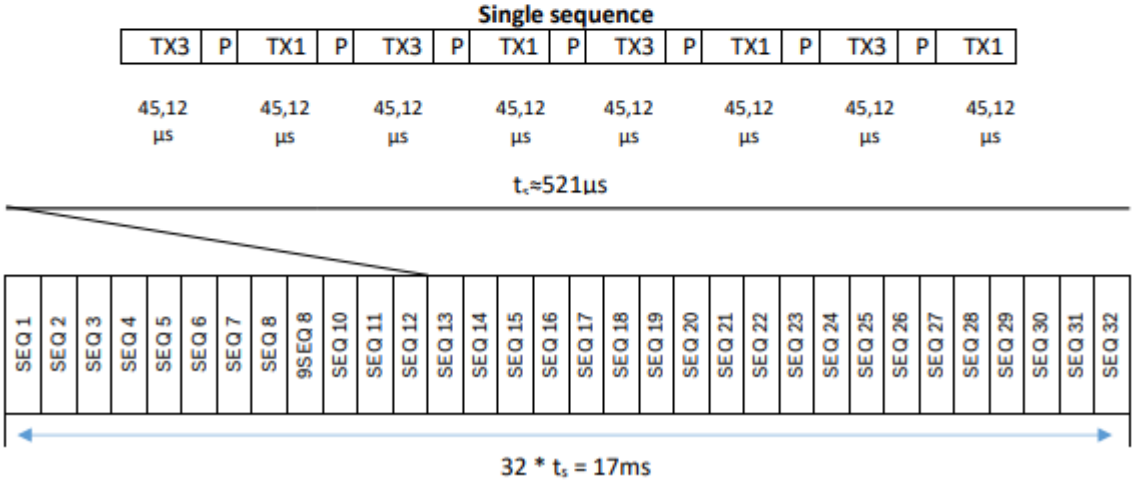
4.3 Modulation description

The CR5CBCC sensor modulation mode depends on vehicle speed, but in both modes TX1 and TX3 are in operation.

Vehicle speed	Modulation mode	Active TX channels
above 7km/h	DMP#1	TX1, TX3
up to 7km/h	DMP#2	TX1, TX3

4.3.1 DMP#1 modulation

Single sequence consists of 8 frequency ramps around constant centre frequency. Each ramp is emitted on different TX channel with frequency swing of 175MHz and takes 45,12µs.
TX channels are activated in following order:



The sequence is repeated 32 times with centre frequency shifted by about 16MHz for each sequence. The centre frequency changes by total 525MHz over whole burst (32 sequences). Therefore, the frequency band used by DMP#1 is 700MHz (525MHz+175MHz).

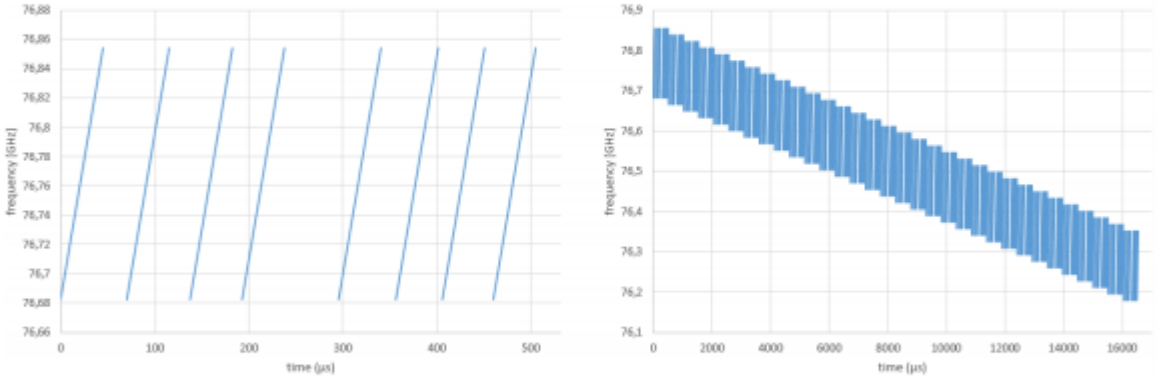
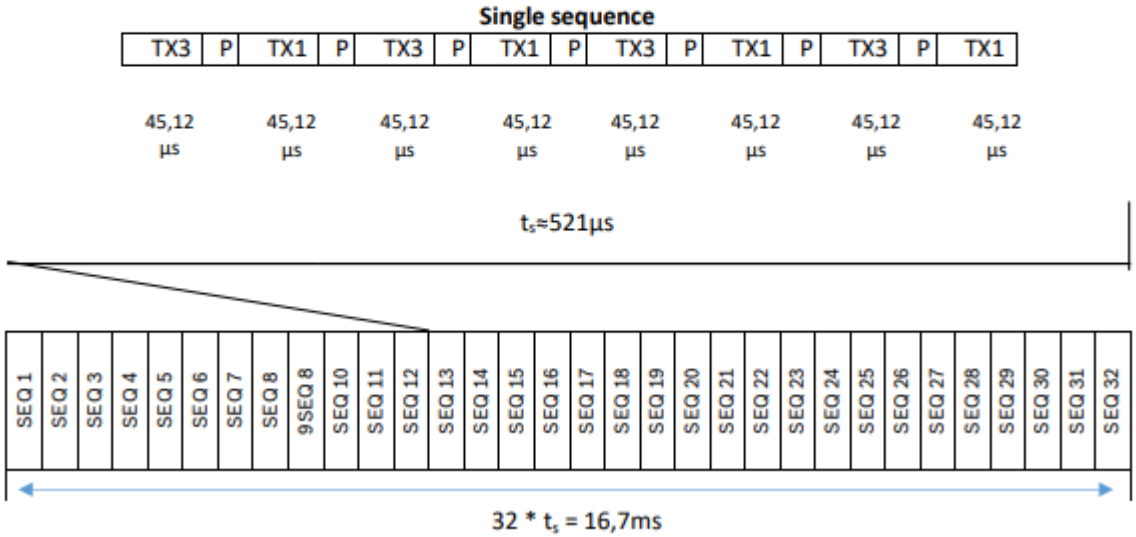


Figure 9: DMP#1 single sequence and complete burst.

The burst takes on average 17ms. After burst period sensor turns off transmitter to cool off for 49ms. Whole cycle takes 66ms.

4.3.2 DMP#2 modulation

Single sequence consists of 8 frequency ramps around constant centre frequency. Each ramp is emitted on different TX channel with frequency swing of 175MHz and takes 45,12µs. TX channels are activated in following order:



The sequence is repeated 32 times with centre frequency shifted by about 16MHz for each sequence. The centre frequency changes by total 525MHz over whole burst (32 sequences). Therefore, the frequency band used by DMP#2 is 700MHz (525MHz+175MHz).
The burst takes 16,7ms. After burst period sensor turns off transmitter to cool off for 49,3ms. Whole cycle takes 66ms.

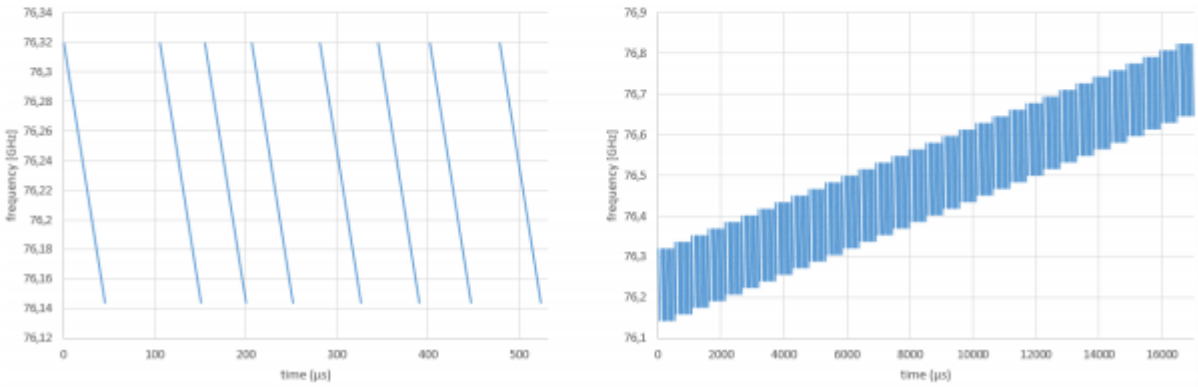


Figure 10: DMP#2 single sequence and complete burst.

4.4 Duty Cycle

Total duration of a single CR5CBCC cycle is always 66ms. Within this time, the sensor transmits a single burst, which duration depends on mode. Additionally, every 2nd cycle, sensor emits a monitoring signal, which takes 0,91ms.
Therefore, sensor duty cycle:

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

Modulation mode	Burst length	Duty cycle
DMP#1	17 ms	26,45%
DMP#2	16,7ms	26,0%

5.2 Antenna characteristics

4.2 Antenna characteristics

4.2.1 TX1 antenna characteristic

Simulation result of TX1 azimuth antenna characteristic is presented below:

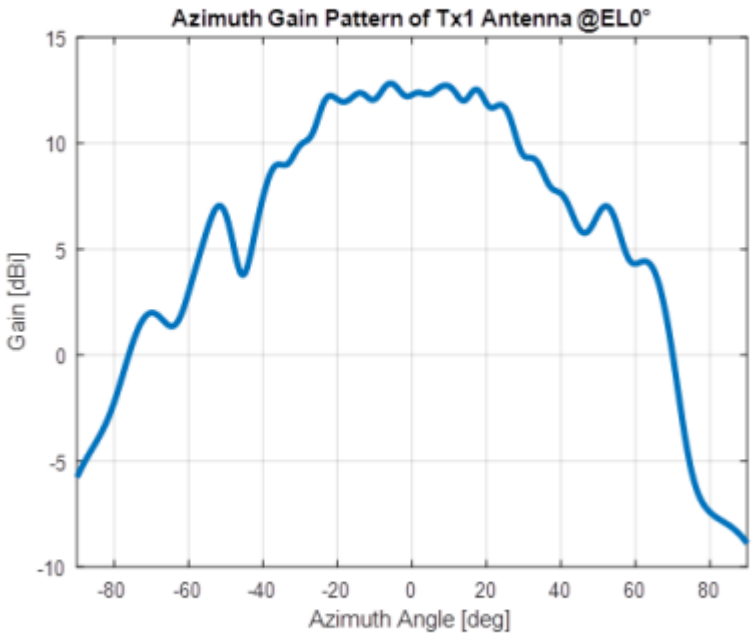


Figure 6: CR5CBCC TX1 antenna characteristics

Maximum gain is 12,8 dBi at angle 0°.

4.2.2 TX3 antenna characteristics

Simulation result of TX3 azimuth antenna characteristic is presented below:

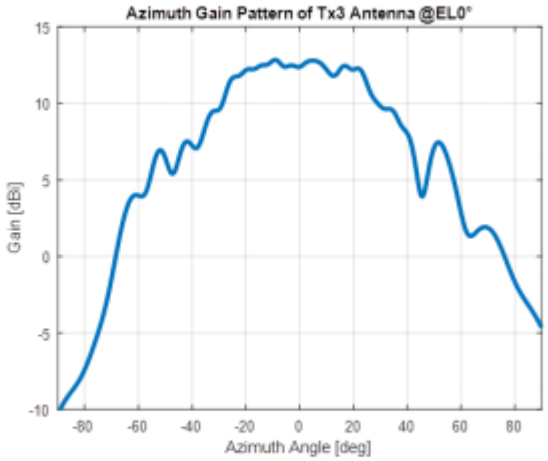


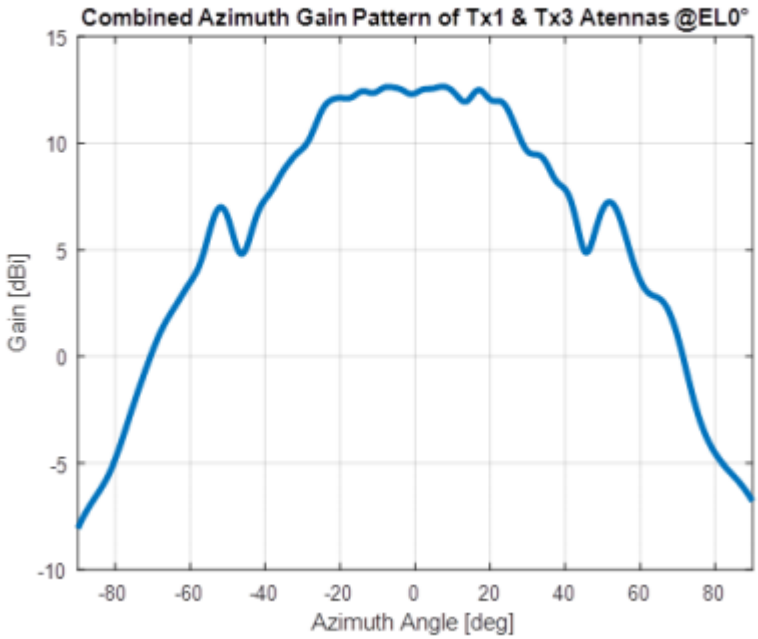
Figure 7: CR5CBCC TX3 antenna characteristics

Maximum gain is 12,8 dBi at angle 0°.

