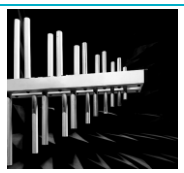
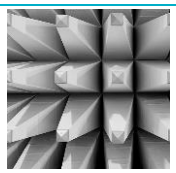

cetecom advanced

Bundesnetzagentur

BNetzA-CAB-02/21-102

TEST REPORT

Test report no.: 1-6402_23-01-02

DAkkS Deutsche Akkreditierungsstelle D-PL-12047-01-00

Testing laboratory

cetecom advanced GmbH
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66117 Saarbruecken / Germany
Phone: + 49 681 5 98 - 0
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Accredited Testing Laboratory:
The testing laboratory (area of testing) is accredited according to DIN EN ISO/IEC 17025 (2018-03) by the Deutsche Akkreditierungsstelle GmbH (DAkkS).
The accreditation is valid for the scope of testing procedures as stated in the accreditation certificate with the registration number: D-PL-12047-01-00.
ISED Testing Laboratory Recognized Listing Number: DE0001
FCC designation number: DE0002

Applicant

Cruise Munich GmbH
Caroline-Herschel-Str. 2
85521 Ottobrunn / GERMANY
Phone: +49 173 2112952
Contact: Sigmund Ott
e-mail: sigmund.ott@getcruise.com

Manufacturer

Cruise Munich GmbH
Caroline-Herschel-Str. 2
85521 Ottobrunn / GERMANY

Test standard/s

CFR 47 Part 95, Subpart M	The 76 – 81 GHz Band Radar Service
CFR 47 Part 2, Subpart J	Frequency allocations and radio treaty matters; general rules and regulations

For further applied test standards please refer to section 3 of this test report.

Test Item

Kind of test item:	**77-81 GHz Radar for Autonomous Driving Applications**
Model name:	**6458 HiRes IV**
FCC ID:	**2ASKB-64582000H0**
Frequency:	77.0 GHz – 81.0 GHz
Antenna:	Integrated patch antenna
Power supply:	9.0 V to 16.0 V DC by external power supply
Temperature range:	-20°C to +75°C

This test report is electronically signed and valid without handwritten signature. For verification of the electronic signatures, the public keys can be requested at the testing laboratory.

Test report authorized:

Thomas Vogler

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2024.03.28 14:21:18 +01'00'

Thomas Vogler
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Test performed:

M. Walla

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Meheza Walla
Lab Manager
Radio Labs

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2 General information

2.1 Notes and disclaimer

The test results of this test report relate exclusively to the test item specified in this test report. cetecom advanced GmbH does not assume responsibility for any conclusions and generalizations drawn from the test results with regard to other specimens or samples of the type of the equipment represented by the test item.
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In no case this test report can be considered as a Letter of Approval.

This test report is electronically signed and valid without handwritten signature. For verification of the electronic signatures, the public keys can be requested at the testing laboratory.

2.2 Application details

Date of receipt of order:	2023-11-13
Date of receipt of test item:	2023-12-04
Start of test:*	2023-12-04
End of test:*	2024-01-19
Person(s) present during the test:	-/-

*Date of each measurement, if not shown in the plot, can be requested. Dates are stored in the measurement software.

2.3 Test laboratories sub-contracted

None

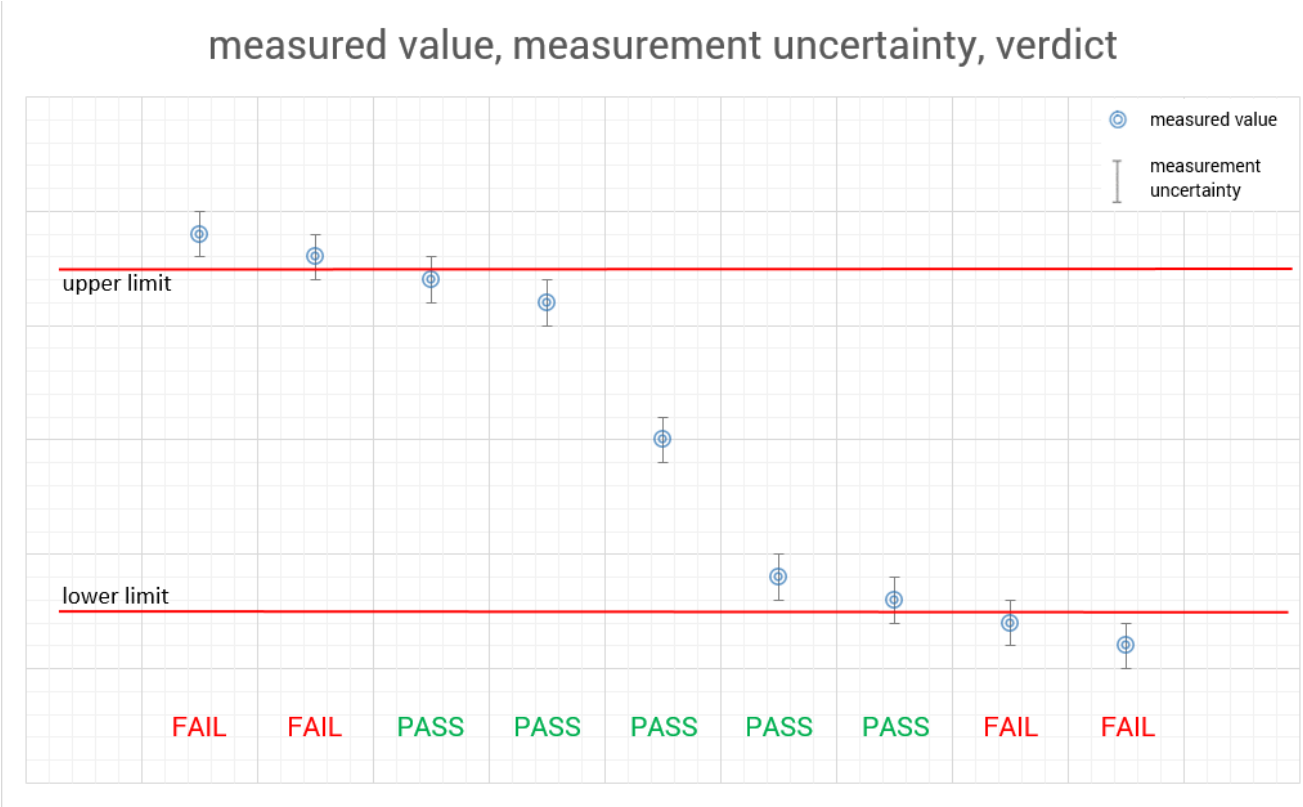
3 Test standard/s, references and accreditations

Test standard	Date	Description
CFR 47 Part 95, Subpart M	-/-	The 76 – 81 GHz Band Radar Service.
CFR 47 Part 2, Subpart J	-/-	Frequency allocations and radio treaty matters; general rules and regulations

Guidance	Version	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	v01r01 2019-04	Equipment Authorization Guidance for 76-81 GHz Radar Devices

4 Reporting statements of conformity – decision rule

Only the measured values related to their corresponding limits will be used to decide whether the equipment under test meets the requirements of the test standards listed in chapter 3.
The measurement uncertainty is mentioned in this test report, see chapter 9, but is not taken into account - neither to the limits nor to the measurement results. Measurement results with a smaller margin to the corresponding limits than the measurement uncertainty have a potential risk of more than 5% that the decision might be wrong."



5 Test environment

Temperature :	T_{nom} T_{max} T_{min}	+22 °C during room temperature tests +75 °C during high temperature tests -20 °C during low temperature tests
Relative humidity content :		55 %
Barometric pressure :		1021 hpa
Power supply :	V_{nom} V_{max} V_{min}	12.0 V DC by external power supply 16.0 V 9.0 V

6 Test item

6.1 General description

Kind of test item	:	77-81 GHz Radar for Autonomous Driving Applications
Model name	:	6458 HiRes IV
S/N serial number	:	112311558L000053 (EUT) 112311558L000050 (INTERFERER) 112311558L000054 (SPARE)
Hardware status	:	ST 6458 2000 L
Software status	:	-/-
Firmware status	:	17.1.0
Frequency band	:	77.0 GHz – 81.0 GHz
Type of modulation	:	FMCW
Antenna	:	Integrated patch antenna
Power supply	:	9.0 V to 16.0 V DC by external power supply
Temperature range	:	-20°C to +75°C

6.2 Additional information

The content of the following annexes is defined in the QA. It may be that not all of the listed annexes are necessary for this report, thus some values in between may be missing.

Test setup and EUT photos are included in test report: 1-6402/23-01-01_AnnexA
1-6402/23-01-01_AnnexB
1-6402/23-01-01_AnnexD

1-6402_23-01-02_MR1

Tests were performed on 3 modulations: City Mode 3, Highway Traffic Mode 3 and StandBy State.

The channel power, the positive peak power, the occupied bandwidth (OBW) and the spurious emissions were measured on all modulations at T_{nom} / V_{nom}.

Tests under extreme test conditions were done according to ANSI 63.10 as worst case mode for given tests:

Frequency Stability: City Mode 3.

7 Description of the test setup

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

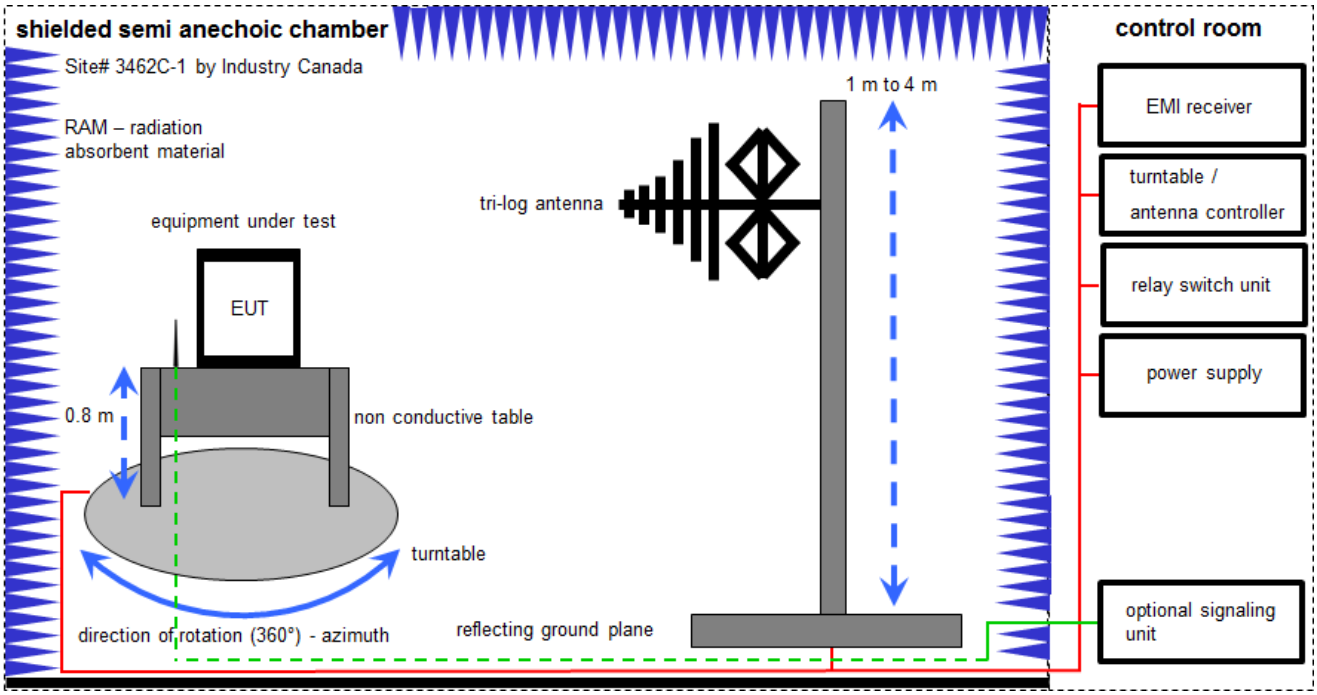
In order to simplify the identification of the equipment used at some special tests, some items of test equipment and ancillaries can be provided with an identifier or number in the equipment list below (Lab/Item).

Agenda: Kind of Calibration

k	calibration / calibrated		EK	limited calibration
ne	not required (k, ev, izw, zw not required)		zw	cyclical maintenance (external cyclical maintenance)
ev	periodic self verification		izw	internal cyclical maintenance
Ve	long-term stability recognized		g	blocked for accredited testing
vlkl!	Attention: extended calibration interval			
NK!	Attention: not calibrated		*)	next calibration ordered / currently in progress

7.1 Shielded semi anechoic chamber

The radiated measurements are performed in vertical and horizontal plane in the frequency range from 30 MHz to 1 GHz in semi-anechoic chambers. The EUT is positioned on a non-conductive support with a height of 0.80 m above a conductive ground plane that covers the whole chamber. The receiving antennas are conform to specifications ANSI C63. These antennas can be moved over the height range between 1.0 m and 4.0 m in order to search for maximum field strength emitted from 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 spectrum analyzers where the detector modes and resolution bandwidths over various frequency ranges are set according to requirement ANSI C63.



Measurement distance: tri-log antenna 10 meter

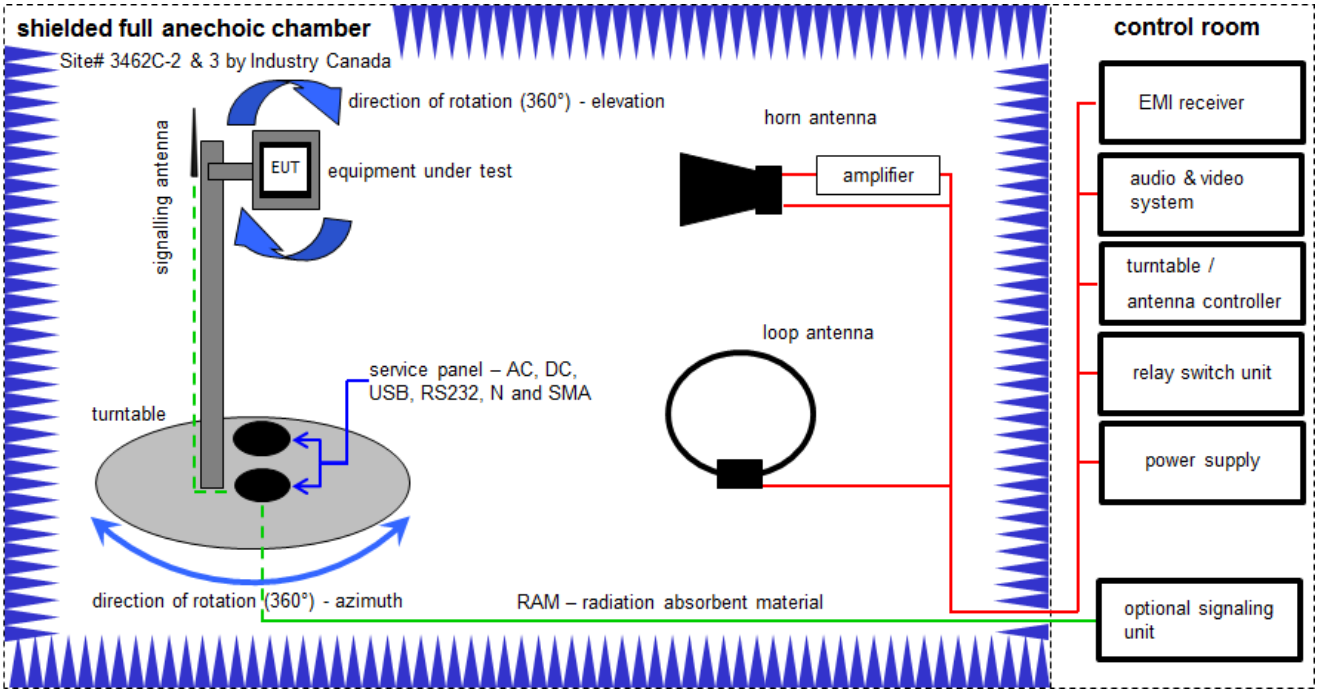
FS = UR + CL + AF
(FS-field strength; UR-voltage at the receiver; CL-loss of the cable; AF-antenna factor)

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

Equipment table:

No.	Lab / Item	Equipment	Type	Manufacturer	Serial No.	INV. No.	Kind of Calibration	Last Calibration	Next Calibration
1	n. a.	Switch-Unit	3488A	HP	2719A14505	300000368	ev	-/-	-/-
2	n. a.	DC power supply, 60Vdc, 50A, 1200 W	6032A	HP	2920A04466	300000580	ne	-/-	-/-
3	n. a.	Meßkabine 1	HF-Absorberhalle	MWB AG 300023		300000551	ne	-/-	-/-
4	n. a.	Antenna Tower	Model 2175	ETS-Lindgren	64762	300003745	izw	-/-	-/-
5	n. a.	Positioning Controller	Model 2090	ETS-Lindgren	64672	300003746	izw	-/-	-/-
6	n. a.	Turntable Interface-Box	Model 105637	ETS-Lindgren	44583	300003747	izw	-/-	-/-
7	n. a.	TRILOG Broadband Test-Antenna 30 MHz - 3 GHz	VULB9163	Schwarzbeck Mess - Elektronik	216	300003288	vlKl!	31.08.2023	31.08.2025
8	n. a.	Switch-Unit	3488A	HP	2719A14505	300000368	ev	-/-	-/-
9	n. a.	EMI Test Receiver	ESR3	Rohde & Schwarz	102587	300005771	k	06.12.2023	31.12.2024

7.1 Shielded fully anechoic chamber



Measurement distance: horn antenna 3 meter; loop antenna 3 meter / 1 meter

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

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

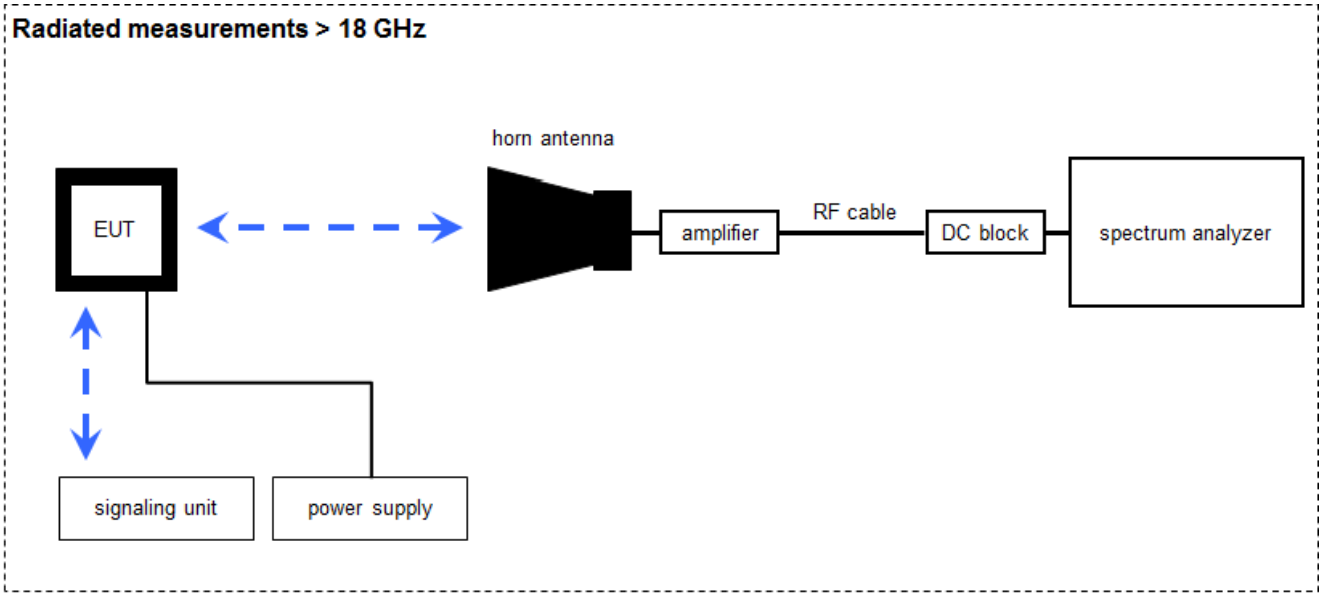
OP = AV + D - G + CA
(OP-radiated output power; AV-analyzer value; D-free field attenuation of measurement distance; G-antenna gain+amplifier gain; CA-loss signal path)

Example calculation:
OP [dBm] = -39.0 [dBm] + 57.0 [dB] - 12.0 [dBi] + (-36.0) [dB] = -30 [dBm] (1 µW)

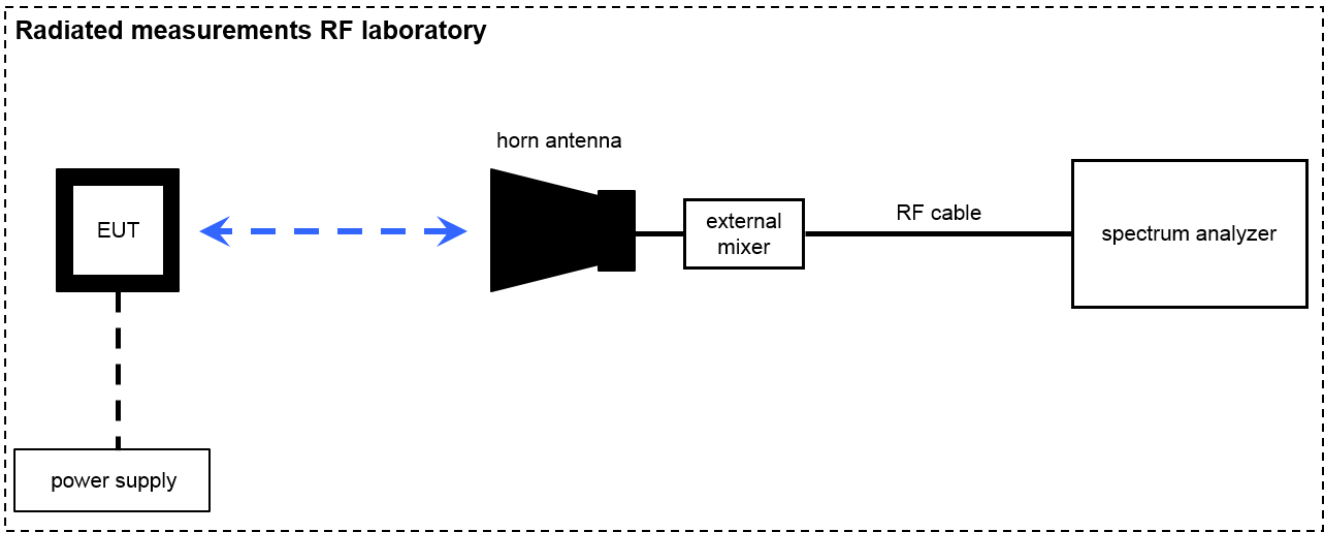
Equipment table:

No.	Equipment	Type	Manufacturer	Serial No.	INV. No.	Kind of Calibration	Last Calibration	Next Calibration
1	Double-Ridged Waveguide Horn Antenna 1-18.0GHz	3115	EMCO	9107-3696	300001604	vlKl!	20.03.2023	19.03.2025
2	Highpass Filter	WHK1.1/15G-10SS	Wainwright	37	400000148	ne	-/-	-/-
3	Highpass Filter	WHKX7.0/18G-8SS	Wainwright	18	300003789	ne	-/-	-/-
4	Band Reject Filter	WRCG2400/2483-2375/2505-50/10SS	Wainwright	26	300003792	ne	-/-	-/-
5	TRILOG Broadband Test-Antenna 30 MHz - 3 GHz	VULB9163	Schwarzbeck Mess - Elektronik	295	300003787	vlKl!	23.05.2023	31.05.2025
6	Broadband Amplifier 0.5-18 GHz	CBLU5184540	CERNEX	22051	300004483	ev	-/-	-/-
7	4U RF Switch Platform	L4491A	Agilent Technologies	MY50000032	300004510	ne	-/-	-/-
8	NEXIO EMV-Software	BAT EMC V2022.0.22.0	Nexio	-/-	300004682	ne	-/-	-/-
9	Anechoic chamber	-/-	TDK	-/-	300003726	ne	-/-	-/-
10	EMI Test Receiver 9kHz-26,5GHz	ESR26	Rohde & Schwarz	101376	300005063	k	15.01.2024	14.01.2025

7.2 Radiated measurements > 18 GHz



7.3 Radiated measurements > 50/85 GHz



Measurement distance: horn antenna e.g. 75 cm
FS = UR + CA + AF
(FS-field strength; UR-voltage at the receiver; CA-loss signal path & distance correction; AF-antenna factor)

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

OP = AV + D - G + CA
(OP-radiated output power; AV-analyzer value; D-free field attenuation of measurement distance;
G-antenna gain+amplifier gain; CA-loss signal path)

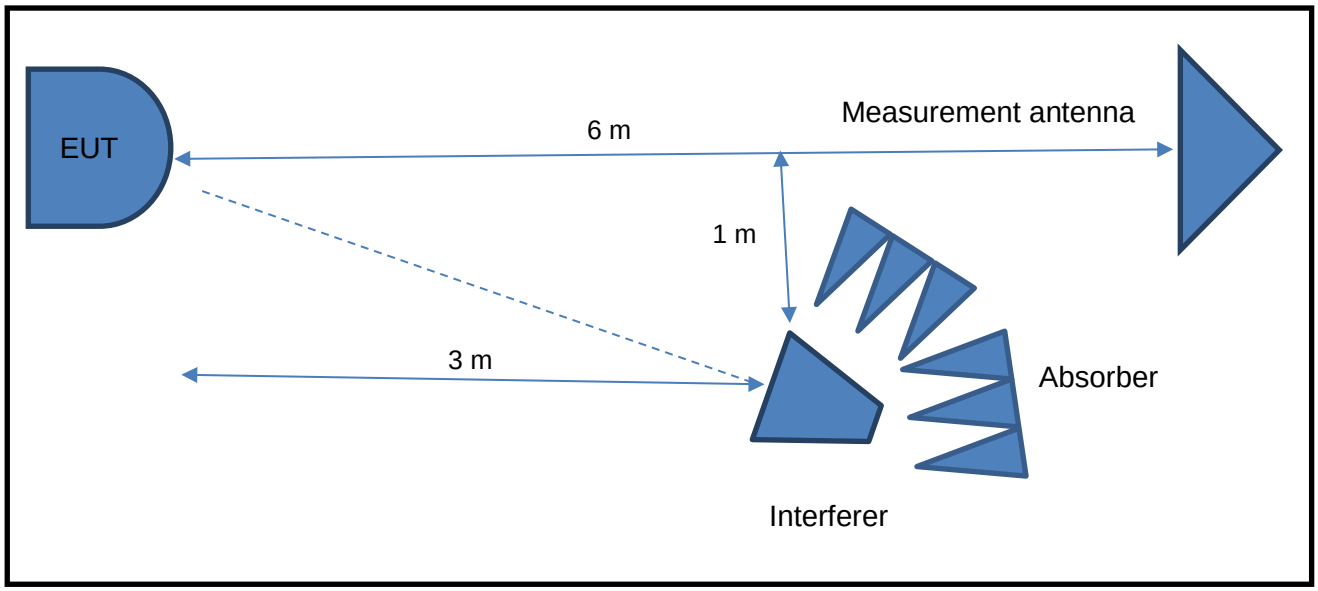
Example calculation:
OP [dBm] = -59.0 [dBm] + 44.0 [dB] - 20.0 [dBi] + 5.0 [dB] = -30 [dBm] (1 µW)

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

Equipment table:

No.	Lab / Item	Equipment	Type	Manufacturer	Serial No.	INV. No.	Kind of Calibration	Last Calibration	Next Calibration
1	n.a.	Horn Antenna 18,0-40,0 GHz	LHAF180	Microw.Devel	39180-103-021	300001747	vIKI!	17.01.2022	31.01.2024
2	n. a.	Std. Gain Horn Antenna 18.0-26.5 GHz	638	Narda		300000486	vIKI!	17.01.2022	31.01.2024
3	n. a.	Std. Gain Horn Antenna 26.5-40.0 GHz	V637	Narda	82-16	300000510	vIKI!	17.01.2022	31.01.2024
4	n.a.	Std. Gain Horn Antenna 40-60 GHz	2424-20	Flann	76	400001981	ne	-/-	-/-
5	n. a.	Std. Gain Horn Antenna 49.9-75.8 GHz	2524-20	Flann	*	300001983	ne	-/-	-/-
6	n. a.	Std. Gain Horn Antenna 60-90 GHz	COR 60_90	Thomson CSF		300000814	ev	-/-	-/-
7	n. a.	Std. Gain Horn Antenna 73.8-112 GHz	2724-20	Flann	*	300001988	ne	-/-	-/-
8	n.a.	Std. Gain Horn Antenna 92.3-140 GHz	2824-20	Flann		300001993	ne	-/-	-/-
9	n. a.	Std. Gain Horn Antenna 114-173 GHz	2924-20	Flann	*	300001999	ne	-/-	-/-
10	n. a.	Std. Gain Horn Antenna 145-220 GHz	3024-20	Flann	*	300002000	ne	-/-	-/-
11	n. a.	Std. Gain Horn Antenna 217-330 GHz	32240-20	Flann	233278	300004960	ne	-/-	-/-
12	n. a.	Broadband LNA 18-50 GHz	CBL18503070PN	CERNEX	25240	300004948	ev	09.03.2022	08.03.2024
13	n. a.	Harmonic Mixer 3-Port, 50-75 GHz	FS-Z75	Rohde & Schwarz	101578	300005788	k	19.07.2023	31.07.2024
14	n. a.	Harmonic Mixer 3-Port, 60-90 GHz	FS-Z90	R&S	101555	300004691	k	25.08.2023	31.08.2024
15	n. a.	Harmonic Mixer 3-Port, 75-110 GHz	FS-Z110	R&S	101411	300004959	k	21.07.2023	31.07.2024
16	n.a.	Harmonic Mixer 3-port, 90-140 GHz	FS-Z140	Rohde & Schwarz	101119	300005581	k	03.08.2023	31.08.2024
17	n. a.	Harmonic Mixer 3-Port, 110-170 GHz	FS-Z170	Radiometer Physics GmbH	100014	300004156	k	21.07.2023	31.07.2024
18	n. a.	Harmonic Mixer 3-Port, 140-220 GHz	SAM-220	Radiometer Physics GmbH	200001	300004157	k	02.08.2023	31.08.2024
19	n. a.	Harmonic Mixer 3-Port, 220-325 GHz	SAM-325	Radiometer Physics GmbH	100002	300004158	k	02.08.2023	31.08.2024
20	n. a.	Spectrum Analyzer 2 Hz - 50 GHz	FSW50	R&S	101332	300005935	k	23.03.2023	31.03.2024
20	n. a.	Spectrum Analyzer 2 Hz - 85 GHz	FSW85	R&S	101333	300005568	k	02.08.2023	31.08.2024
21	n.a.	Power Supply	E3632A	Agilent Technologies	MY40001320	400000396	ev	14.12.2021	31.12.2024
22	n. a.	Temperature Test Chamber	T-40/50	CTS GmbH	064023	300003540	ev	09.05.2022	31.05.2024
23	n.a.	Power Supply	1108-32	Heiden Elektonik	003202	300001187	vIKI!	14.12.2021	31.12.2024

7.4 Occupied bandwidth interferer



Note: The general measurement set-up is identical to section 7.3

No.	Lab / Item	Equipment	Type	Manufacturer	Serial No.	INV. No.	Kind of Calibration	Last Calibration	Next Calibration
1	n. a.	Std. Gain Horn Antenna 60-90 GHz	COR 60_90	Thomson CSF		300000814	ev	-/-	-/-
2	n. a.	Harmonic Mixer 3-Port, 60-90 GHz	FS-Z90	R&S	101555	300004691	k	25.08.2023	31.08.2024
3	n. a.	Spectrum Analyzer 2 Hz - 85 GHz	FSW85	R&S	101333	300005568	k	02.08.2023	31.08.2024
4	n.a.	Power Supply	E3632A	Agilent Technologies	MY40001320	400000396	ev	-/-	-/-

8 Sequence of testing

8.1 Sequence of testing radiated spurious 9 kHz to 30 MHz

Setup

- The equipment is set up to simulate normal operation mode as described in the user manual or defined by the manufacturer.
- If the EUT is a tabletop system, it is placed on a table with 0.8 m height.
- If the EUT is a floor standing device, it is placed directly on the turn table.
- Auxiliary equipment and cables are positioned to simulate normal operation conditions as described in ANSI C 63.4.
- The AC power port of the EUT (if available) is connected to a power outlet below the turntable.
- Measurement distance is 3 m (see ANSI C 63.4) – see test details.
- EUT is set into operation.

Premeasurement*

- The turntable rotates from 0° to 315° using 45° steps.
- The antenna height is 1 m.
- At each turntable position the analyzer sweeps with positive-peak detector to find the maximum of all emissions.

Final measurement

- Identified emissions during the pre-measurement are maximized by the software by rotating the turntable from 0° to 360°.
- Loop antenna is rotated about its vertical axis for maximum response at each azimuth about the EUT. (For certain applications, the loop antenna plane may also need to be positioned horizontally at the specified distance from the EUT)
- The final measurement is done in the position (turntable and elevation) causing the highest emissions with quasi-peak (as described in ANSI C 63.4).
- Final levels, frequency, measuring time, bandwidth, turntable position, correction factor, margin to the limit and limit will be recorded. A plot with the graph of the premeasurement and the limit is stored.

*)Note: The sequence will be repeated three times with different EUT orientations.

8.2 Sequence of testing radiated spurious 30 MHz to 1 GHz

Setup

- The equipment is set up to simulate normal operation mode as described in the user manual or defined by the manufacturer.
- If the EUT is a tabletop system, a table with 0.8 m height is used, which is placed on the ground plane.
- If the EUT is a floor standing device, it is placed on the ground plane with insulation between both.
- Auxiliary equipment and cables are positioned to simulate normal operation conditions as described in ANSI C 63.4.
- The AC power port of the EUT (if available) is connected to a power outlet below the turntable.
- Measurement distance is 10 m or 3 m (see ANSI C 63.4) – see test details.
- EUT is set into operation.

Premeasurement

- The turntable rotates from 0° to 315° using 45° steps.
- The antenna is polarized vertical and horizontal.
- The antenna height changes from 1 m to 3 m.
- At each turntable position, antenna polarization and height the analyzer sweeps three times in peak to find the maximum of all emissions.

Final measurement

- The final measurement is performed for at least six highest peaks according to the requirements of the ANSI C63.4.
- Based on antenna and turntable positions at which the peak values are measured the software maximize the peaks by changing turntable position ± 45° and antenna height between 1 and 4 m.
- The final measurement is done with quasi-peak detector (as described in ANSI C 63.4).
- Final levels, frequency, measuring time, bandwidth, antenna height, antenna polarization, turntable angle, correction factor, margin to the limit and limit are recorded. A plot with the graph of the premeasurement with marked maximum final results and the limit is stored.

8.3 Sequence of testing radiated spurious 1 GHz to 18 GHz

Setup

- The equipment is set up to simulate normal operation mode as described in the user manual or defined by the manufacturer.
- If the EUT is a tabletop system, a 2-axis positioner with 1.5 m height is used.
- If the EUT is a floor standing device, it is placed directly on the turn table.
- Auxiliary equipment and cables are positioned to simulate normal operation conditions as described in ANSI C 63.4.
- The AC power port of the EUT (if available) is connected to a power outlet below the turntable.
- Measurement distance is 3 m (see ANSI C 63.4) – see test details.
- EUT is set into operation.

Premeasurement

- The turntable rotates from 0° to 315° using 45° steps.
- The antenna is polarized vertical and horizontal.
- The antenna height is 1.5 m.
- At each turntable position and antenna polarization the analyzer sweeps with positive peak detector to find the maximum of all emissions.

Final measurement

- The final measurement is performed for at least six highest peaks according to the requirements of the ANSI C63.4.
- Based on antenna and turntable positions at which the peak values are measured the software maximizes the peaks by rotating the turntable from 0° to 360°. This measurement is repeated for different EUT-table positions (0° to 150° in 30°-steps) and for both antenna polarizations.
- The final measurement is done in the position (turntable, EUT-table and antenna polarization) causing the highest emissions with Peak and RMS detector (as described in ANSI C 63.4).
- Final levels, frequency, measuring time, bandwidth, turntable position, EUT-table position, antenna polarization, correction factor, margin to the limit and limit are recorded. A plot with the graph of the premeasurement with marked maximum final results and the limit is stored.

8.4 Sequence of testing radiated spurious above 18 GHz

Setup

- The equipment is set up to simulate normal operation mode as described in the user manual or defined by the manufacturer.
- Auxiliary equipment and cables are positioned to simulate normal operation conditions as described in ANSI C 63.4.
- The AC power port of the EUT (if available) is connected to a power outlet.
- The measurement distance is as appropriate (e.g. 0.5 m).
- The EUT is set into operation.

Premeasurement

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

Final measurement

- The final measurement is performed at the position and antenna orientation causing the highest emissions with Peak and RMS detector (as described in ANSI C 63.4).
- Final levels, frequency, measuring time, bandwidth, correction factor, margin to the limit and limit are recorded. A plot with the graph of the premeasurement and the limit is stored.

8.5 Sequence of testing radiated spurious above 50/85 GHz with external mixers

Setup

- The equipment is set up to simulate normal operation mode as described in the user manual or defined by the manufacturer.
- Auxiliary equipment and cables are positioned to simulate normal operation conditions as described in ANSI C 63.4.
- The AC power port of the EUT (if available) is connected to a power outlet.
- The measurement distance is as appropriate for far field (e.g. 0.25 m).
- The EUT is set into operation.

Premeasurement

- The test antenna with external mixer is handheld and moved carefully over the EUT to cover the EUT's whole sphere and different polarizations of the antenna.
- Caution is taken to reduce the possible overloading of the external mixer.

Final measurement

- The final measurement is performed at the position and antenna orientation causing the highest emissions with Peak and RMS detector (as described in ANSI C 63.4).
- As external mixers may generate false images care is taken to ensure that any emission measured by the spectrum analyzer does indeed originate in the EUT. Signal identification feature of spectrum analyzer is used to eliminate false mixer images (i.e., it is not the fundamental emission or a harmonic falling precisely at the measured frequency).
- Final levels, frequency, measuring time, bandwidth, correction factor, margin to the limit and limit are recorded. A plot with the graph of the premeasurement and the limit is stored.

9 Measurement uncertainty

Test case	Uncertainty
Equivalent isotropically radiated power (e.i.r.p.)	Conducted value ± 1 dB Radiated value ± 3 dB
Permitted range of operating frequencies	± 100 kHz
Conducted unwanted emissions in the spurious domain (up to 18 GHz)	± 1 dB
Radiated unwanted emissions in the spurious domain (up to 18 GHz)	± 3 dB
Conducted unwanted emissions in the spurious domain (18 to 40 GHz)	± 4 dB
Radiated unwanted emissions in the spurious domain (18 to 40 GHz)	± 4 dB
Conducted unwanted emissions in the spurious domain (40 to 50 GHz)	± 4.5 dB
Radiated unwanted emissions in the spurious domain (40 to 50 GHz)	± 4.5 dB
Conducted unwanted emissions in the spurious domain (above 50 GHz)	± 5 dB
Radiated unwanted emissions in the spurious domain (above 50 GHz)	± 5 dB
DC and low frequency voltages	± 3 %
Temperature	± 1 °C
Humidity	± 3 %

10 Far field consideration for measurements above 18 GHz

Far field distance calculation:

$D_{ff} = 2 \times D^2/\lambda$

with

D_{ff} Far field distance

D Antenna dimension

λ wavelength

Spurious emission measurements:

Antenna frequency range in GHz	Highest measured frequency in GHz	D in cm	λ in cm	D_{ff} in cm
18-26	26	3.4	1.15	20.04
26-40	40	2.2	0.75	12.91
40-50	50	2.77	0.60	25.58
50-75	75	1.85	0.40	17.11
75-110	110	1.24	0.27	11.28
90-140	140	1.02	0.22	9.72
110-170	170	0.85	0.18	8.19
140-220	220	0.68	0.14	6.78
220-325	325	0.43	0.09	4.01
325-500	500	0.26	0.06	2.22

11 Summary of measurement results

☒	**No deviations from the technical specifications were ascertained**
☐	There were deviations from the technical specifications ascertained
☐	This test report is only a partial test report. The content and verdict of the performed test cases are listed below.

TC Identifier	Description	Verdict	Date	Remark
RF-Testing	47 CFR Part 95 Subpart M	see below	2024-03-28	-/-

Test specification clause	Test case	Temperature conditions	Power source voltages	C	NC	NA	NP	Results (max.)
§2.1046 §95.3367 (a) / (b)	Radiated power, EIRP (RF1.1)	Nominal	Nominal	☒	☐	☐	☐	-/-
§2.1047	Modulation characteristics	-/-	-/-	☒	☐	☐	☐	-/-
§2.1049	Occupied bandwidth (99% bandwidth) (RF2.2 and RF2.6)	Nominal	Nominal	☒	☐	☐	☐	-/-
§2.1051	Spurious emissions at antenna terminals	Nominal	Nominal	☐	☐	☒	☐	see note
§2.1053 §95.3379 (a)(1) §95.3379 (a)(2) §95.3379 (a)(3)	Field strength of emissions (radiated spurious) (RF1.3 and RF2.5)	Nominal	Nominal	☒	☐	☐	☐	-/-
§2.1055 §95.3379 (b)	Frequency stability (RF2.6)	Nominal Extreme	Nominal Extreme	☒	☐	☐	☐	-/-
---	Occupied bandwidth interferer (RF4.2)	Nominal	Nominal	☒	☐	☐	☐	-/-

Note: C = Compliant; NC = Not compliant; NA = Not applicable; NP = Not performed

ADVP&R / VCRI Ref # from manufacturer's Test Requirements Summary see in column 'Test case' above.

See 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 of devices operating under Sections 15.253 and 15.255 may exceed the +20 dBm input power limit of many commercially available mixers. For these reasons a radiated method is preferred.

12 Measurement results

12.1 Radiated power

Description:

§95.3367:
The fundamental radiated emission limits within the 76-81 GHz band are expressed in terms of Equivalent Isotropically Radiated Power (EIRP) and are as shown below.

Limits: **FCC §95.3367 (a) (b)/ RSS-251 (5.2.2)**

Frequency	Limit (eirp)
76.0 - 81.0 GHz	50 dBm (Average)
76.0 - 81.0 GHz	55 dBm/MHz (PEAK)

Measurement: Average Power

Measurement parameter	
Detector:	RMS
Resolution bandwidth:	1 MHz
Video bandwidth:	3 MHz
Trace-Mode:	Clear Write

Measurement: Peak Power

Measurement parameter	
Detector:	Pos-Peak
Resolution bandwidth:	50 MHz
Video bandwidth:	80 MHz
Trace-Mode:	Max Hold

Note: KDB 653005 4.(c)(1)
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.

Consequence:
Worst case measurement, the peak power measurement is performed with a greater resolution bandwidth to solve the problem with the desensitization.

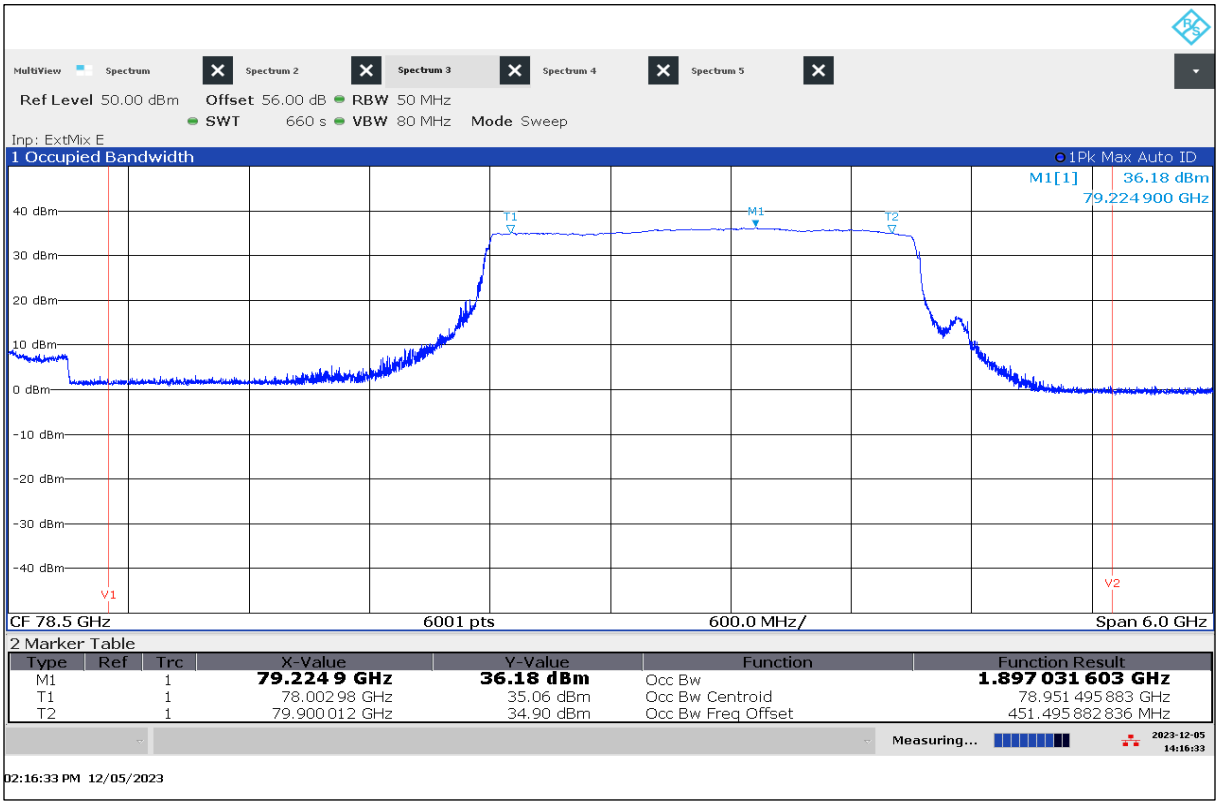
Measurement results:

Mode	Test conditions	Radiated peak power (eirp) [dBm]	Channel power [dBm]	Mean Power spectral density [dBm/MHz]	Peak Power spectral density [dBm/MHz]
City Mode 3	T_{nom} / $V_{min-max}$	36.18	21.36	-9.79	25.19
Highway Traffic Mode 3	T_{nom} / $V_{min-max}$	35.54	21.86	-4.25	27.44
Standby State	T_{nom} / $V_{min-max}$	Noise floor			

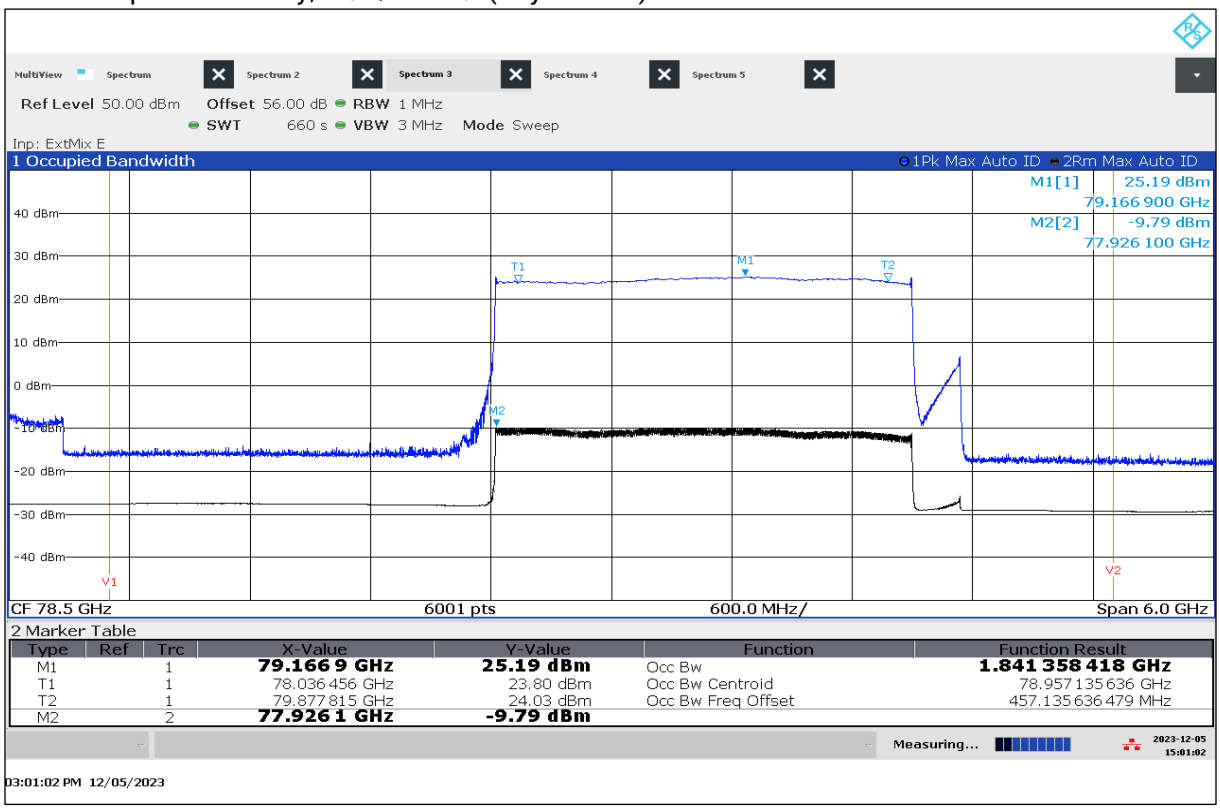
Note: Voltage variation does not affect the radiated signal; the worst-case scenario is recorded.