4.2.3 TXall antenna characteristics

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

Figure 8: CR5CBCC All TX antenna characteristics



Maximum gain is 12.6 dBi @Az0°

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	18.11 dBm mean 27.90 dBm peak	P
§2.1047	Modulation characteristics	Nominal		P
§2.1049	Occupied bandwidth	Nominal	713.92 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		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

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.

Test procedure

Peak Power

Method with a spectrum analyser

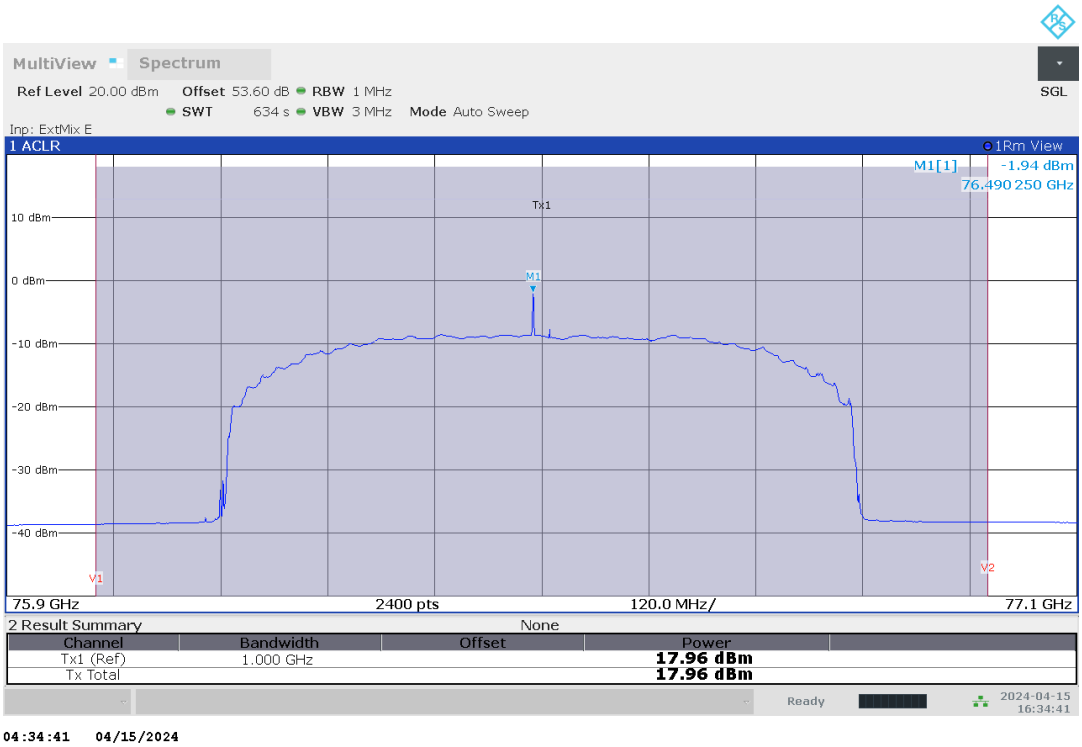
A spectrum analyser with the following settings is used as measuring receiver in the test set-up:

- 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.
- Averaging time: larger than one EUT cycle time.
- Sweep time: averaging time × number of sweep points.

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

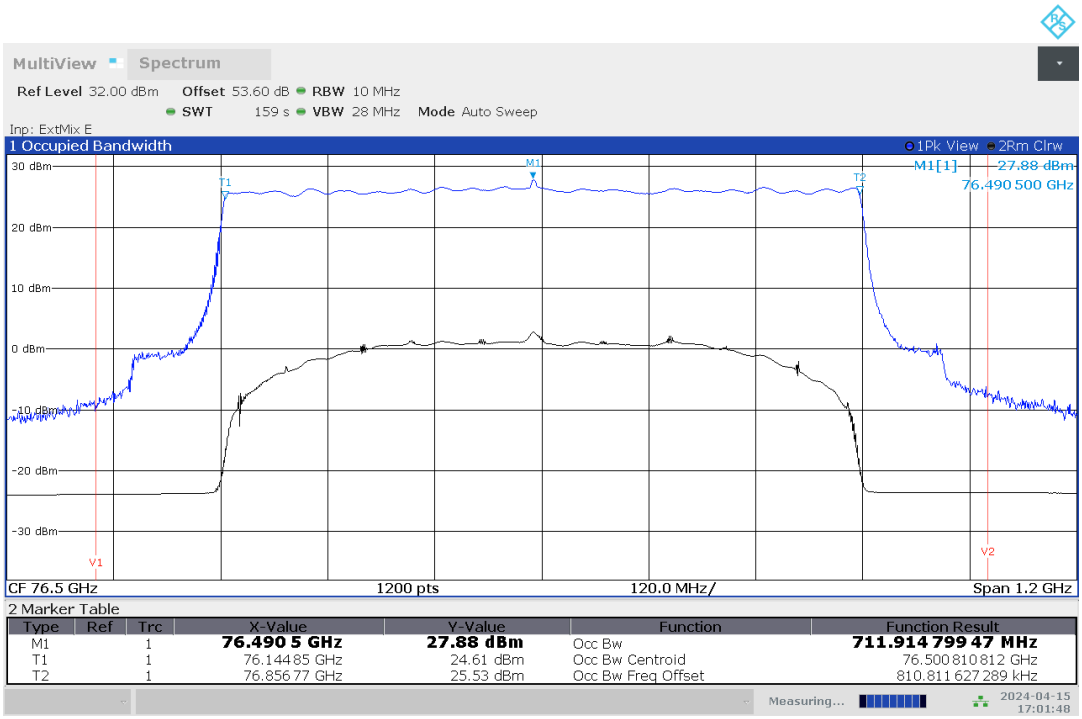
Test setup: 8.3			
Test results:			
EUT mode	**Test distance**	**Radiated Mean Power (EIRP) [dBm]**	**Radiated Peak Power (EIRP) [dBm]**
1	1.5 m	17.96	27.88
2	1.5 m	18.11	27.90

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

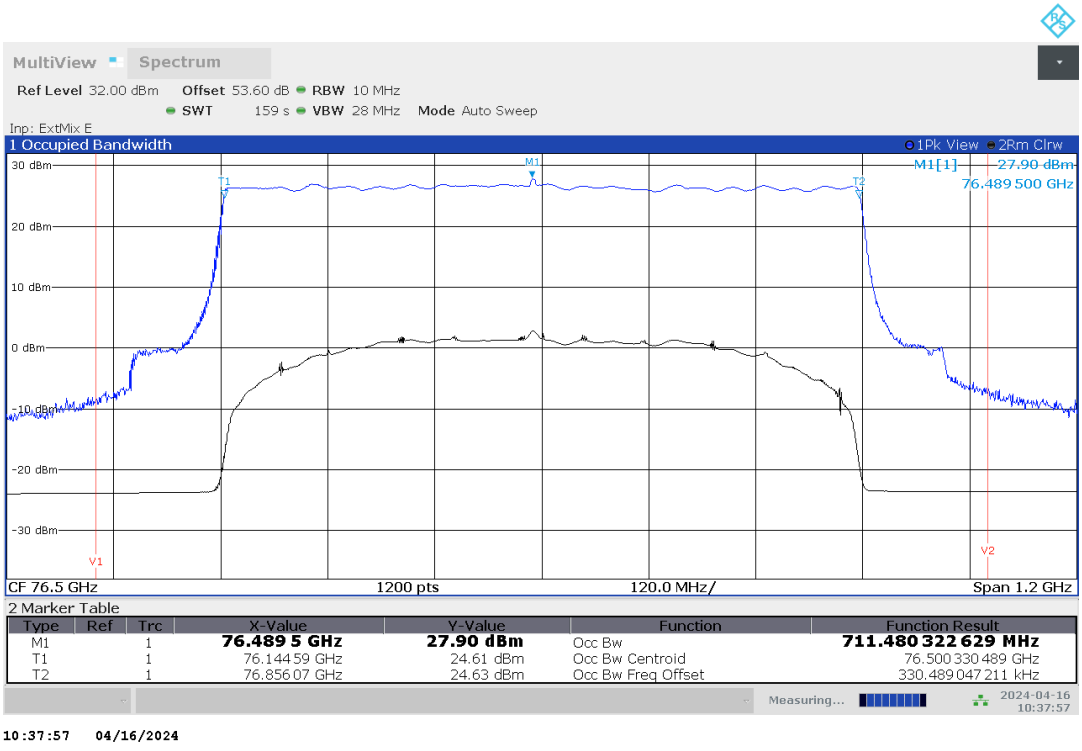


Plot no. 2: Mean Power EIRP, RMS detector / Channel Power, EUT Mode 2

Plot no. 3: Peak Power EIRP, Peak detector, EUT Mode 1



Plot no. 4: Peak Power EIRP, Peak detector, EUT Mode 2



7.2 Modulation characteristics (§2.1047 & KDB 653005 D01 76-81 GHz Radars v01r01)

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 V01r01:

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

See chapter 5.1

7.3 Occupied bandwidth (§2.1049)

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 76-81GHz 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).

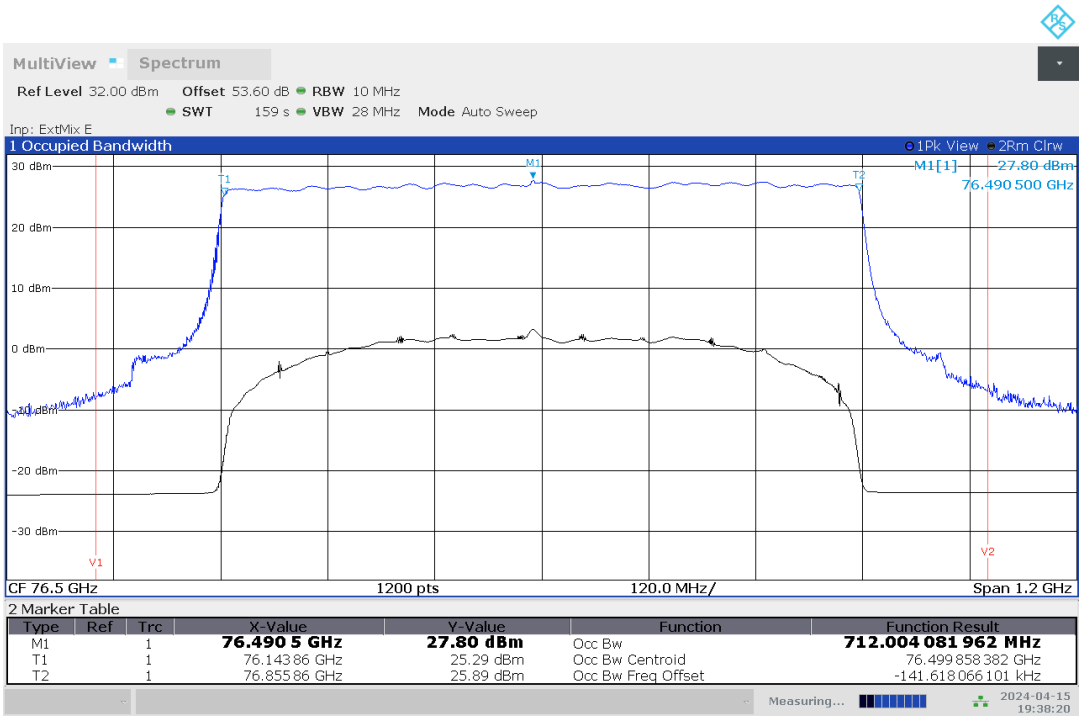
Note

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).

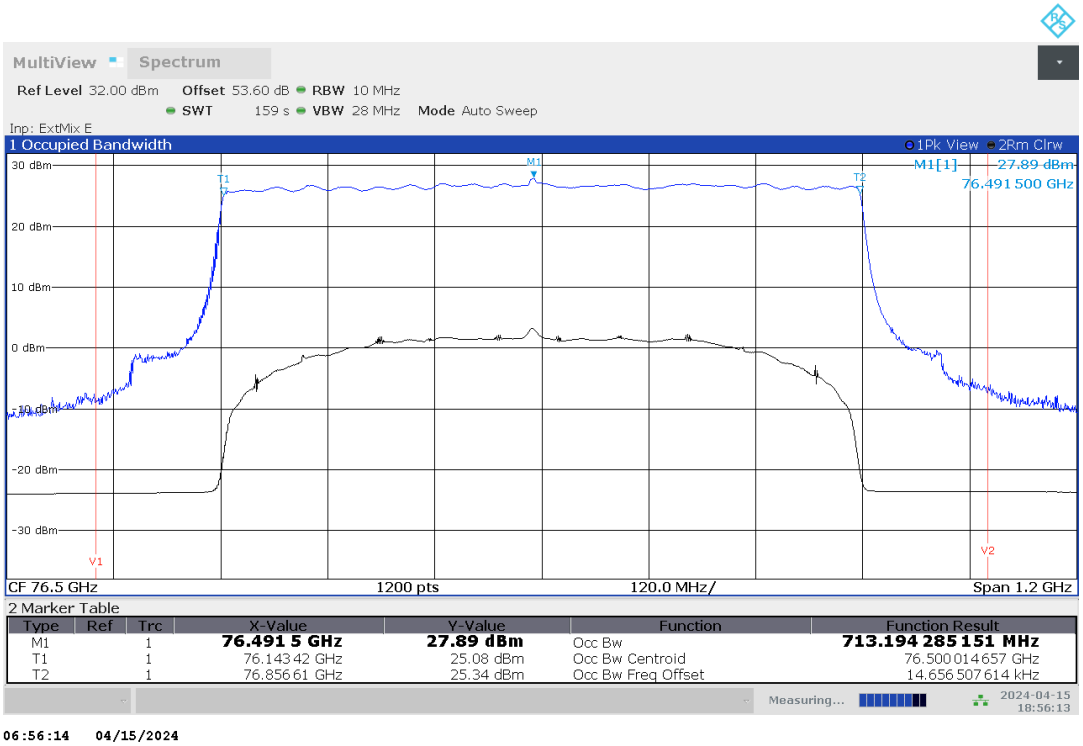
Test setup: 8.3, 8.4

Test results under normal and extreme test conditions:				
EUT mode	**Test conditions**	**f_L [GHz]**	**f_H [GHz]**	**99% OBW [MHz]**
1	85 °C / V_{nom}	76.144	76.856	712
1	60 °C / V_{nom}	76.143	76.857	713
1	50 °C / V_{nom}	76.143	76.857	714
1	40 °C / V_{nom}	76.143	76.857	713
1	30 °C / V_{nom}	76.144	76.856	712
1	20 °C / V_{nom}	76.145	76.857	712
1	20 °C / V_{min}	76.145	76.857	712
1	20 °C / V_{max}	76.144	76.857	713
1	10 °C / V_{nom}	76.145	76.856	711
1	0 °C / V_{nom}	76.145	76.857	712
1	-10 °C / V_{nom}	76.146	76.857	712
1	-20 °C / V_{nom}	76.146	76.857	710
1	-30 °C / V_{nom}	76.147	76.858	711
1	-40 °C / V_{nom}	76.147	76.858	711
2	85 °C / V_{nom}	76.144	76.856	713
2	60 °C / V_{nom}	76.143	76.857	714
2	50 °C / V_{nom}	76.144	76.856	712
2	40 °C / V_{nom}	76.144	76.857	713
2	30 °C / V_{nom}	76.144	76.856	712
2	20 °C / V_{nom}	76.145	76.856	711
2	20 °C / V_{min}	76.144	76.857	713
2	20 °C / V_{max}	76.145	76.856	712
2	10 °C / V_{nom}	76.145	76.856	712
2	0 °C / V_{nom}	76.145	76.857	711
2	-10 °C / V_{nom}	76.145	76.857	712
2	-20 °C / V_{nom}	76.146	76.857	711
2	-30 °C / V_{nom}	76.147	76.857	711
2	-40 °C / V_{nom}	76.146	76.858	711

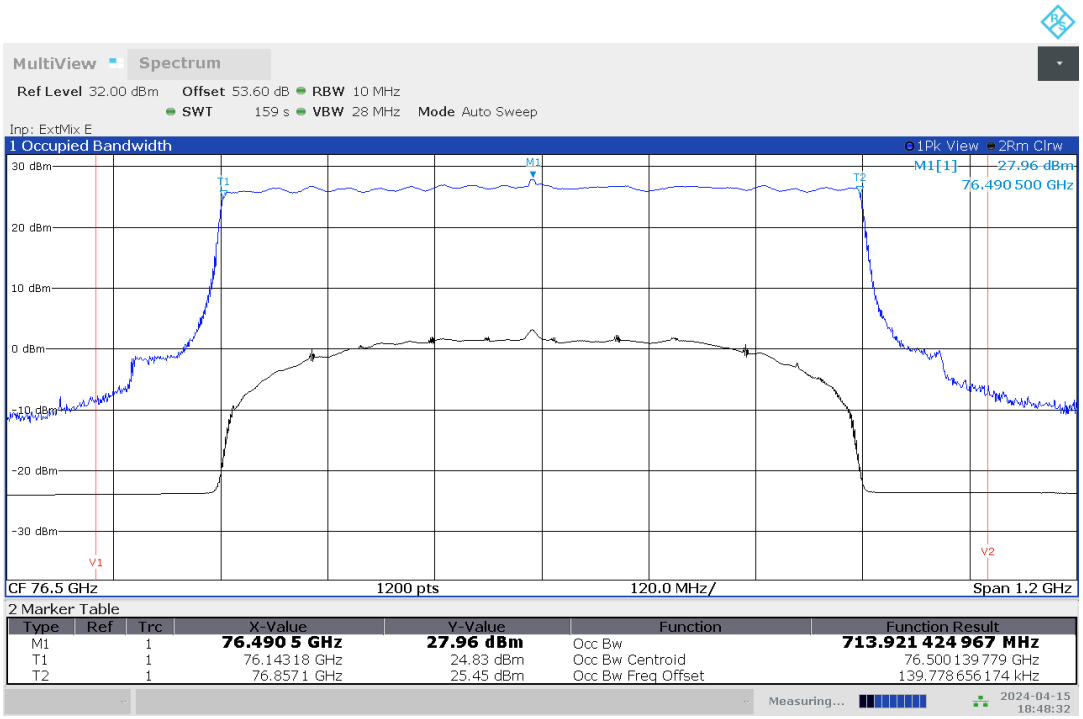
Plot no. 5: 99% OBW, Peak detector, 85 °C, Test mode 1



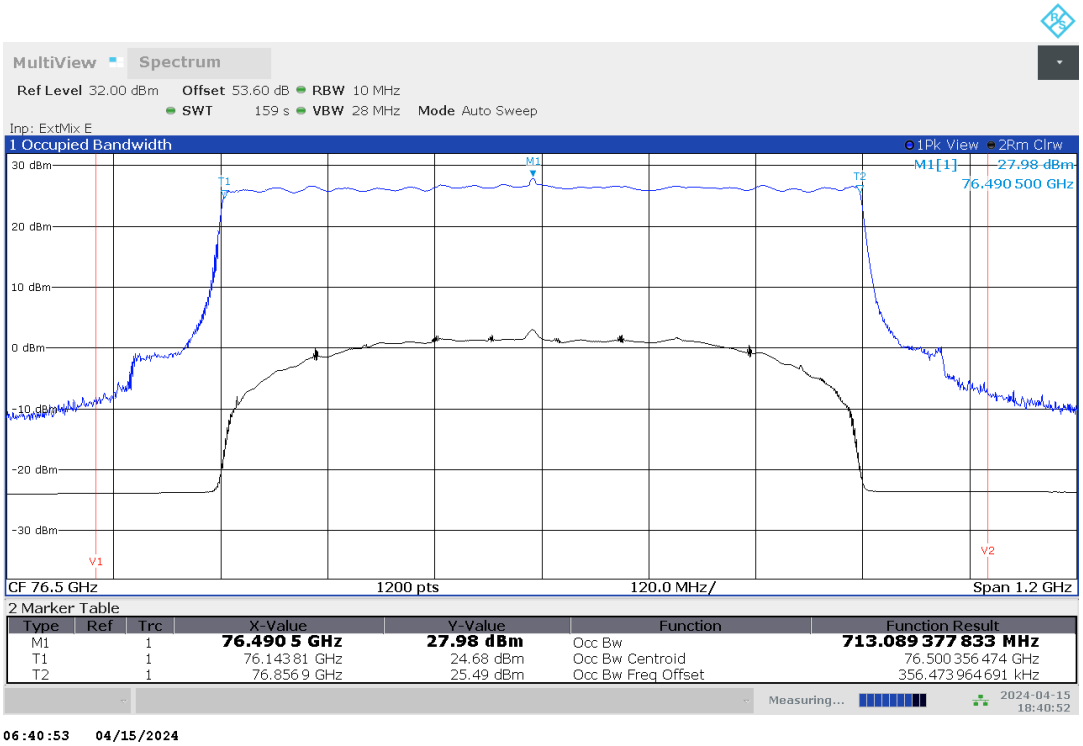
Plot no. 6: 99% OBW, Peak detector, 60 °C, Test mode 1



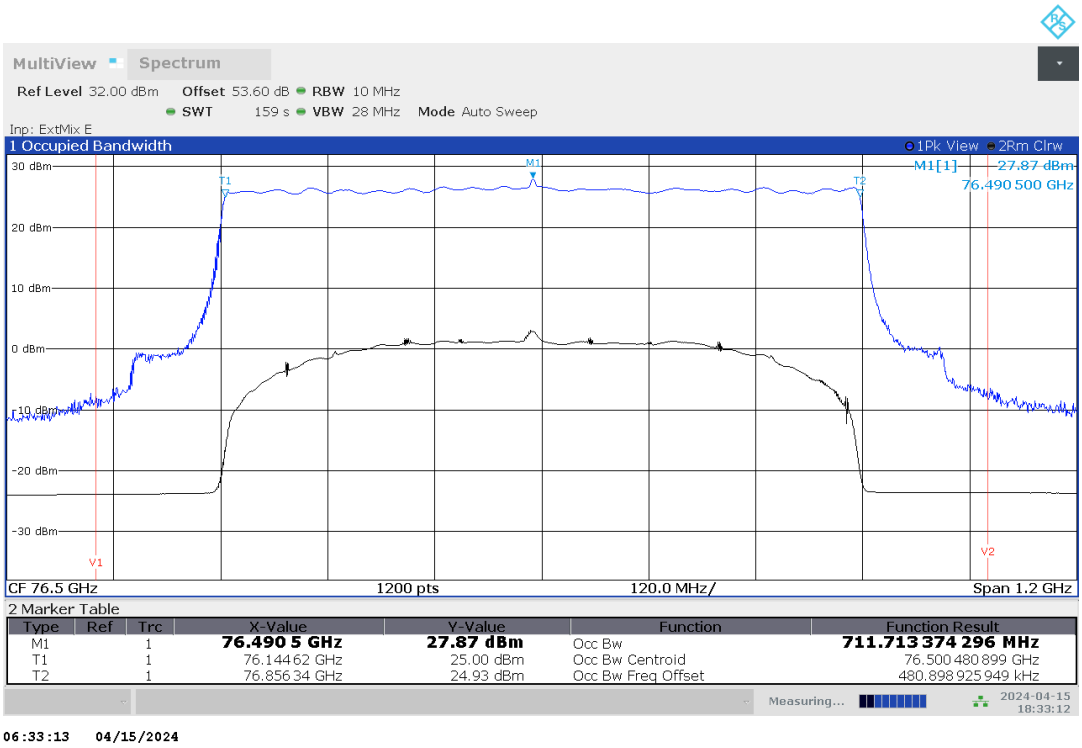
Plot no. 7: 99% OBW, Peak detector, 50 °C, Test mode 1