Verdict: Complies

Plot 1: OBW, Peak Power, T_{nom} / $V_{min-max}$ (City Mode 3)

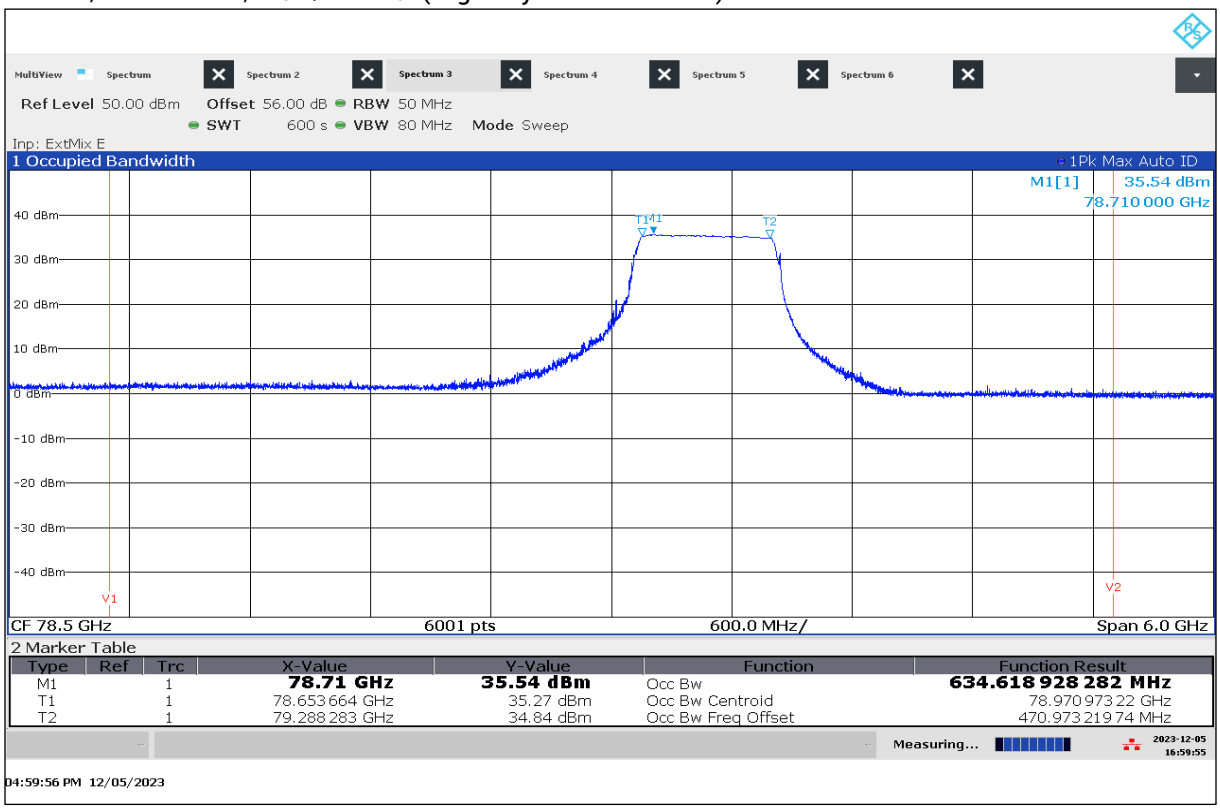


Plot 2: Power Spectral Density, T_{nom} / $V_{min\text{-}max}$ (City Mode 3)



Plot 3: Mean Power, T_{nom} / $V_{min\text{-}max}$ (City Mode 3)

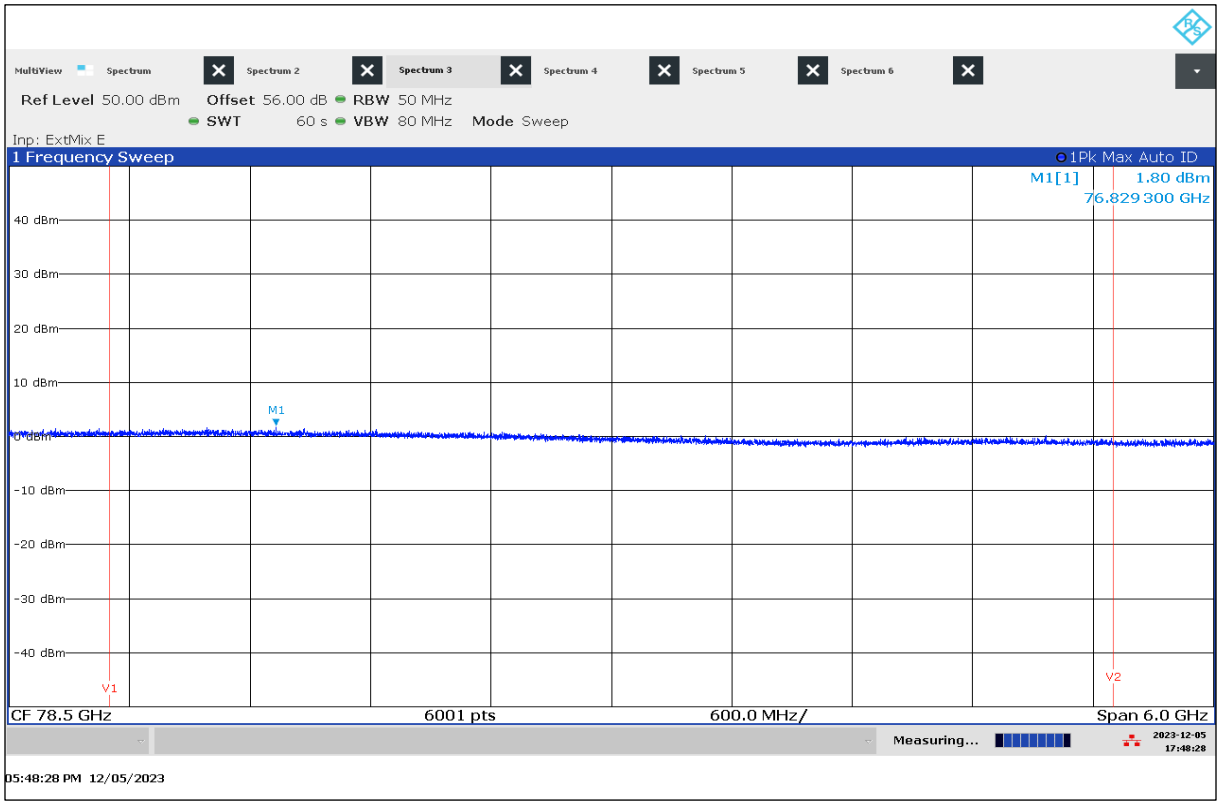
Plot 4: OBW, Peak Power, T_{nom} / $V_{min\text{-}max}$ (Highway Traffic Mode 3)



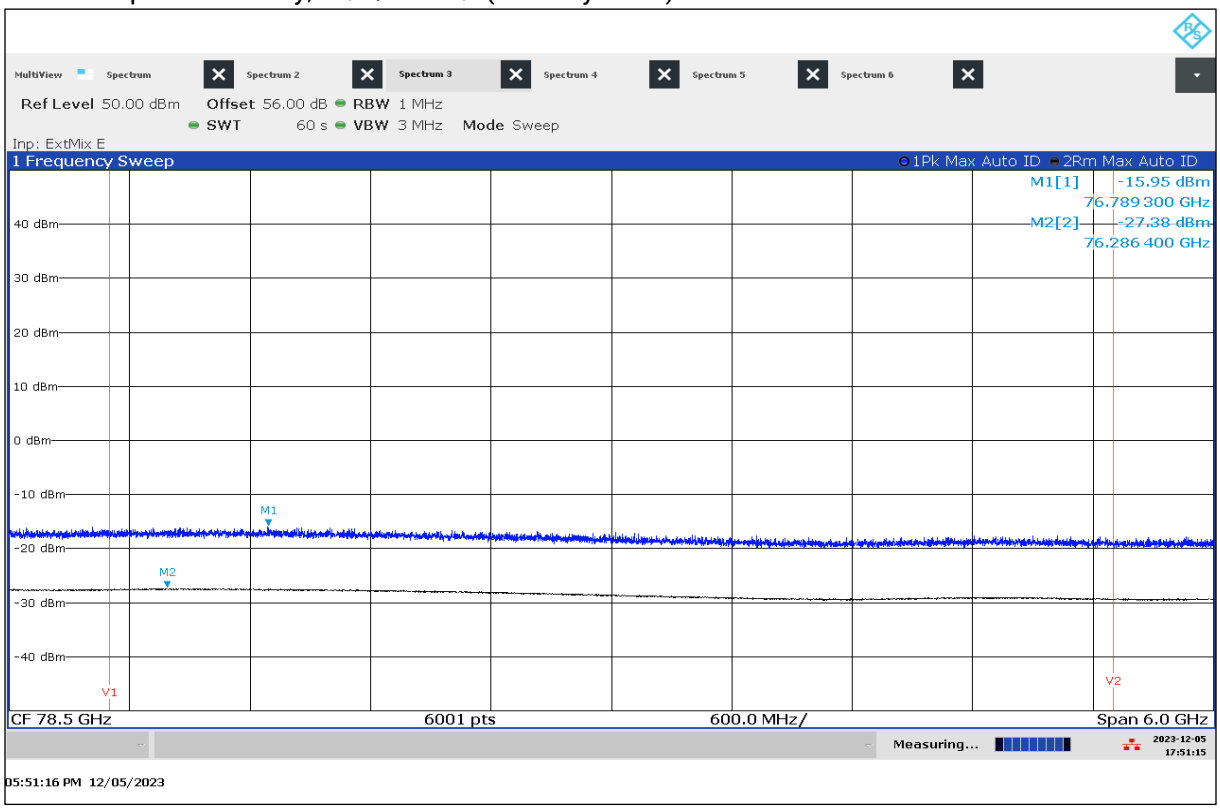
Plot 5: Power Spectral Density, T_{nom} / $V_{min\text{-}max}$ (Highway Traffic Mode 3)

Plot 6: Mean Power, T_{nom} / $V_{min\text{-}max}$ (Highway Traffic Mode 3)

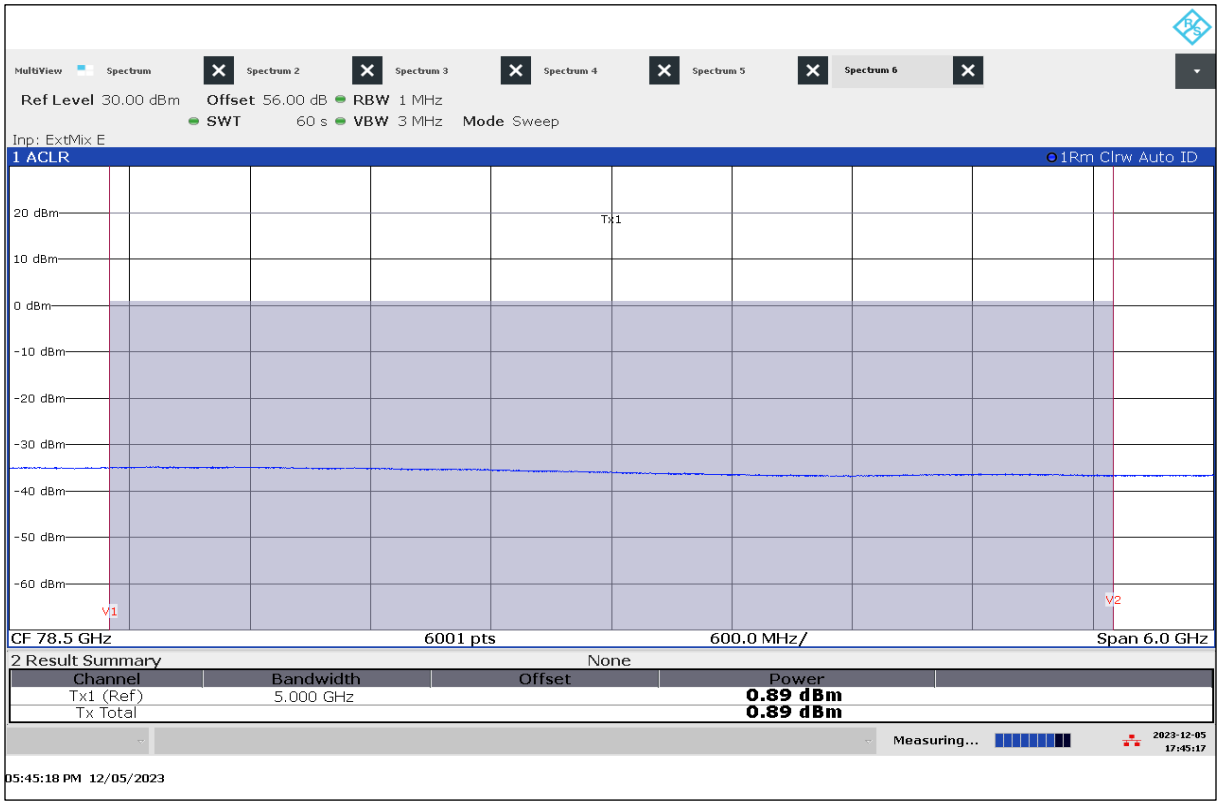
Plot 7: OBW, Peak Power, T_{nom} / $V_{min\text{-}max}$ (StandBy State)



Plot 8: Power Spectral density, T_{nom} / $V_{min\text{-}max}$ (StandBy State)



Plot 9: Mean Power, T_{nom} / $V_{min\text{-}max}$ (StandBy State)



12.2 Modulation characteristics

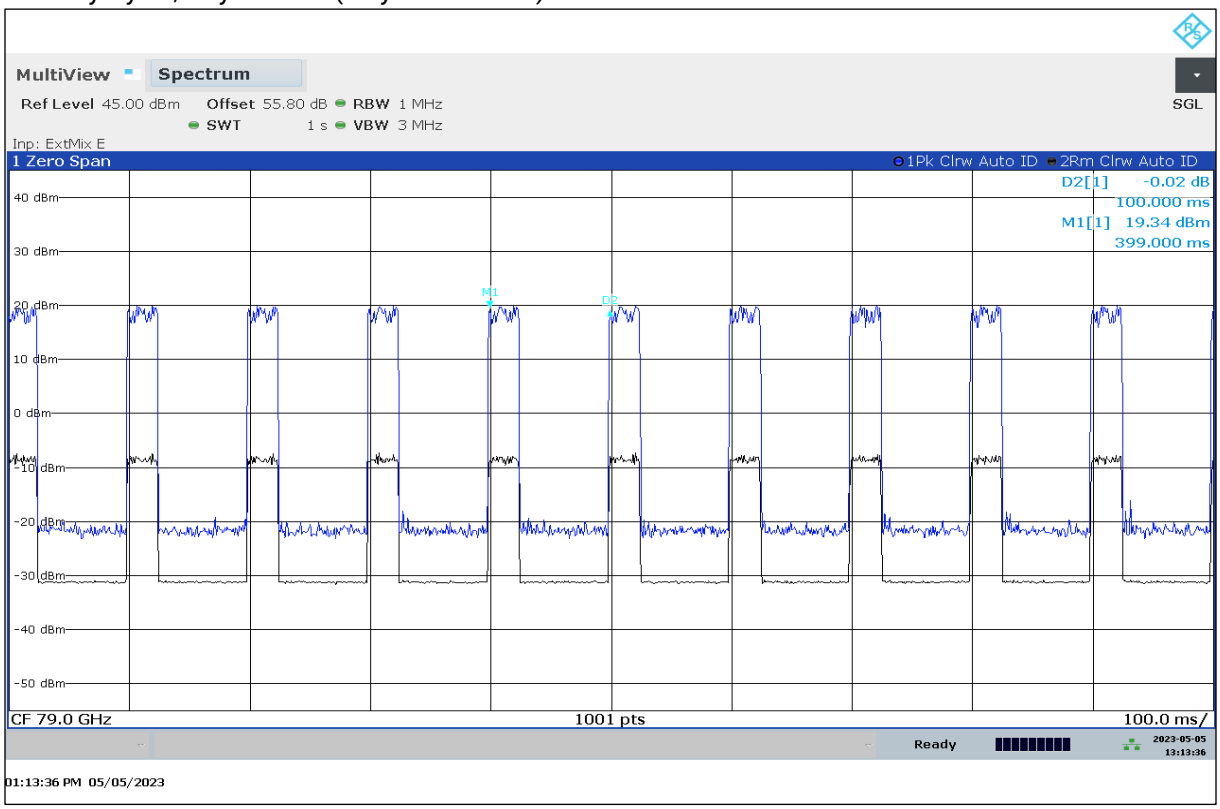
Description:

§2.1047 (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.