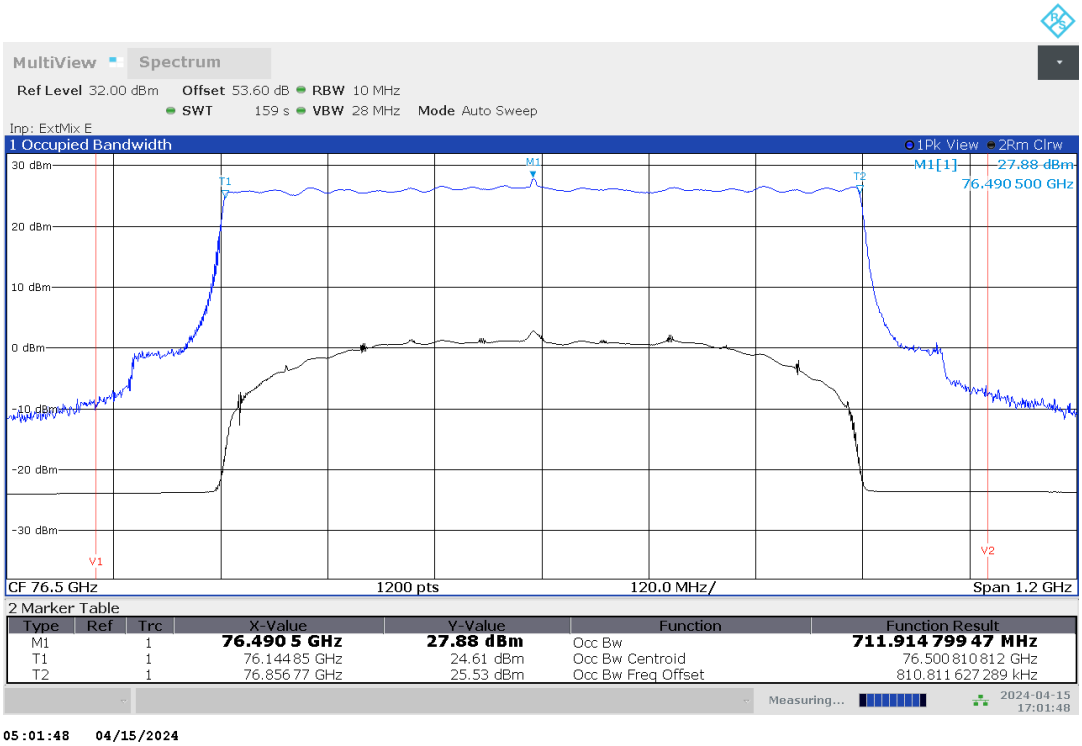
Plot no. 8: 99% OBW, Peak detector, 40 °C, Test mode 1



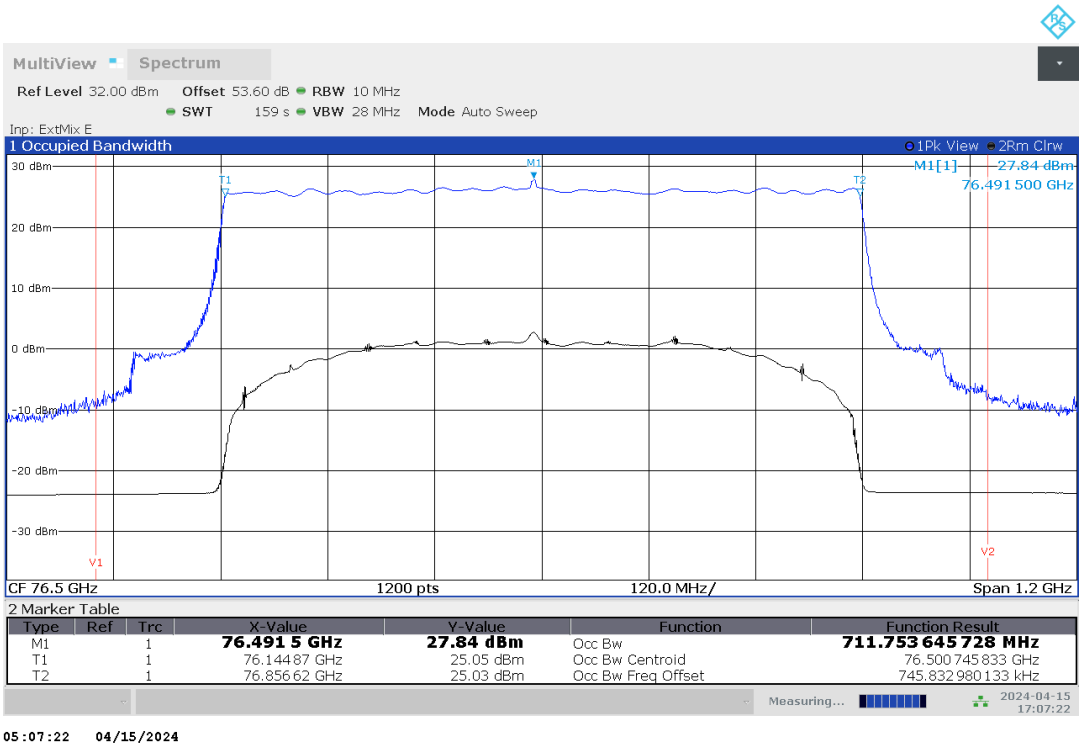
Plot no. 9: 99% OBW, Peak detector, 30 °C, Test mode 1



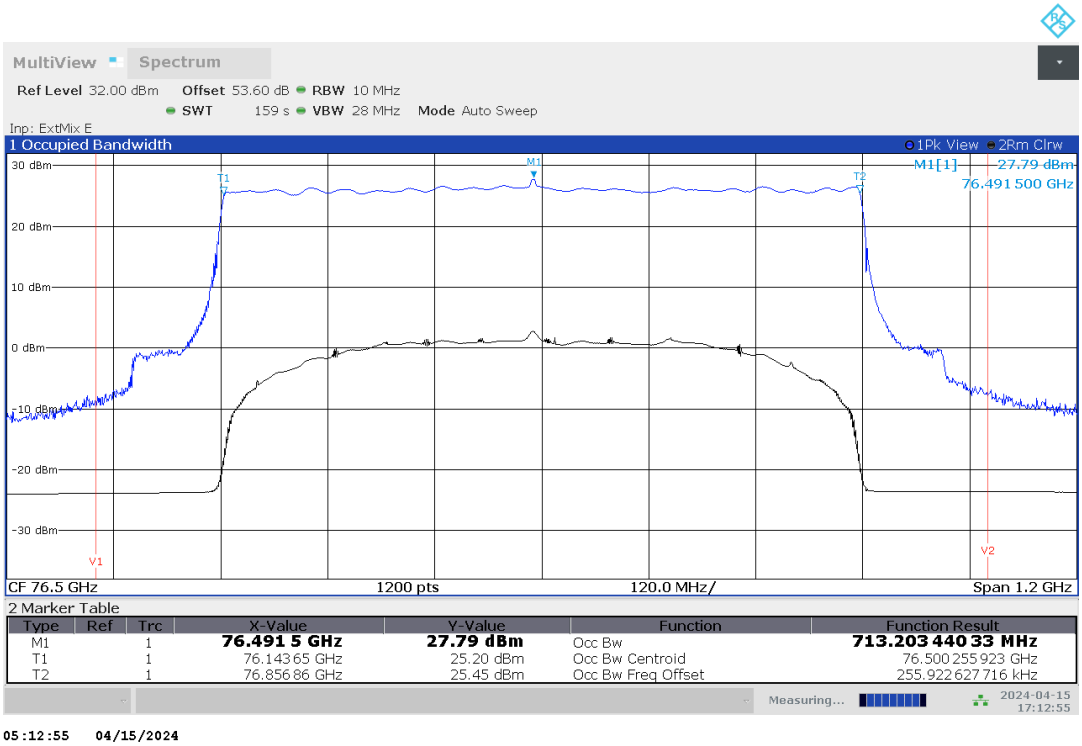
Plot no. 10: 99% OBW, Peak detector, 20 °C / V_{nom}, Test mode 1



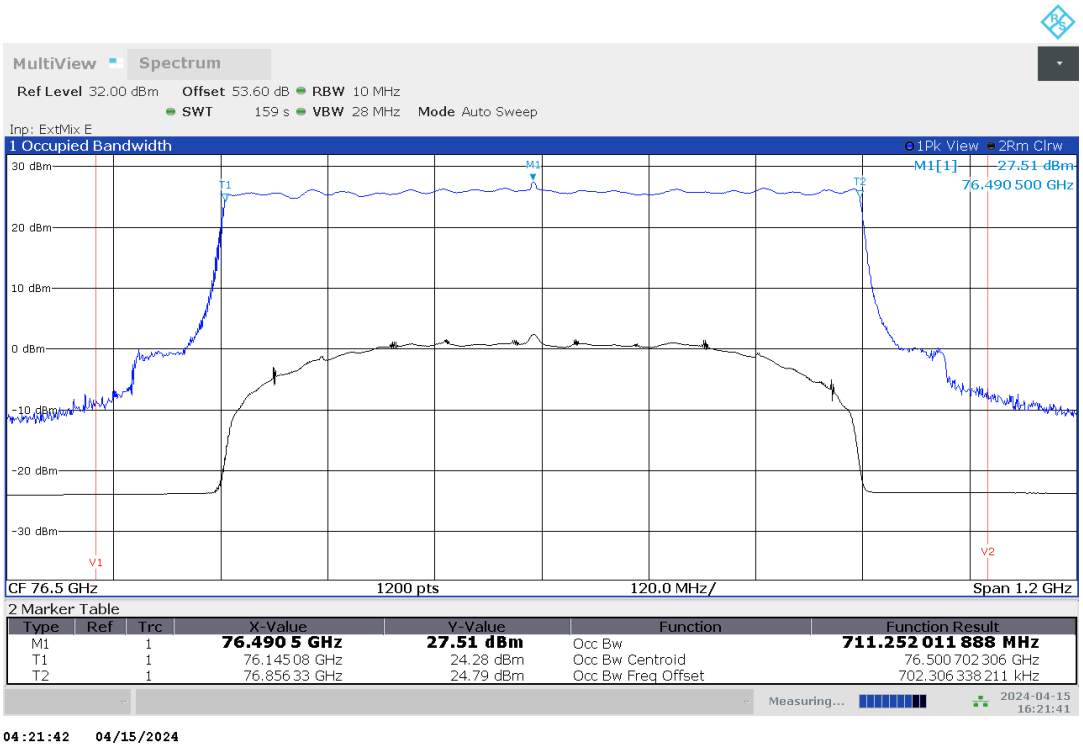
Plot no. 11: 99% OBW, Peak detector, 20 °C / V_{min}, Test mode 1