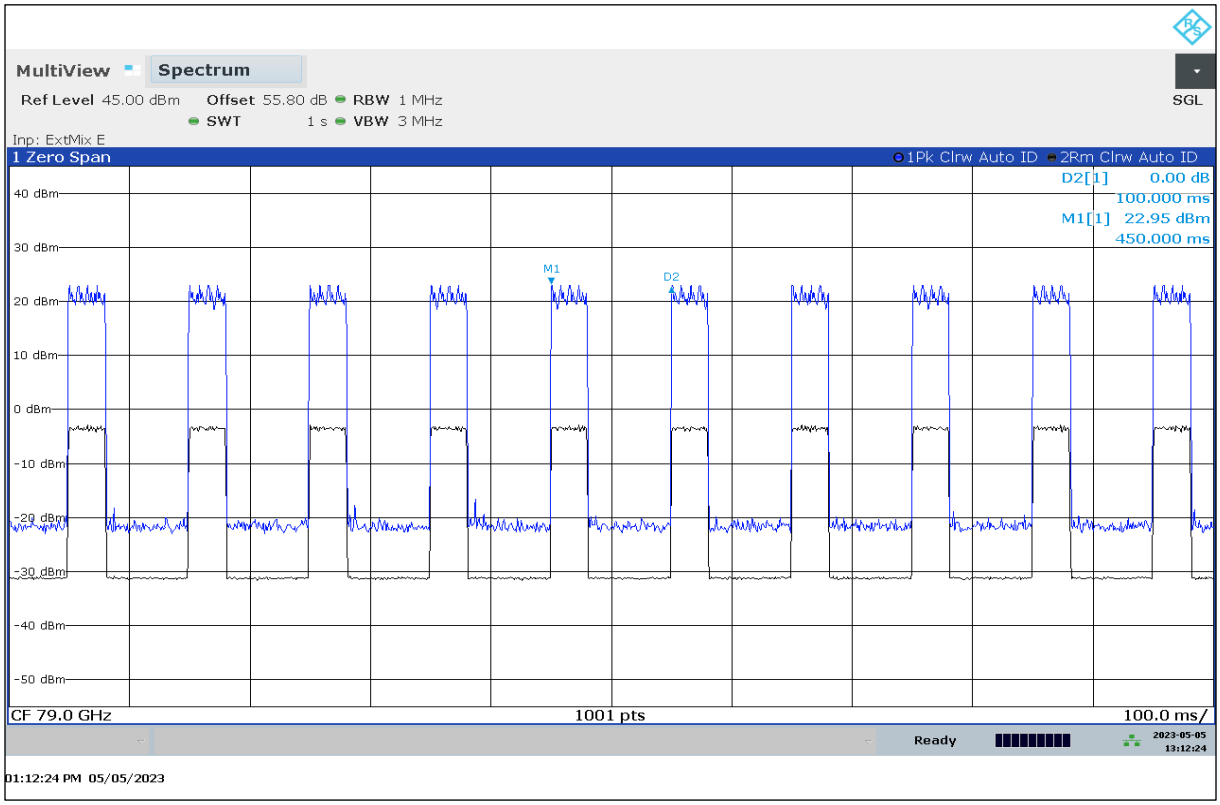
Comments from manufacturer on modulation characteristics according to KDB:

Parameter	City Mode 3	Highway Traffic Mode 3
Duty Cycle %	25.6 %	30.4 %
Timing RF on (ms)	25.6 ms	30.4 ms
Timing RF off (ms)	74.4 ms	69.6 ms
Power	Constant during RF on	Constant during RF on
Steepness of Ramps (GHz/s)	26 042.0 GHz/s	15 625.0 GHz/s
Calibration	N/A	N/A
Characteristic	FMCW	FMCW
Sweep Bandwidth (GHz)	2.078 GHz	642.19 MHz
Sweep Time (us)	79.8 µs	41.1 µs

Plot 10: Duty Cycle, City Mode 3 (only informative)



Plot 11: Duty Cycle, Highway Traffic Mode 3 (only informative)



12.3 Occupied bandwidth

Description:

§2.1049 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.

Limits:

FCC
FCC §95.3379 (b)
The occupied bandwidth from intentional radiators operated within the specified frequency band shall comply with the following:
Frequency range
76 GHz – 81 GHz

Measurement:

Parameters	
Detector:	Pos-Peak
Resolution bandwidth:	50 MHz
Video bandwidth:	80 MHz
Trace-Mode:	Max Hold

Measurement results:

Mode	Operating Frequency Range		
	f_L [GHz]	f_H [GHz]	OBW [MHz]
City Mode 3	78.002 980	79.900 012	1897
Highway Traffic Mode 3	78.653 664	79.288 283	635
Standby State	Noise floor		

Note: for corresponding plots refer to chapter 12.1

Verdict: **Complies**

12.4 Band edge compliance

Description:

Investigation of the emission limits at the band edge.

Limits: **FCC §95.3379 (a) (2) (i) + (ii) / ANSI C63.10-2013 / 6.10**

Frequency Range [GHz]	Measurement distance	Power Density
40 – 76 and 81 – 200	3.0 m	600 pW/cm^2 → -1.7 dBm

Measurement:

Parameters	
Detector:	RMS
Resolution bandwidth:	1 MHz
Video bandwidth:	3 MHz
Trace-Mode:	Max Hold

Refer to plots in Chapter 12.5

Verdict: **Complies**

12.5 Unwanted emissions

Description:

Measurement of the radiated unwanted emissions.

Limits:

FCC §95.3379

(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.

FCC		
CFR Part 95.3379 (a) (1) / CFR Part 95.3379 (a) (3)		
Radiated unwanted emissions		
Frequency (MHz)	Field Strength (µV/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	30
30 88	100	3
88 – 216	150	3
216 – 960	200	3
960 – 40 000	500	3

(i) In the emissions table in paragraph (a)(1) of this section, the tighter limit applies at the band edges.

(ii) The limits in the table in paragraph (a)(1) of this section are based on the frequency of the unwanted emissions and not the fundamental frequency. However, the level of any unwanted emissions shall not exceed the level of the fundamental frequency.

(iii) The emissions limits shown in the table in paragraph (a)(1) of this section are based on measurements employing a CISPR quasi-peak detector except for the frequency bands 9.0-90.0 kHz, 110.0-490.0 kHz, and above 1000 MHz. Radiated emissions limits in these three bands are based on measurements employing an average detector with a 1 MHz RBW

(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:

(i) For radiated emissions outside the 76-81 GHz band between 40 GHz and 200 GHz from field disturbance sensors and radar systems operating in the 76-81 GHz band: 600 pW/cm2 at a distance of 3 meters from the exterior surface of the radiating structure.

(ii) For radiated emissions above 200 GHz from field disturbance sensors and radar systems operating in the 76-81 GHz band: 1000 pW/cm2 at a distance of 3 meters from the exterior surface of the radiating structure.

Frequency Range (GHz)	Power Density	EIRP
40 – 200	600 pW/cm^2 @ 3m	-1.7 dBm
200 – 231	1000 pW/cm^2 @ 3m	+0.5 dBm

(3) For field disturbance sensors and radar systems operating in the 76-81 GHz band, the spectrum shall be investigated up to 231.0 GHz.

Limit conversion (ANSI C63.10-2013 9.6):

$EIRP[dBm] = 10 \times \log(4 \times \pi \times d^2 \times PD[W/m^2])$

- Power density at the distance specified by the limit: PD [W/m²]
- Equivalent isotropically radiated power: EIRP [dBm]
- Distance at which the power density limit is specified: d [m]

According to this formula, an emission limit of PD = 600 pW/cm² at a distance of d = 3 m corresponds to an equivalent isotropically radiated power of EIRP = -1.7 dBm.

Measurement:

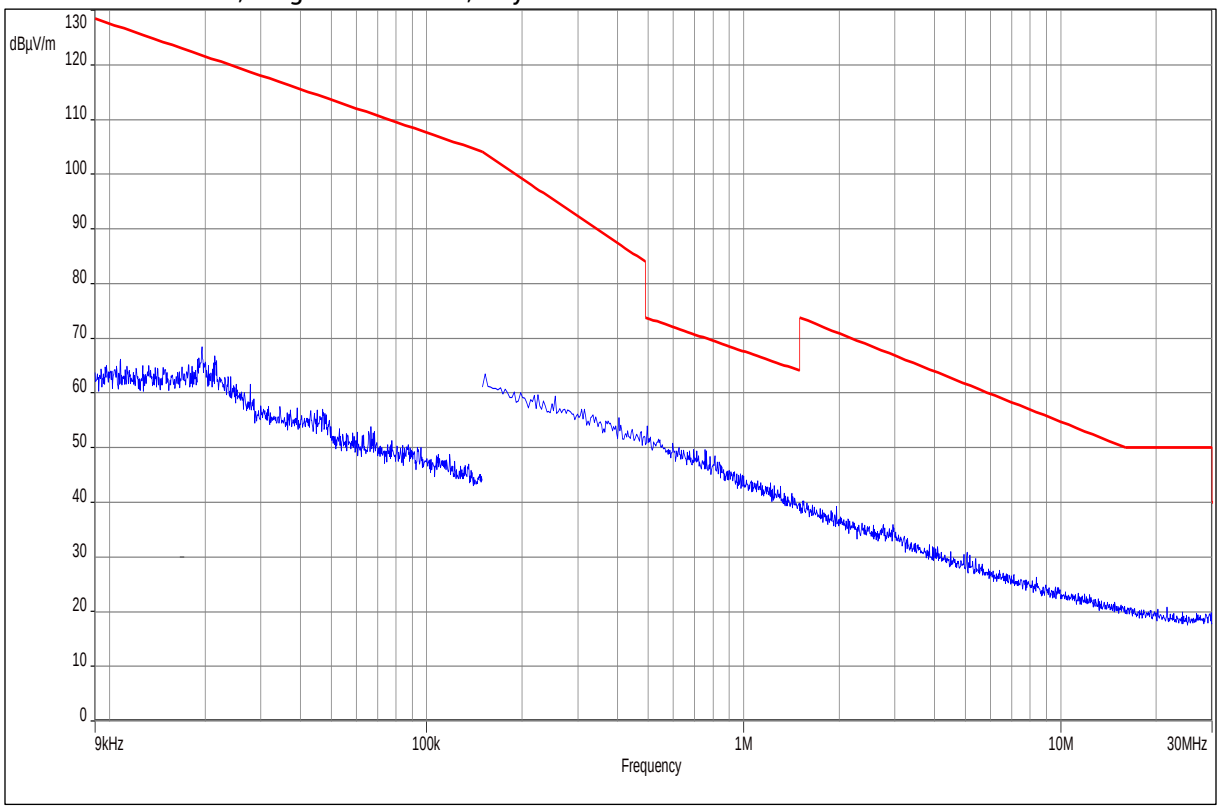
Measurement parameter	
Detector:	Quasi Peak / Pos-Peak / LinAV / RMS
Resolution bandwidth:	F < 1 GHz: 100 kHz F > 1 GHz: 1 MHz
Video bandwidth:	F < 1 GHz: 300 kHz F > 1 GHz: 3 MHz
Trace-Mode:	Max Hold

Measurement results:

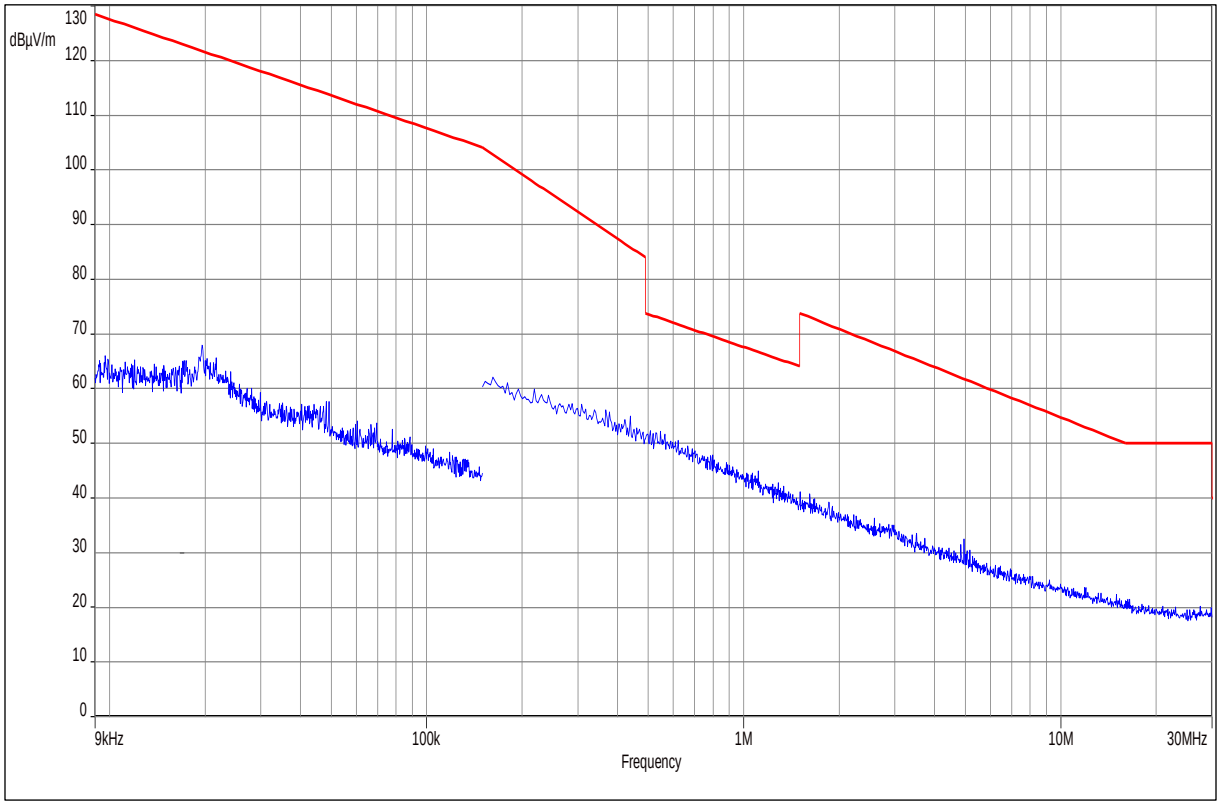
Frequency [GHz]	Detector	Bandwidth [MHz]	Level	Limit	Margin [dB]
-/-	-/-	-/-	-/-	-/-	-/-
Please refer to the following plots for more information on the level of spurious emissions					

Verdict: Complies

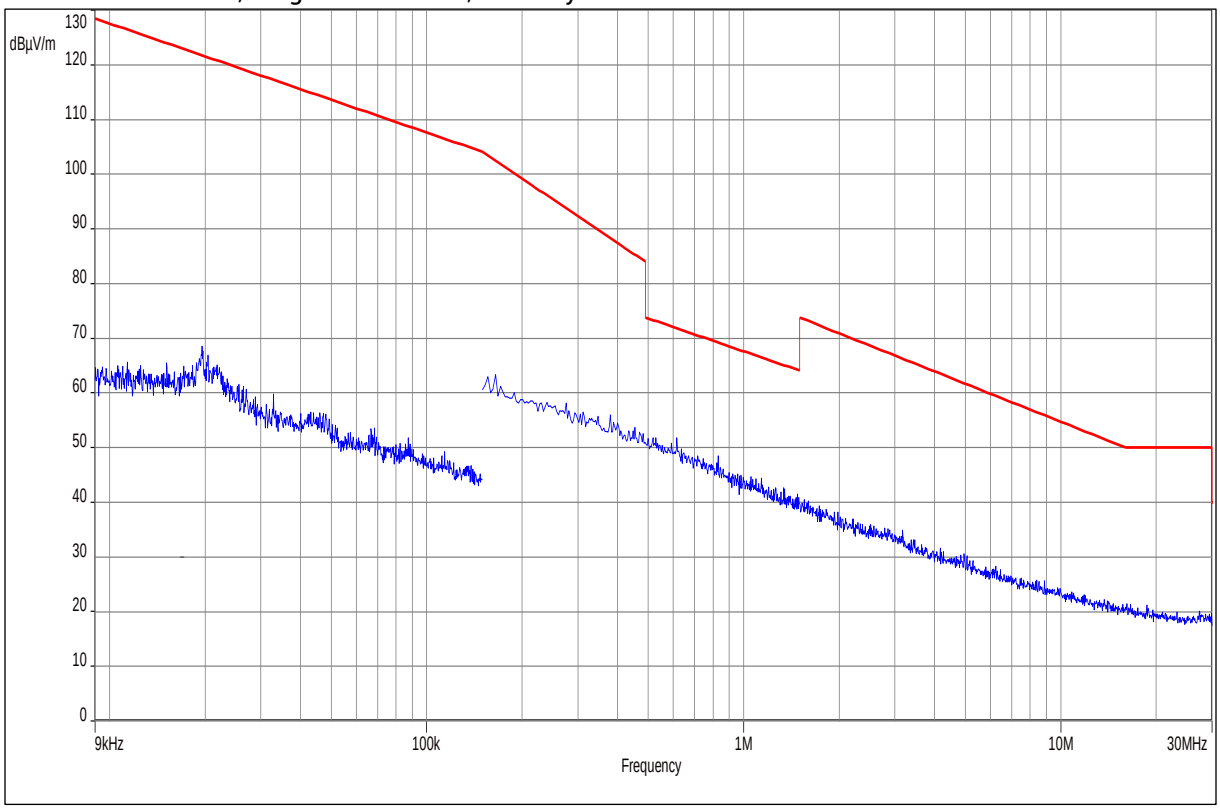
Plot 12: 9 kHz – 30 MHz, Magnetic antenna, City Mode 3



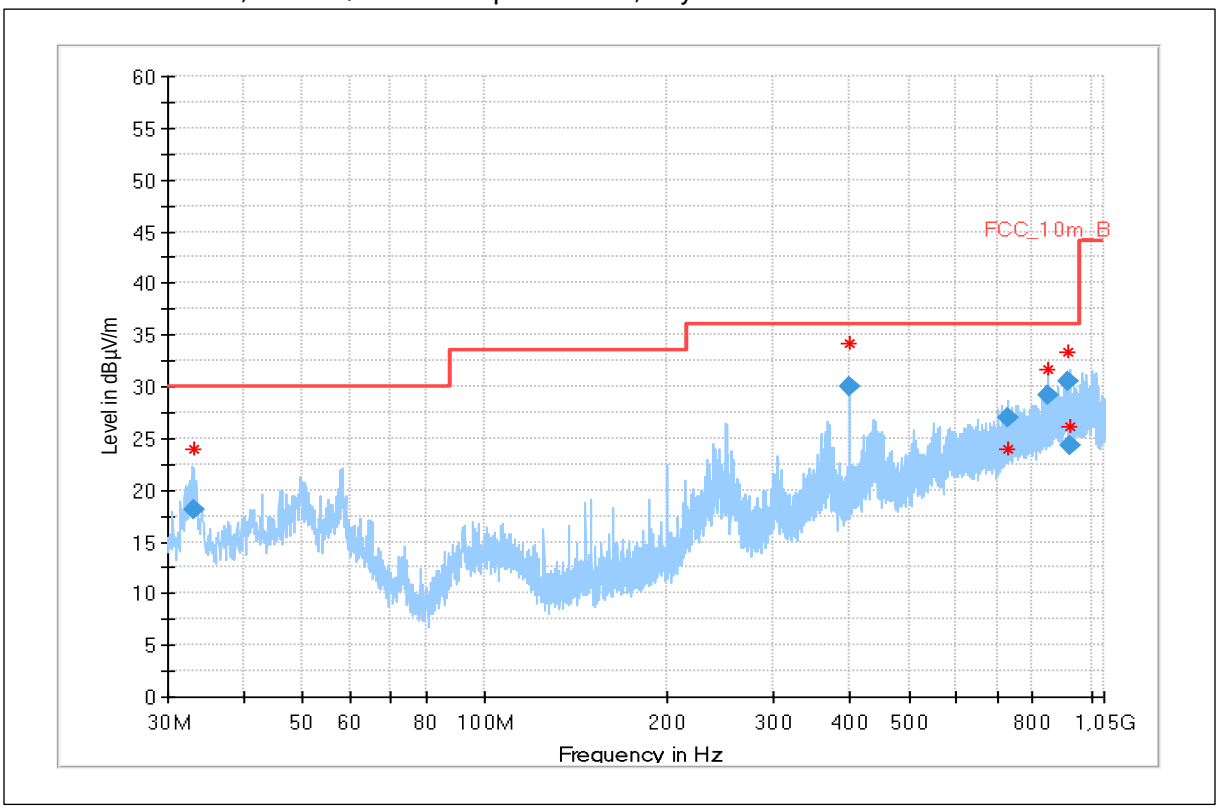
Plot 13: 9 kHz – 30 MHz, Magnetic antenna, Highway City Mode 3



Plot 14: 9 kHz – 30 MHz, Magnetic antenna, Standby State



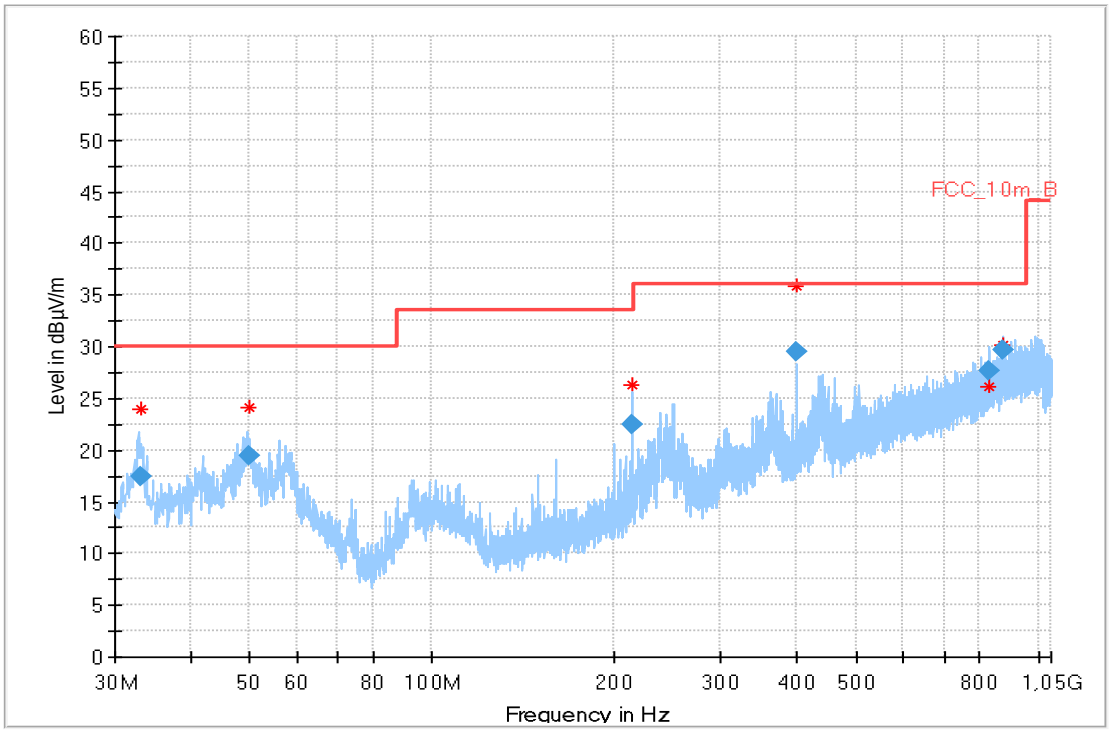
Plot 15: 30 MHz – 1 GHz, vertical / horizontal polarization, City Mode 3



Red stars are with peak detector and only informative. Blue diamonds are the right and quasi-peak values.

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
33.038	18.09	30.0	11.9	1000	120.0	98.0	V	149	13
399.997	29.97	36.0	6.0	1000	120.0	104.0	V	199	18
728.821	27.02	36.0	9.0	1000	120.0	134.0	V	195	23
850.009	29.11	36.0	6.9	1000	120.0	146.0	H	127	24
912.517	30.47	36.0	5.5	1000	120.0	195.0	V	245	25
921.753	24.28	36.0	11.7	1000	120.0	195.0	V	37	25

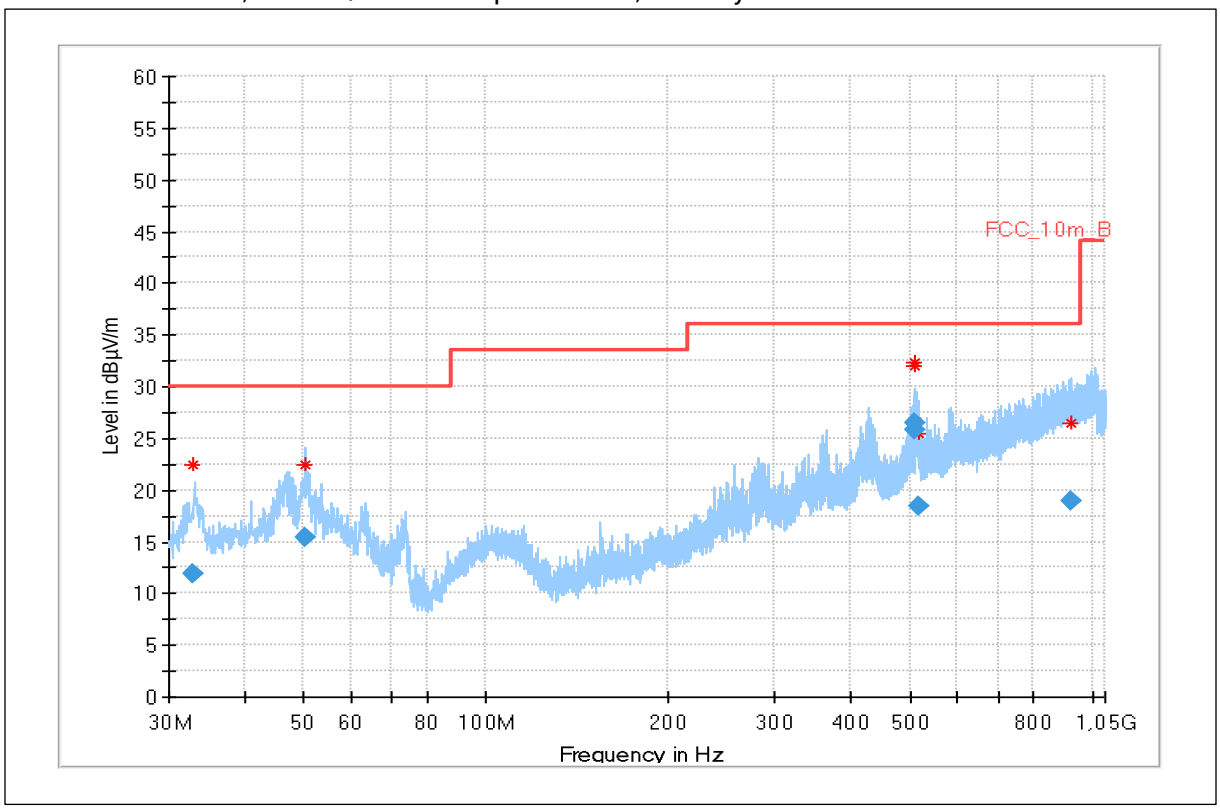
Plot 16: 30 MHz – 1 GHz, vertical / horizontal polarization, Highway Traffic Mode 3



Red stars are with peak detector and only informative. Blue diamonds are the right and quasi-peak values.

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
33.040	17.44	30.0	12.6	1000	120.0	148.0	V	127	13
49.796	19.36	30.0	10.6	1000	120.0	104.0	V	-36	15
213.357	22.52	33.5	11.0	1000	120.0	98.0	V	143	13
399.977	29.58	36.0	6.4	1000	120.0	98.0	V	237	18
826.682	27.66	36.0	8.3	1000	120.0	124.0	V	142	24
874.996	29.65	36.0	6.4	1000	120.0	110.0	H	-37	25

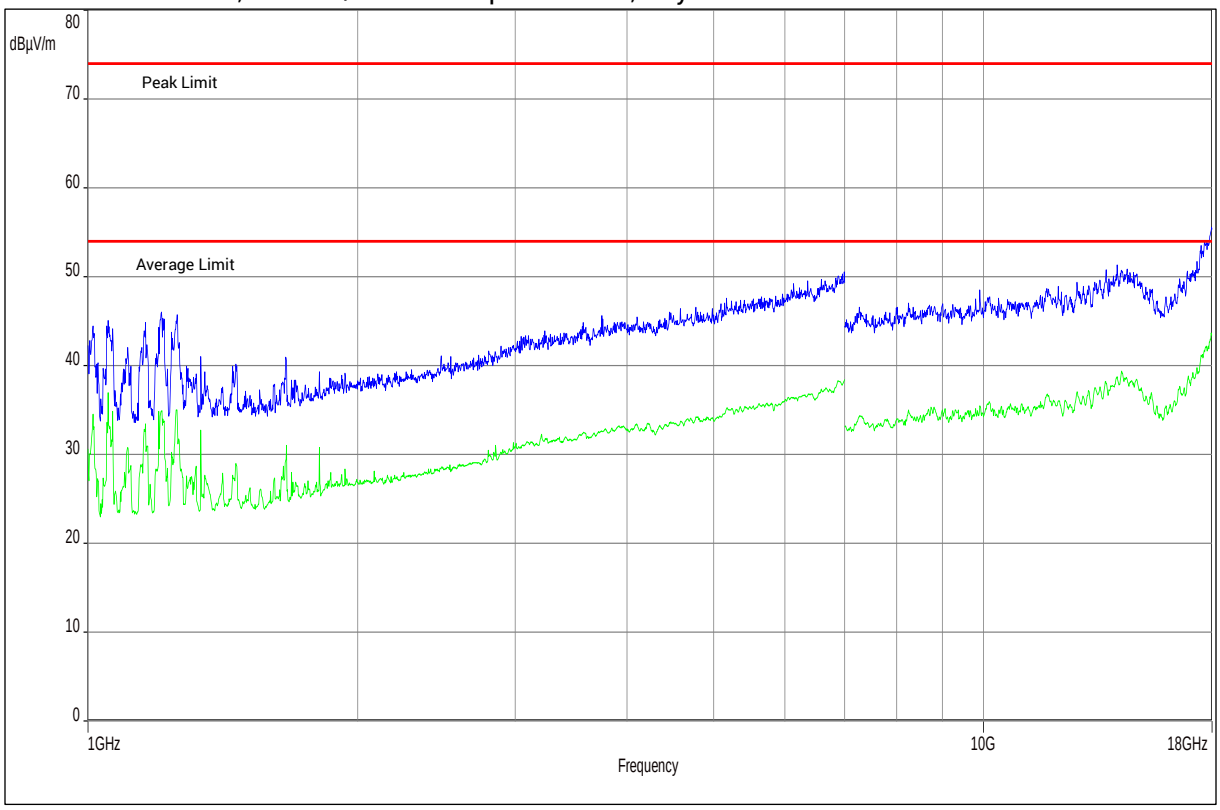
Plot 17: 30 MHz – 1 GHz, vertical / horizontal polarization, Standby State



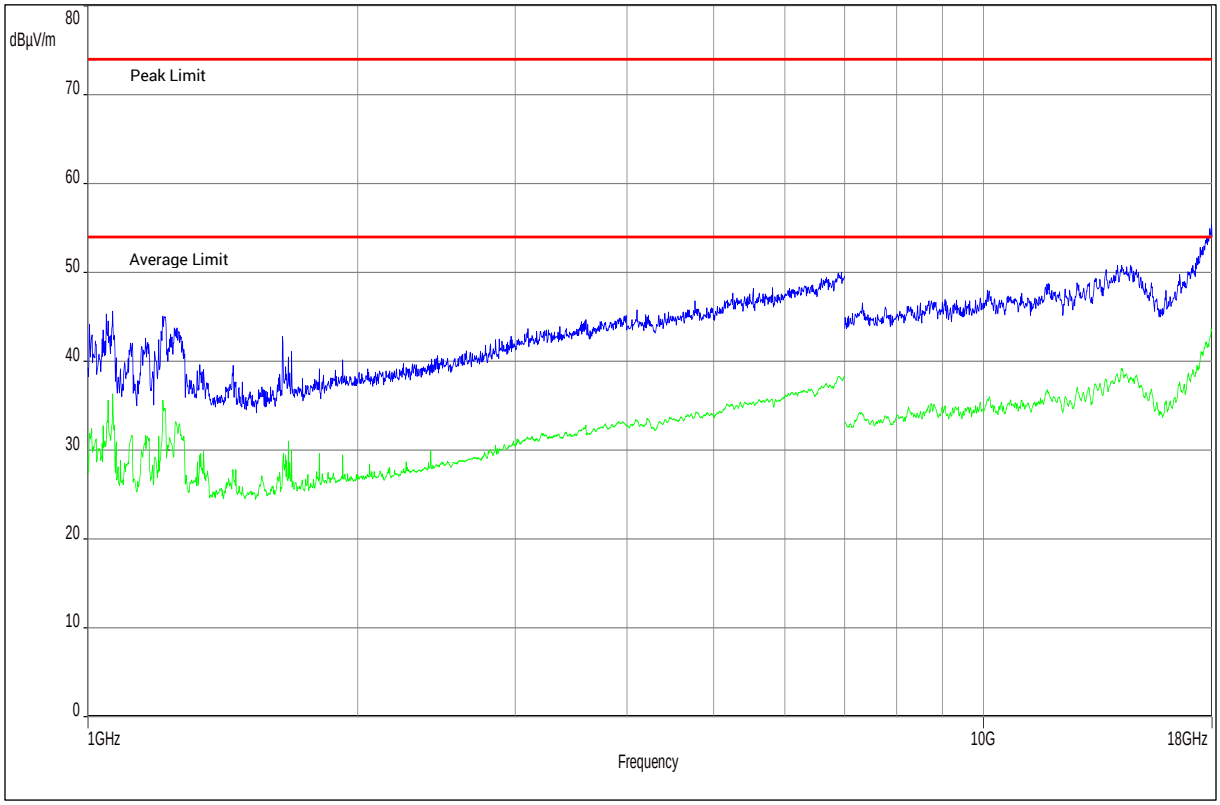
Red stars are with peak detector and only informative. Blue diamonds are the right and quasi-peak values.