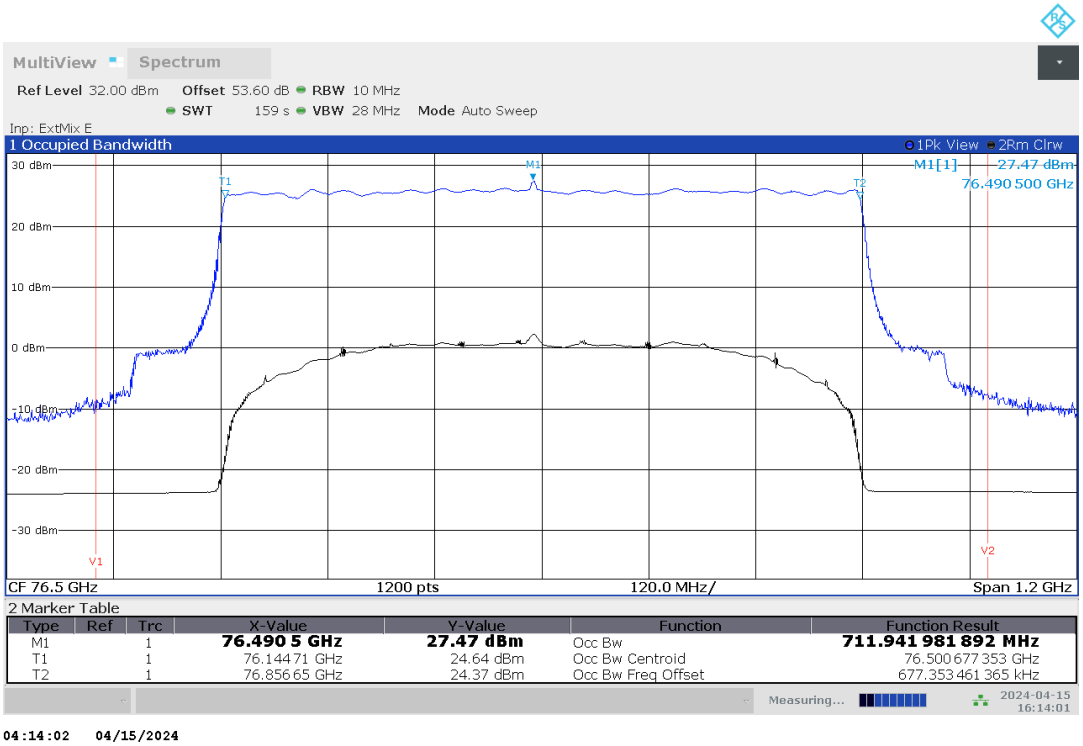
Plot no. 12: 99% OBW, Peak detector, 20 °C / V_{max}, Test mode 1



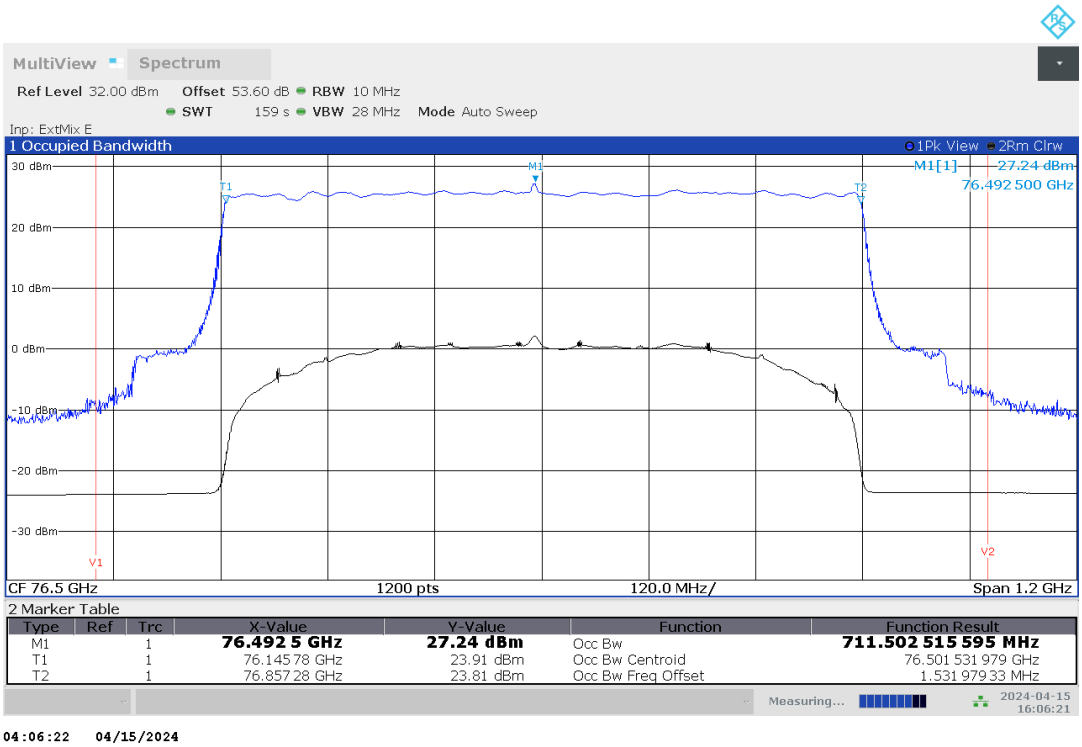
Plot no. 13: 99% OBW, Peak detector, 10 °C, Test mode 1



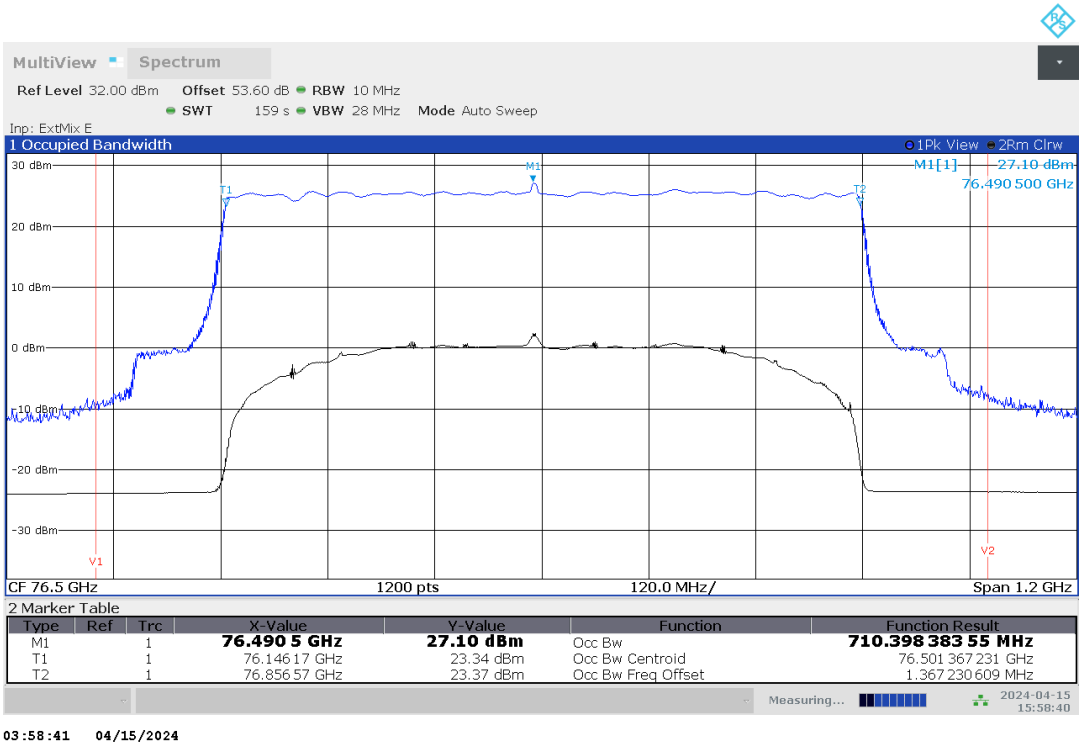
Plot no. 14: 99% OBW, Peak detector, 0 °C, Test mode 1



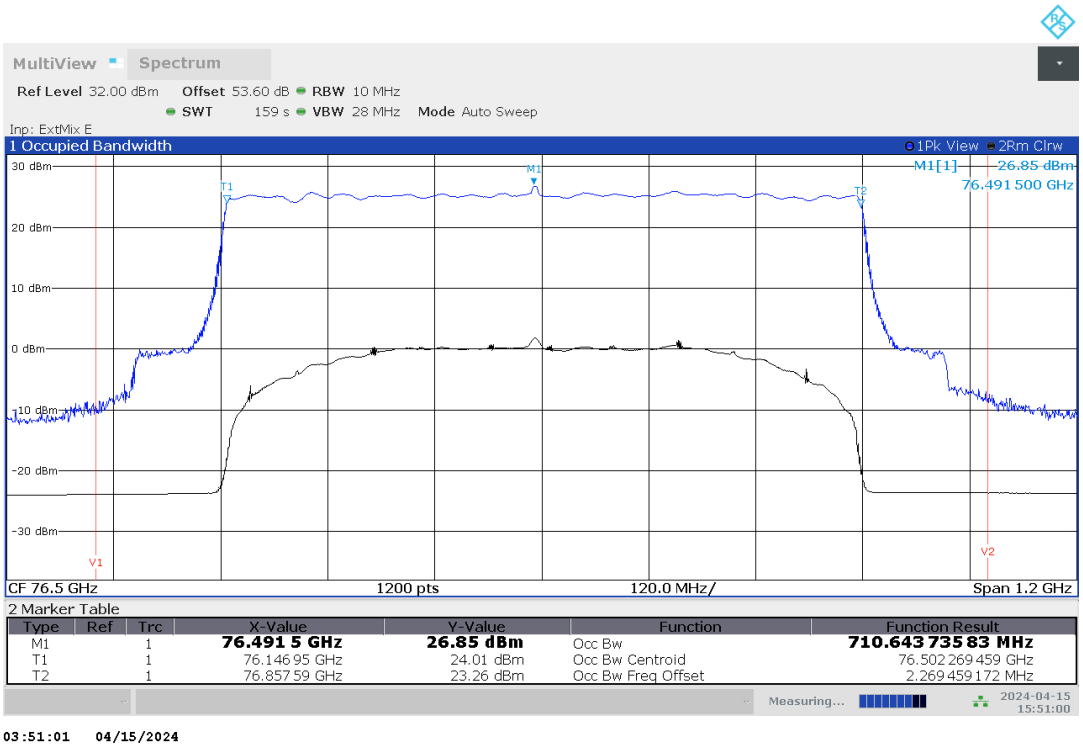
Plot no. 15: 99% OBW, Peak detector, -10 °C, Test mode 1



Plot no. 16: 99% OBW, Peak detector, -20 °C, Test mode 1

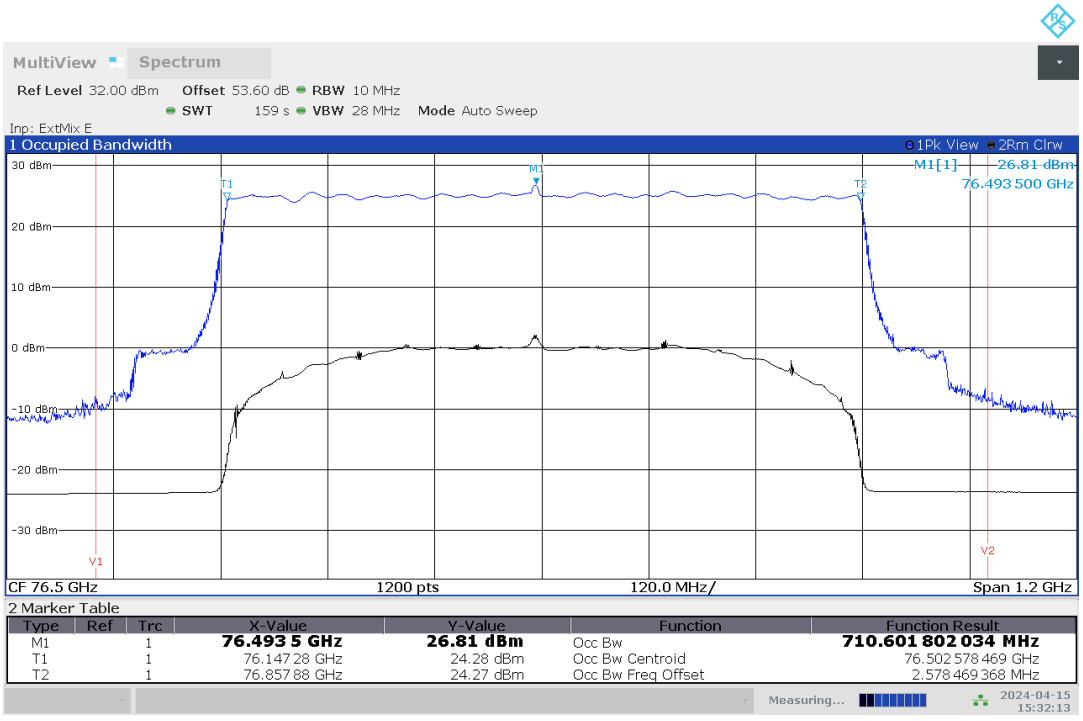


Plot no. 17: 99% OBW, Peak detector, -30 °C, Test mode 1



03:51:01 04/15/2024

Plot no. 18: 99% OBW, Peak detector, -40 °C, Test mode 1



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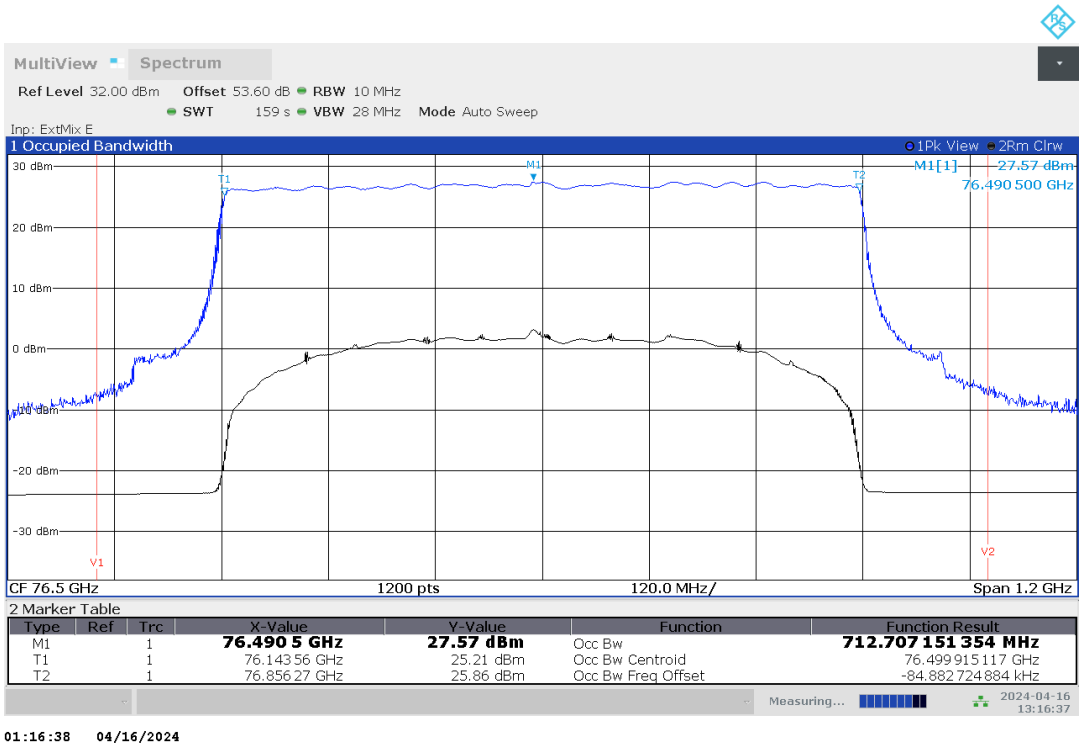
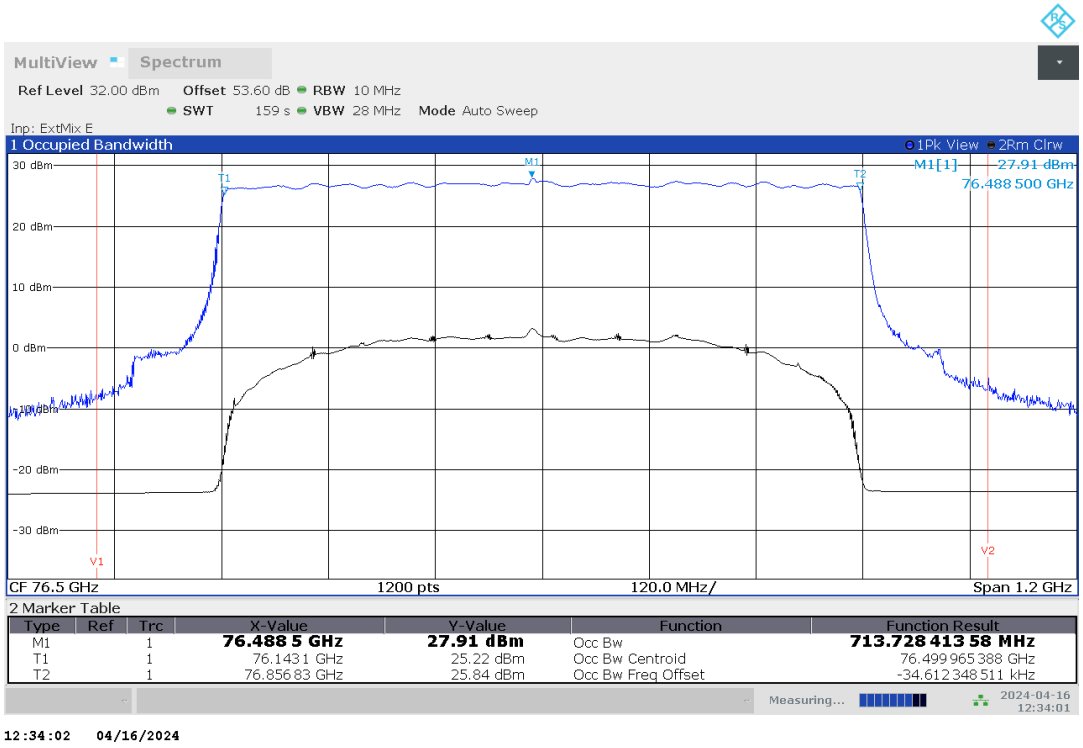
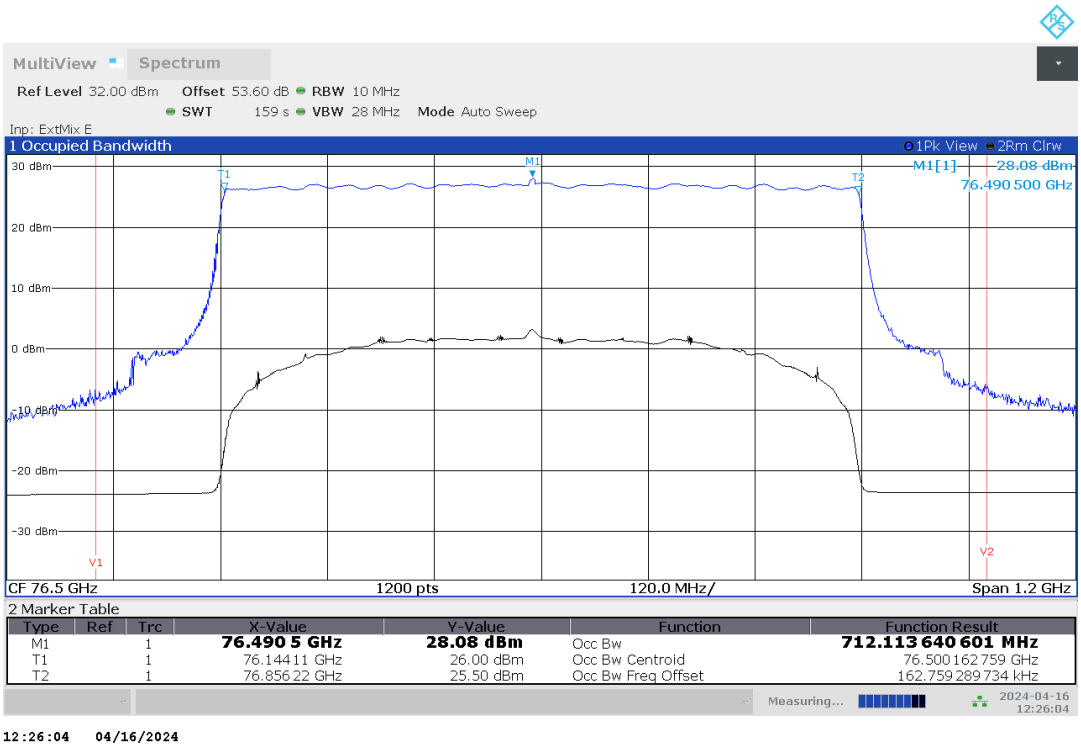
Plot no. 19: 99% OBW, Peak detector, 85 °C, Test mode 2



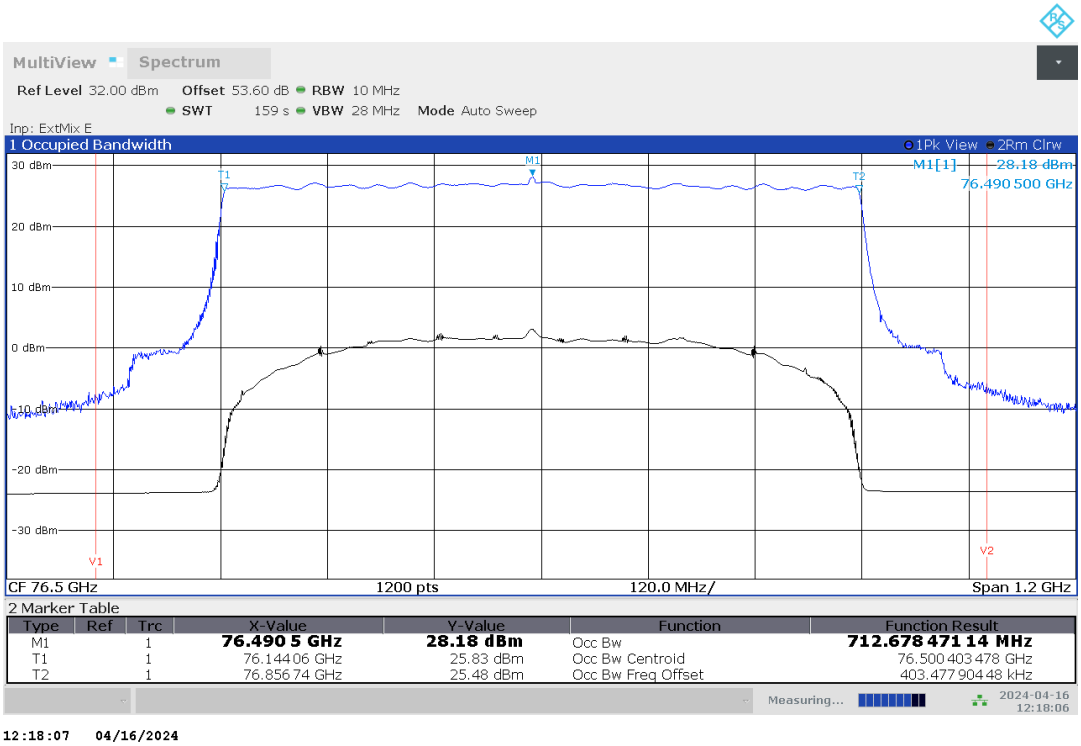
Plot no. 20: 99% OBW, Peak detector, 60 °C, Test mode 2