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
32.903	11.90	30.0	18.1	1000	120.0	119.0	V	125	13
50.470	15.39	30.0	14.6	1000	120.0	200.0	V	-45	15
507.619	26.54	36.0	9.5	1000	120.0	200.0	V	178	20
509.919	25.89	36.0	10.1	1000	120.0	200.0	V	161	20
518.329	18.45	36.0	17.6	1000	120.0	100.0	V	21	20
924.958	18.96	36.0	17.0	1000	120.0	200.0	H	45	25

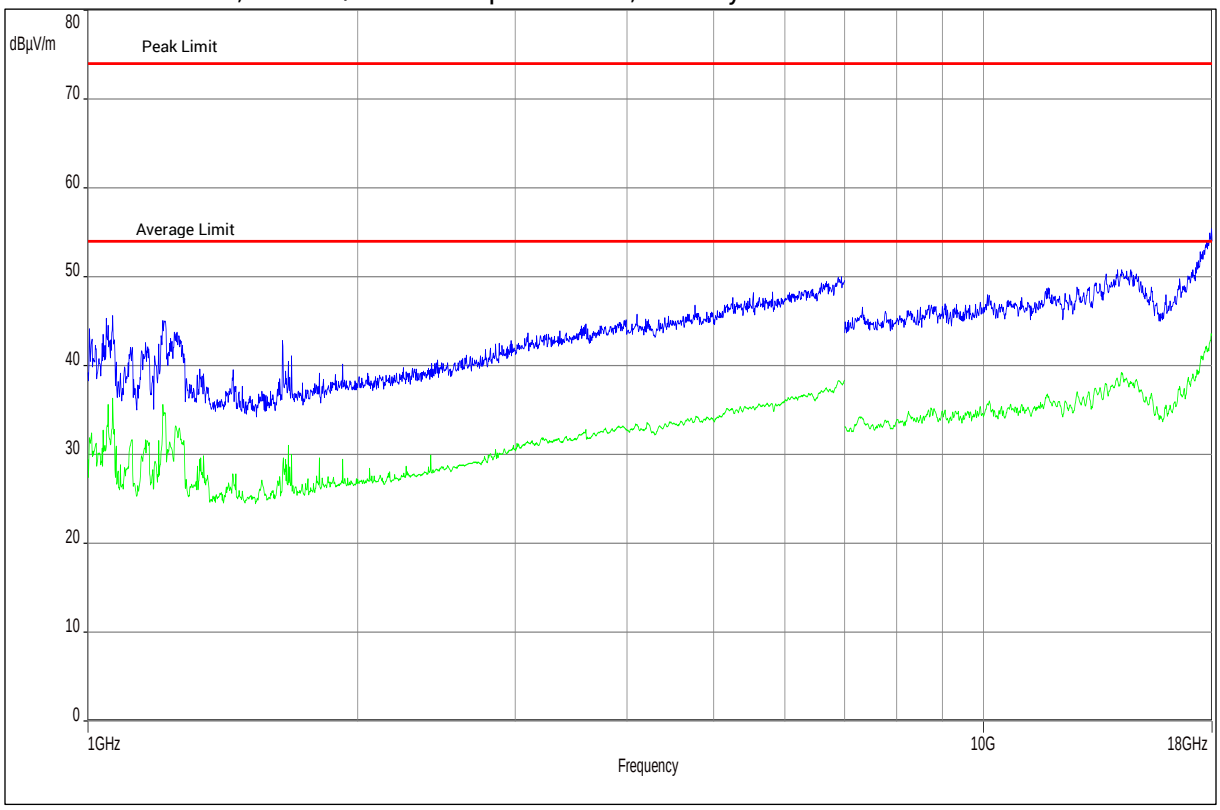
Plot 18: 1 GHz – 18 GHz, vertical / horizontal polarization, City Mode 3



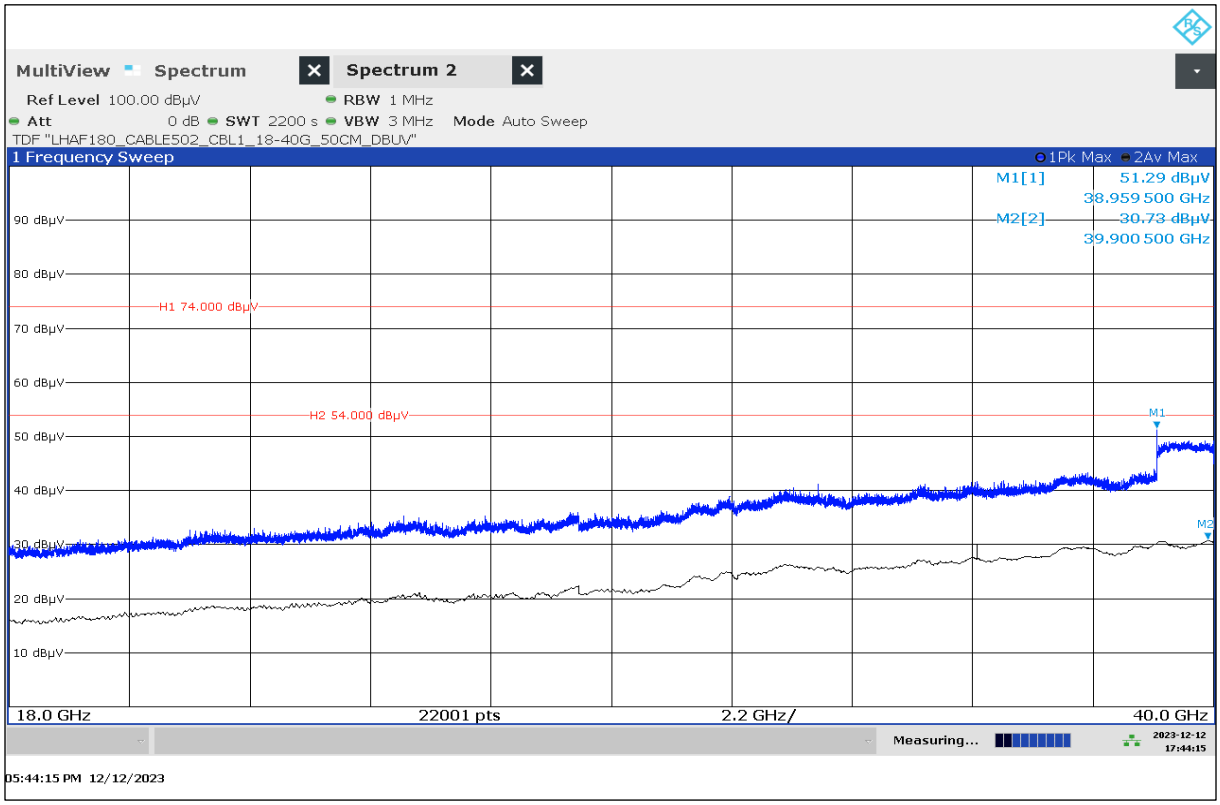
Plot 19: 1 GHz – 18 GHz, vertical / horizontal polarization, Highway Traffic Mode 3



Plot 20: 1 GHz – 18 GHz, vertical / horizontal polarization, Standby State

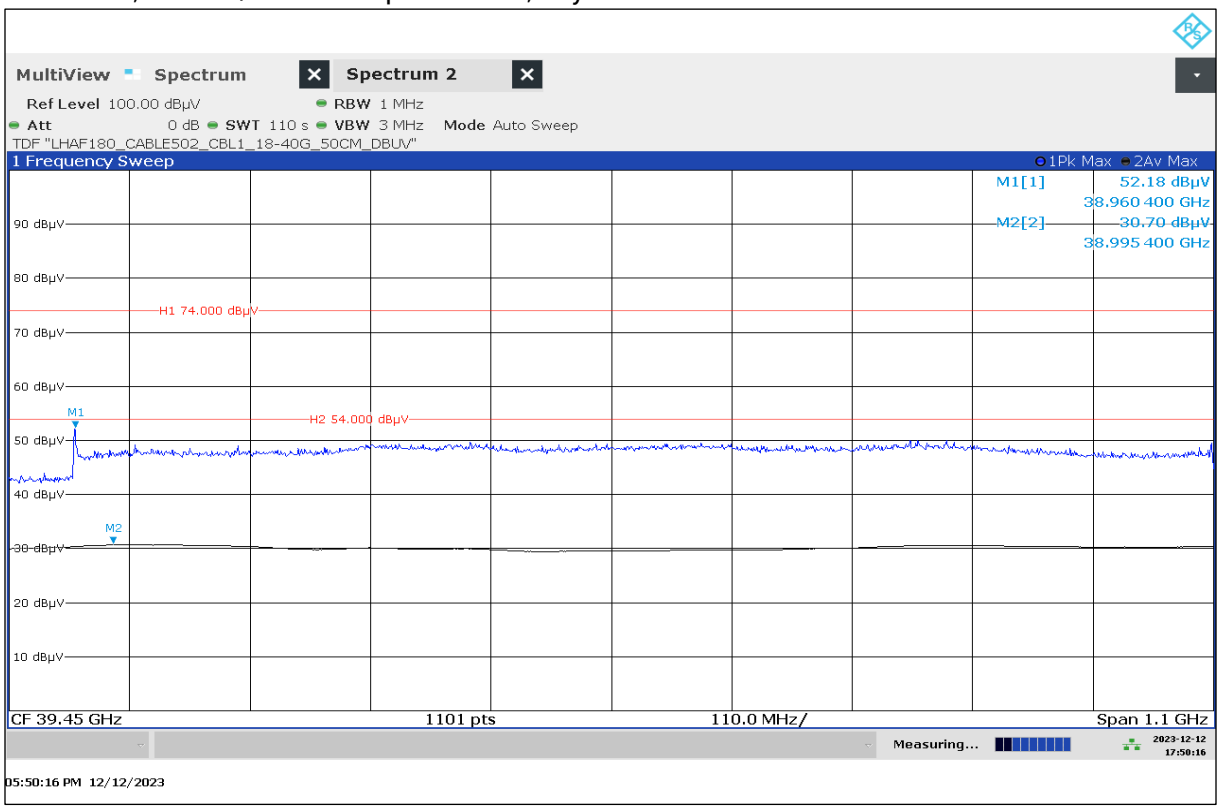


Plot 21: 18 GHz – 40 GHz, vertical / horizontal polarization, City Mode 3



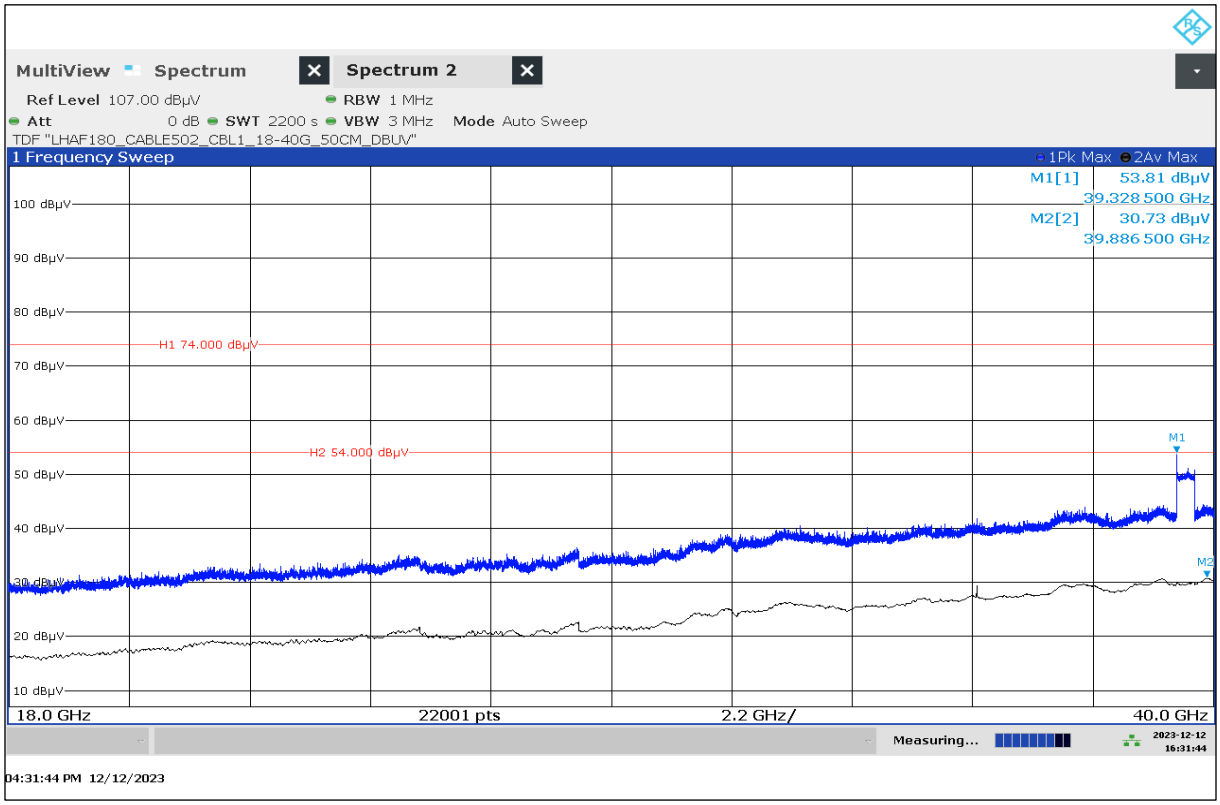
M1 with peak detector is just informative; FCC limit is 54 dBuV/m with Average detector.

Plot 22: 39 GHz, vertical / horizontal polarization, City Mode 3



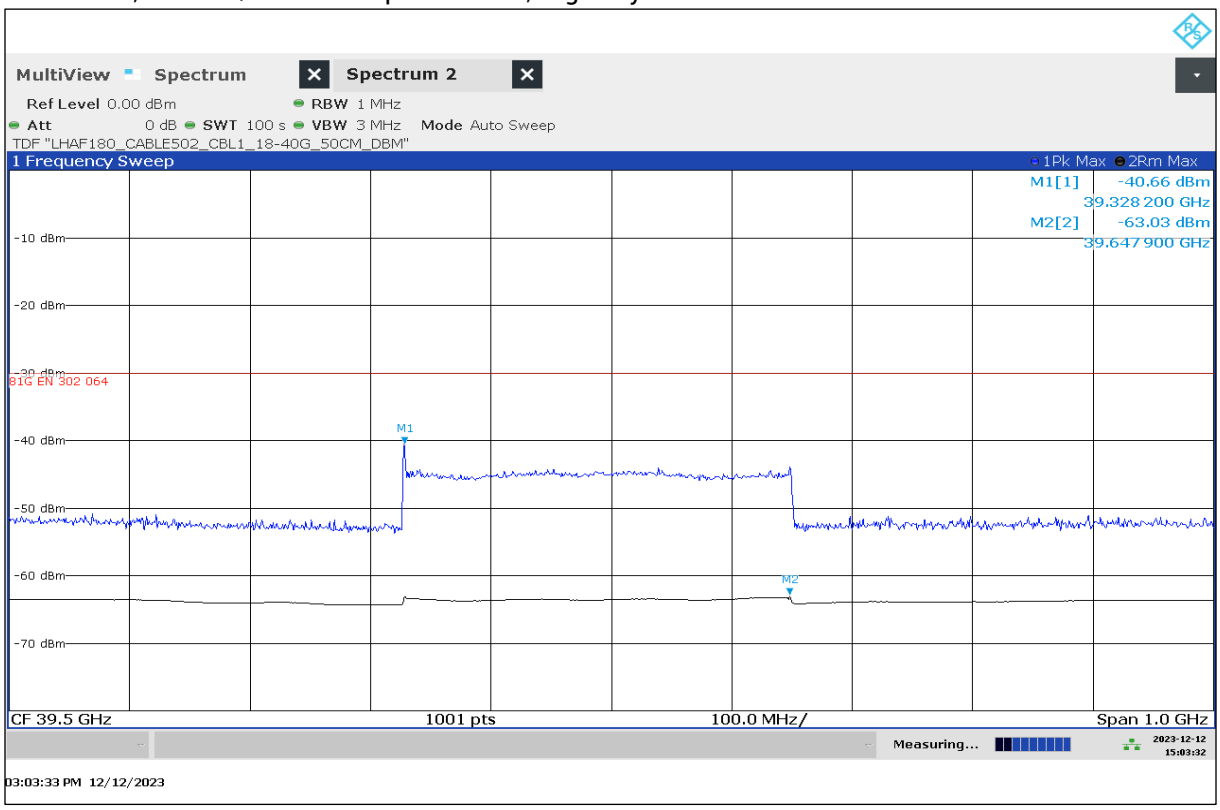
M1 with peak detector is just informative; FCC limit is 54 dBuV/m with Average detector.