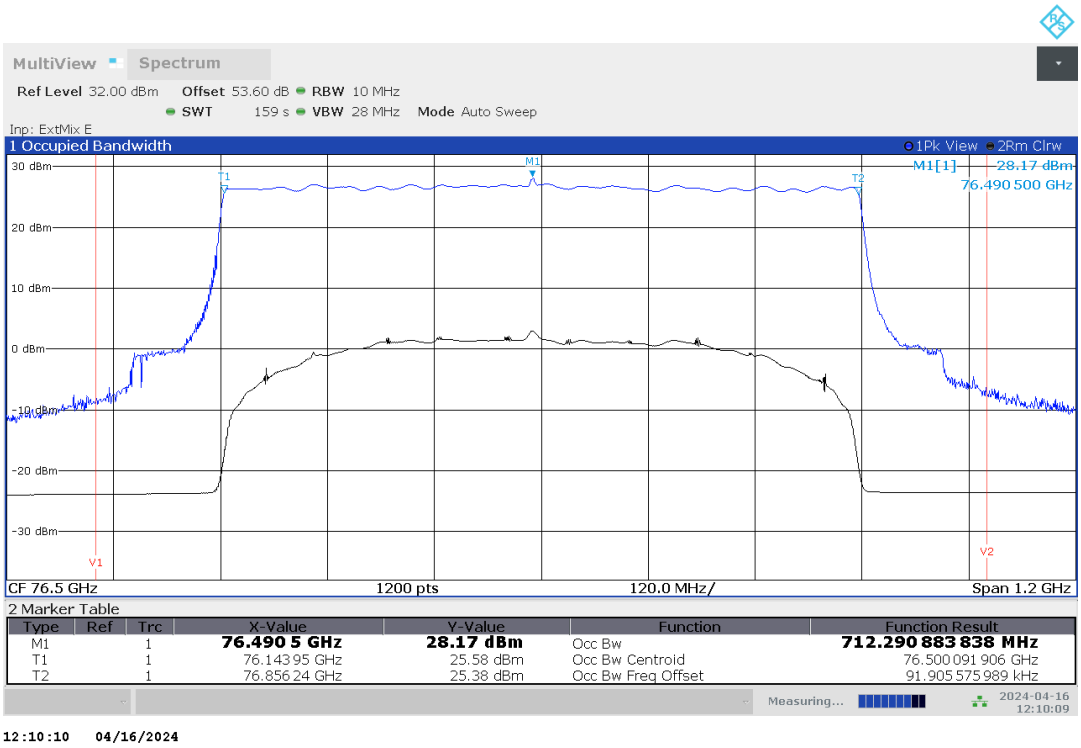
Plot no. 21: 99% OBW, Peak detector, 50 °C, Test mode 2



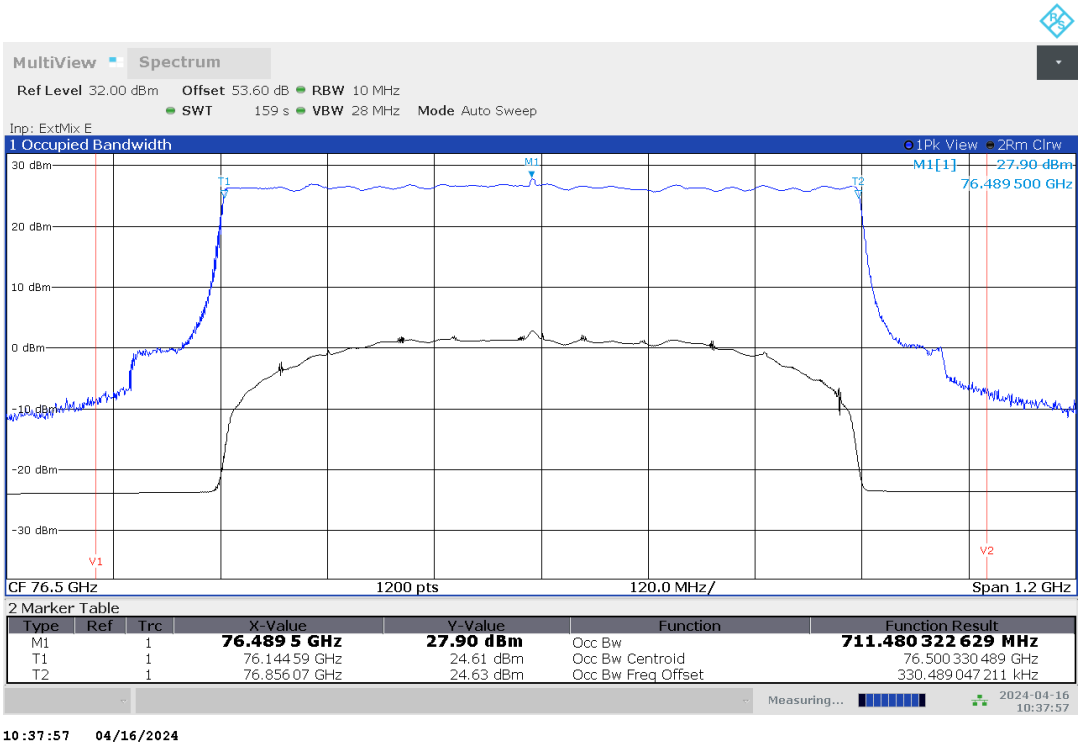
Plot no. 22: 99% OBW, Peak detector, 40 °C, Test mode 2



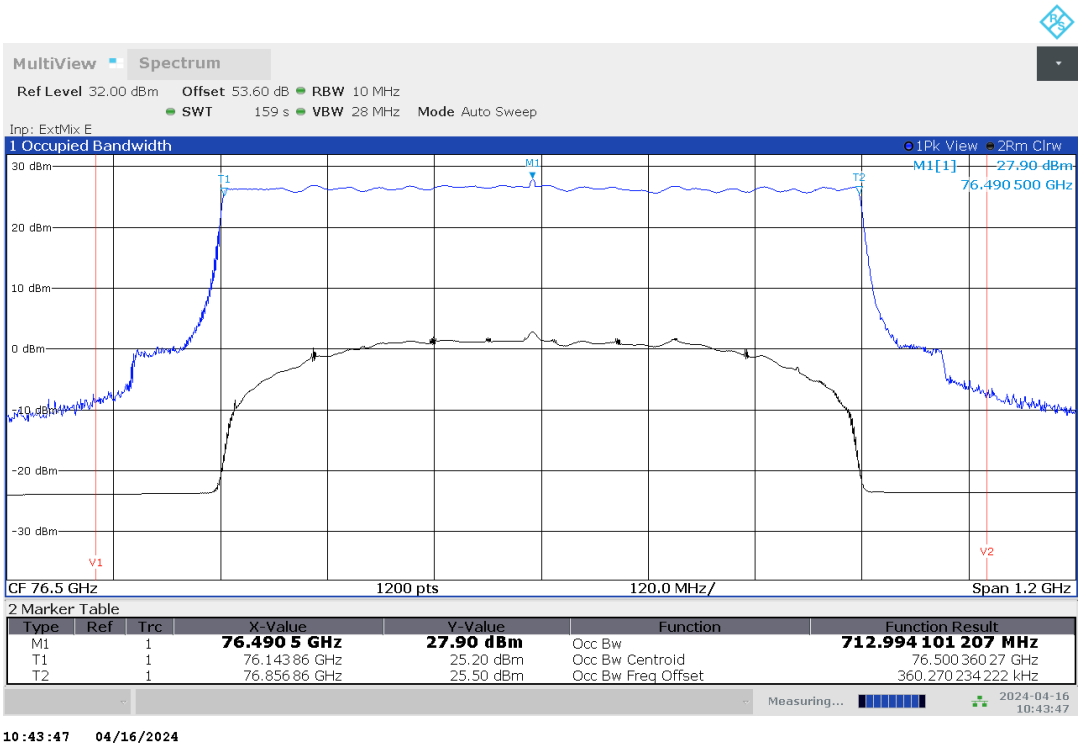
Plot no. 23: 99% OBW, Peak detector, 30 °C, Test mode 2



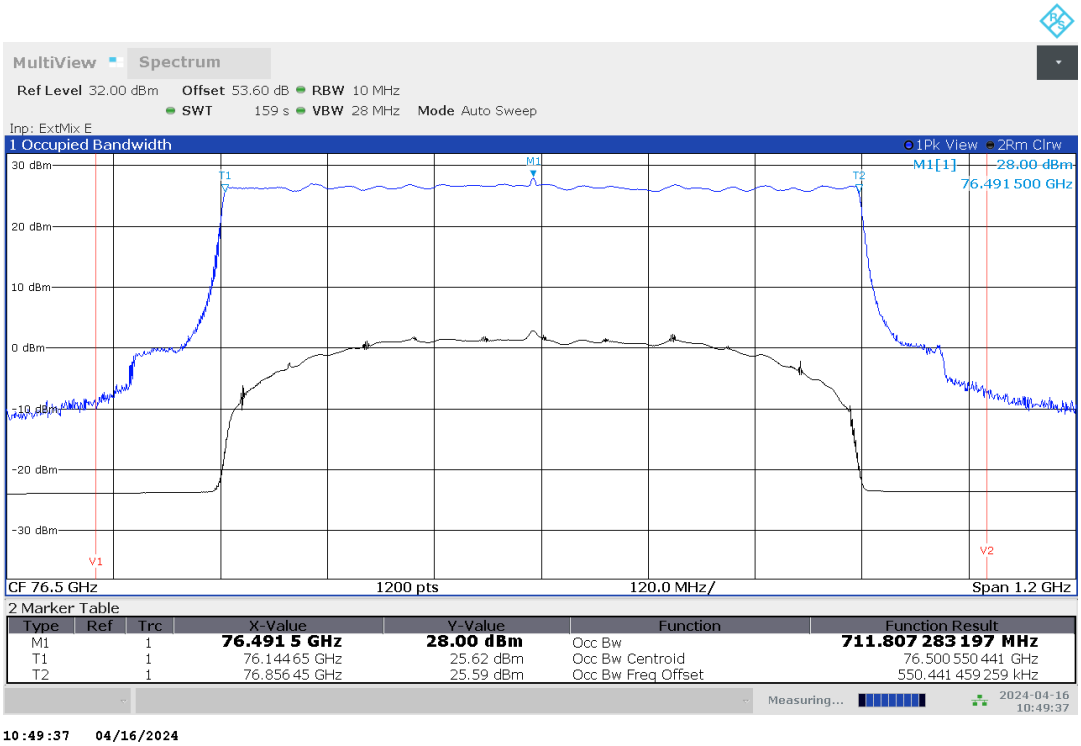
Plot no. 24: 99% OBW, Peak detector, 20 °C / V_{nom}, Test mode 2



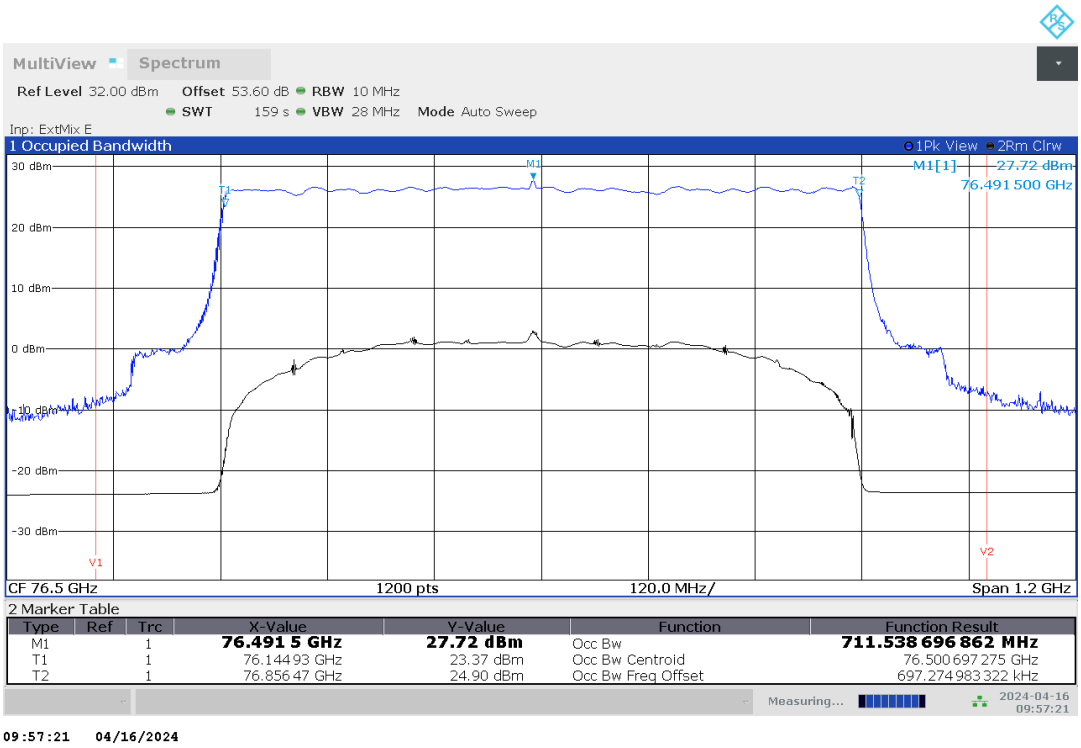
Plot no. 25: 99% OBW, Peak detector, 20 °C / V_{min}, Test mode 2



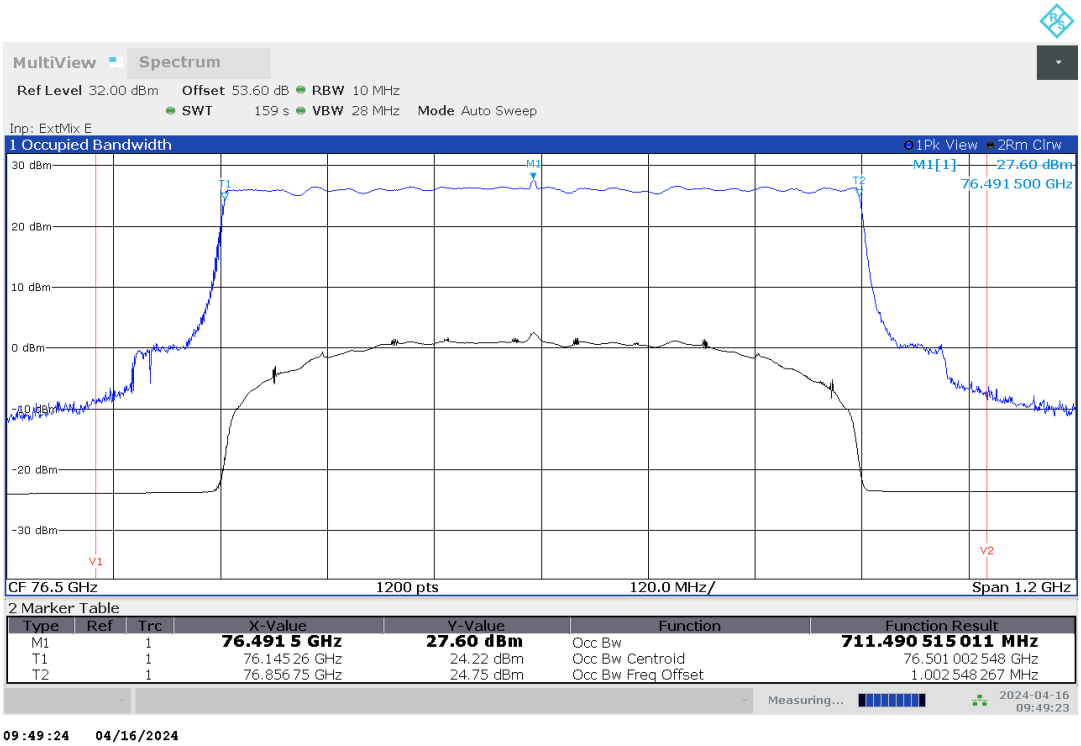
Plot no. 26: 99% OBW, Peak detector, 20 °C / V_{max}, Test mode 2



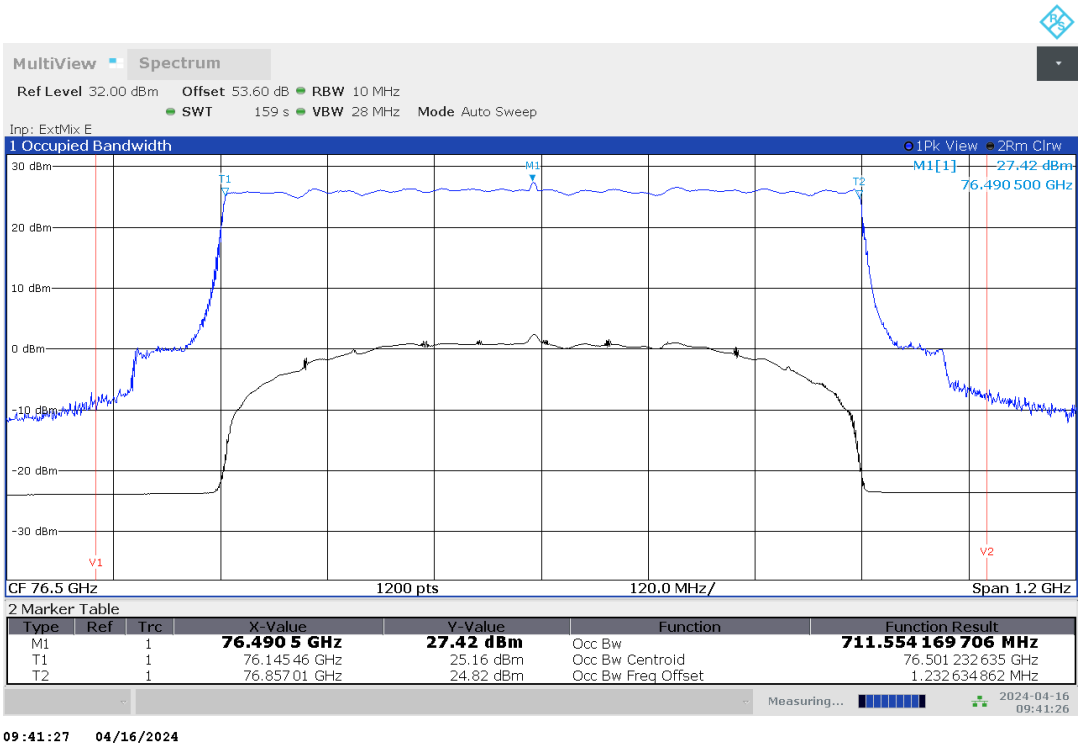
Plot no. 27: 99% OBW, Peak detector, 10 °C, Test mode 2



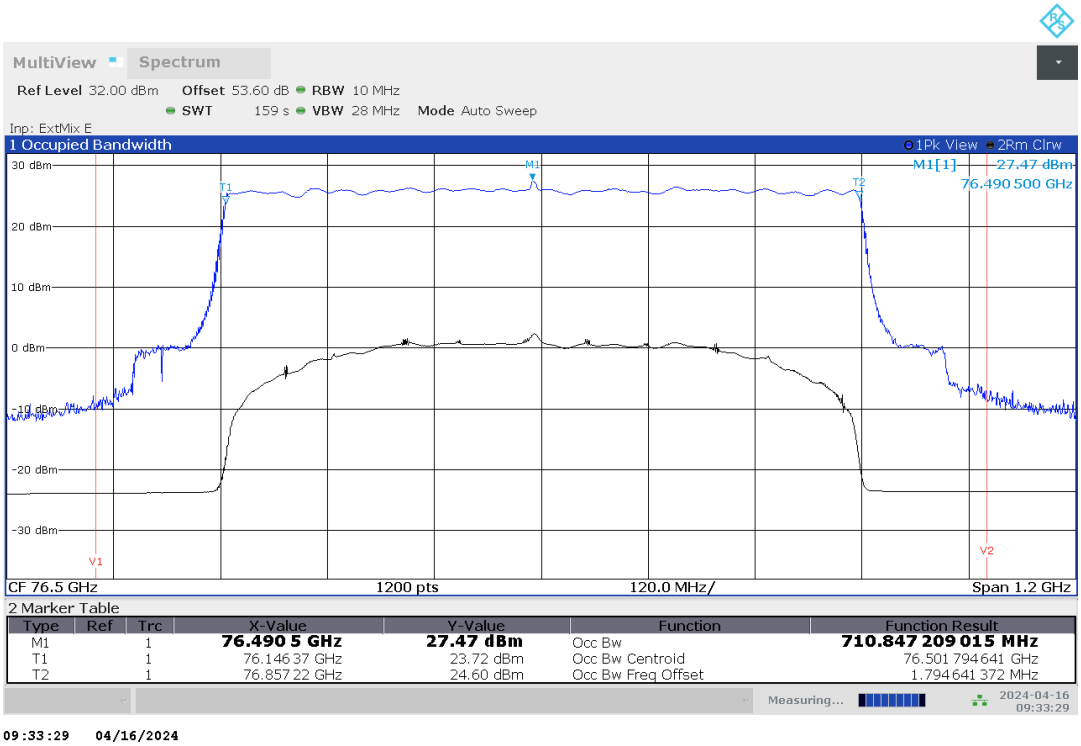
Plot no. 28: 99% OBW, Peak detector, 0 °C, Test mode 2



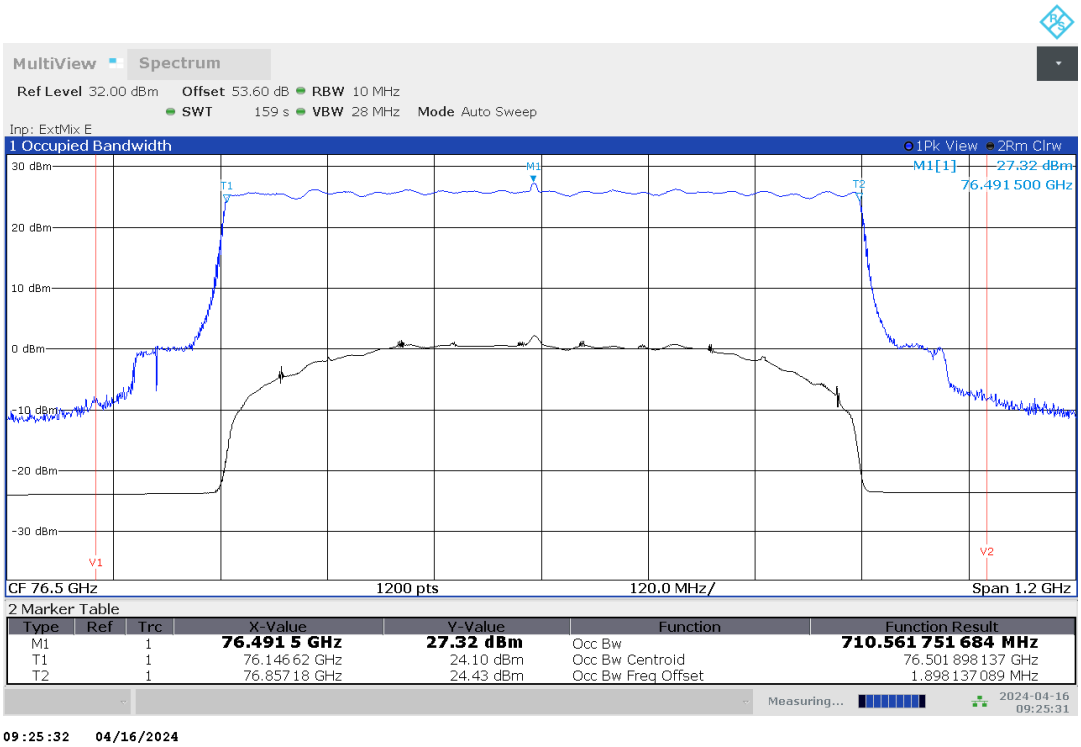
Plot no. 29: 99% OBW, Peak detector, -10 °C, Test mode 2



Plot no. 30: 99% OBW, Peak detector, -20 °C, Test mode 2



Plot no. 31: 99% OBW, Peak detector, -30 °C, Test mode 2



Plot no. 32: 99% OBW, Peak detector, -40 °C, Test mode 2