Plot 23: 18 GHz – 40 GHz, vertical / horizontal polarization, Highway traffic Mode 3



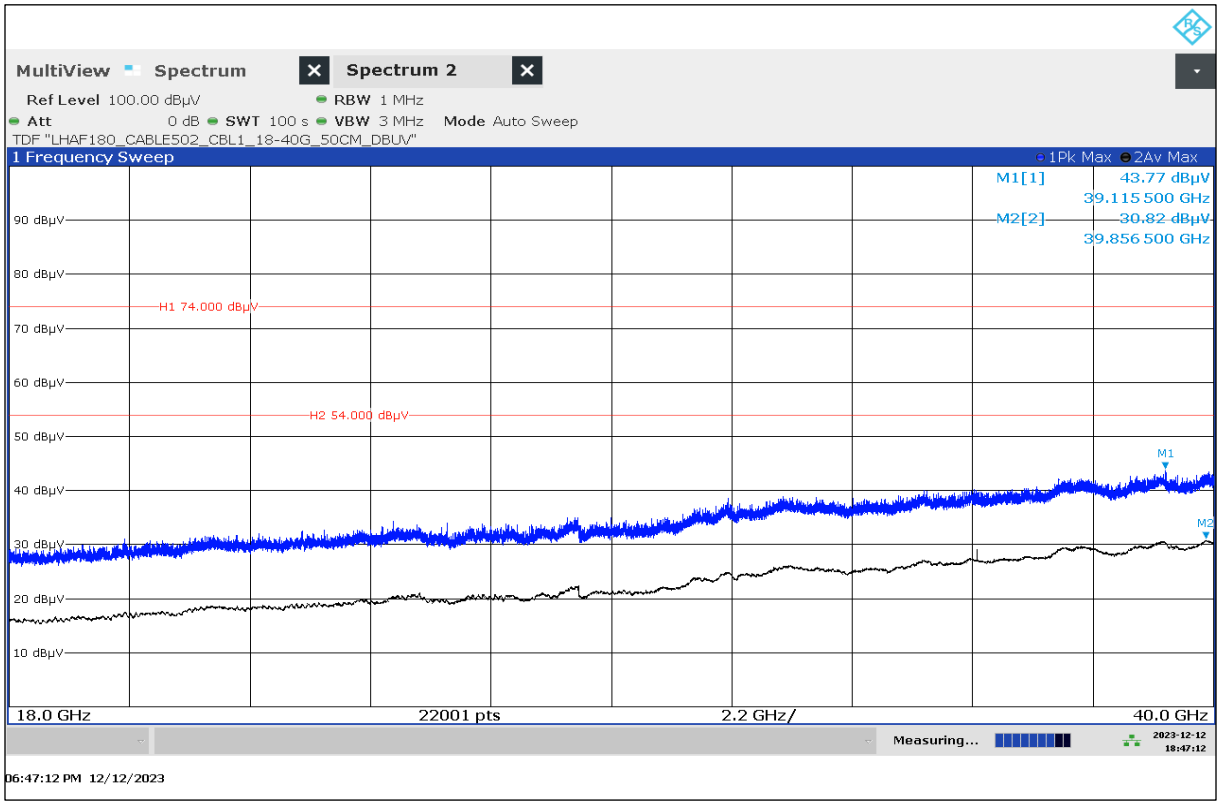
M1 with peak detector is just informative; FCC limit is 54 dBuV/m with Average detector.

Plot 24: 39 GHz, vertical / horizontal polarization, Highway traffic Mode 3



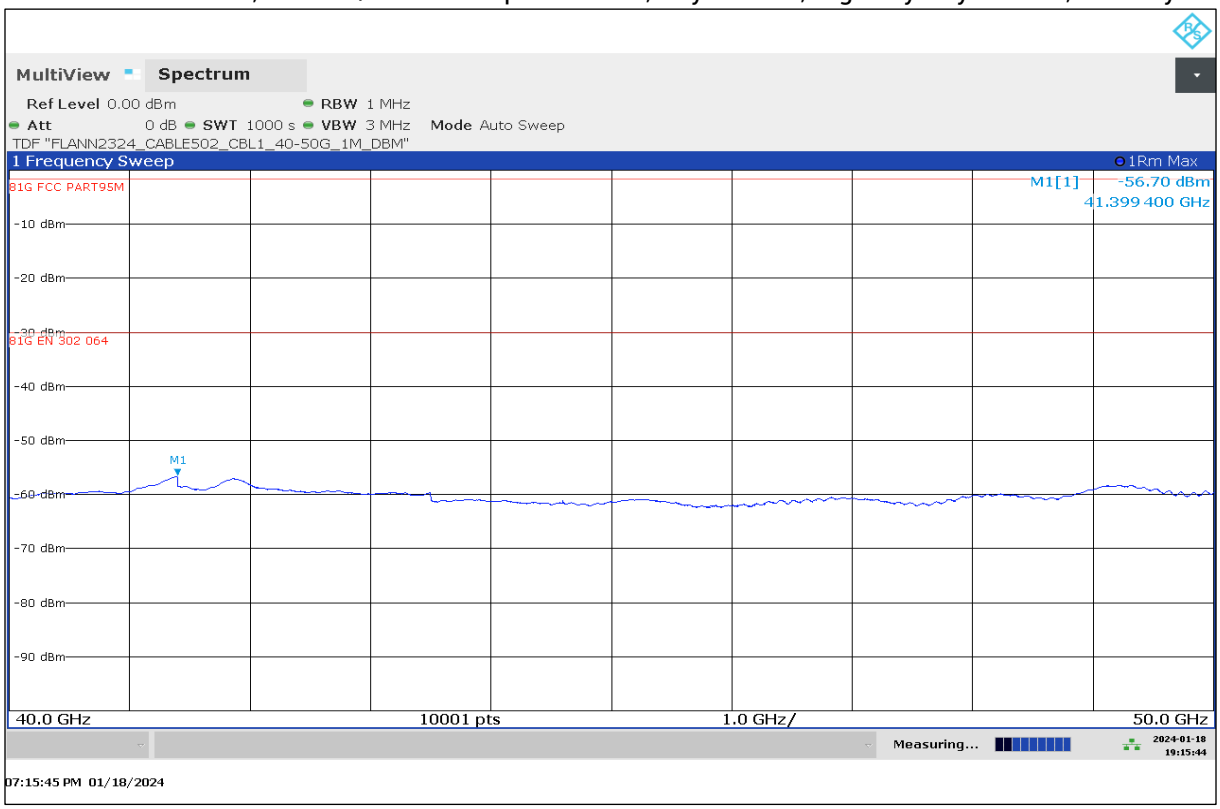
M1 with peak detector is just informative; FCC limit is 54 dBuV/m with Average detector.

Plot 25: 18 GHz – 40 GHz, vertical / horizontal polarization, Standby State

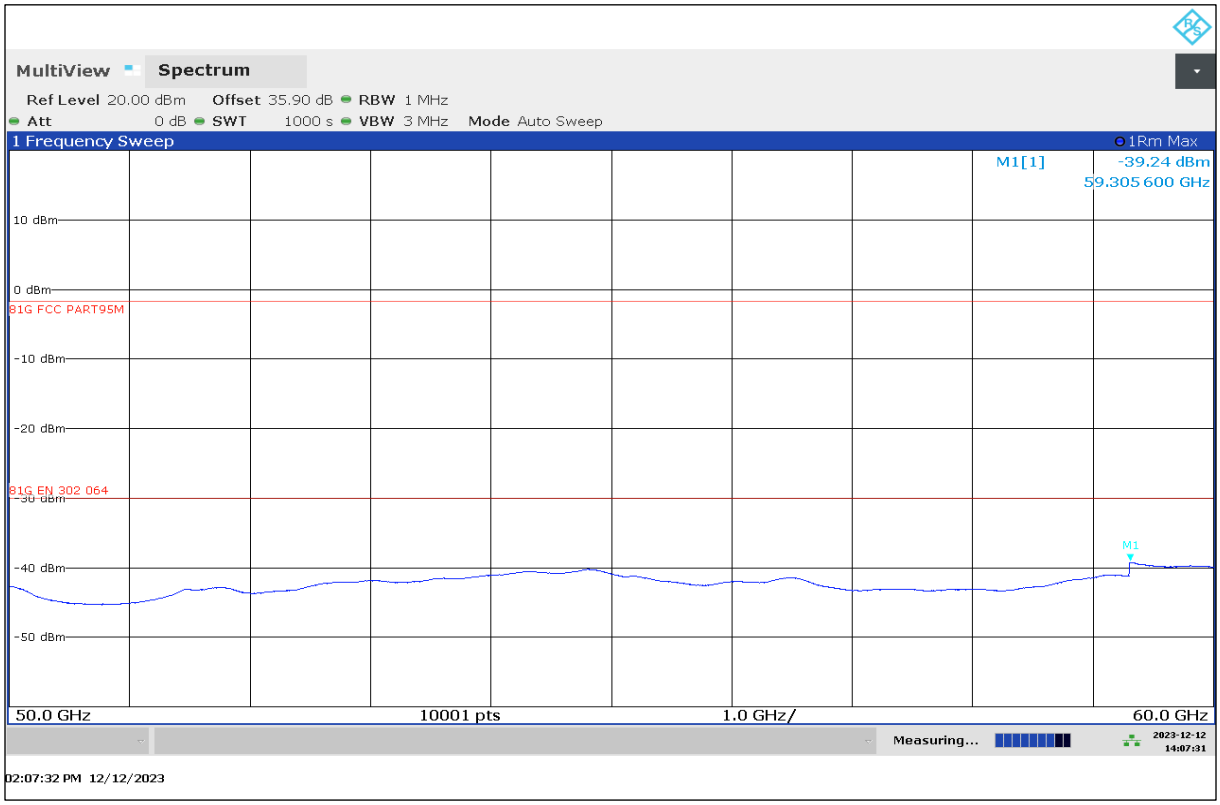


M1 with peak detector is just informative; FCC limit is 54 dBuV/m with Average detector.

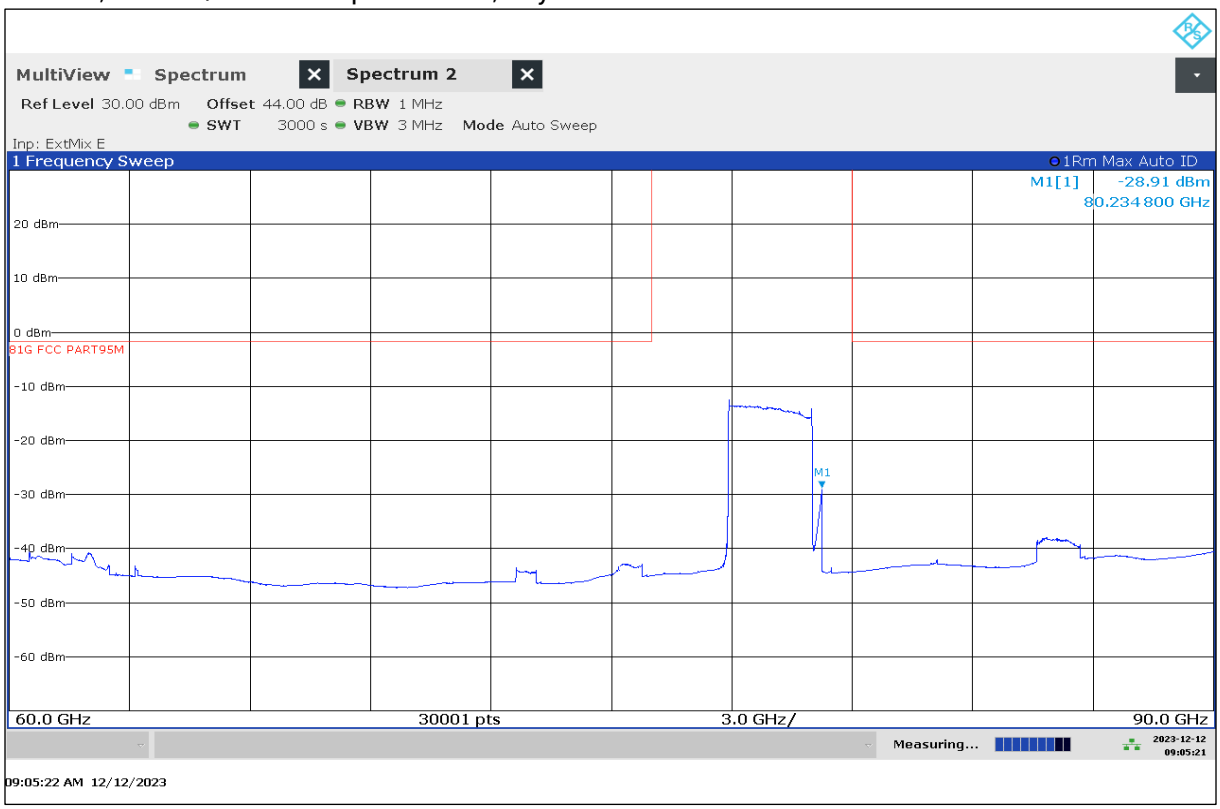
Plot 26: 40 GHz – 50 GHz, vertical / horizontal polarization, City Mode 3, Highway City Mode 3, Standby



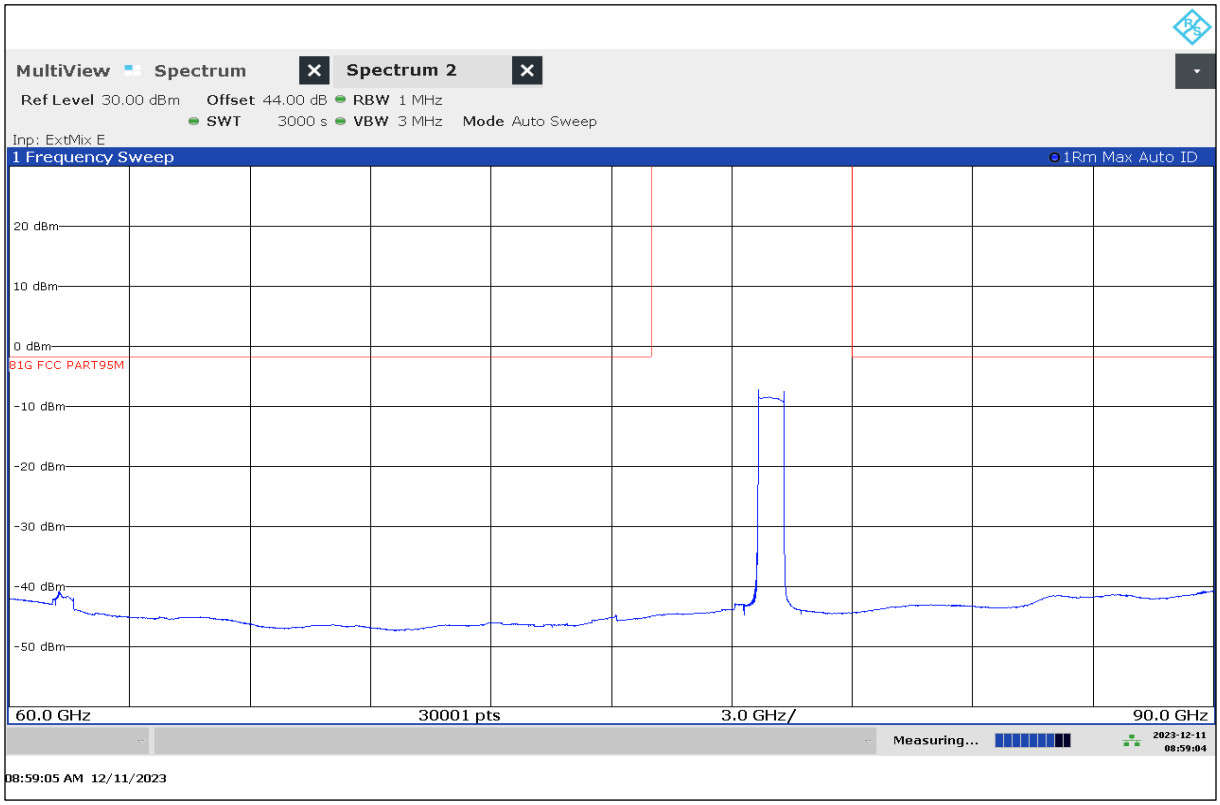
Plot 27: 50 GHz – 60 GHz, vertical / horizontal polarization, City Mode 3, Highway City Mode 3, Standby



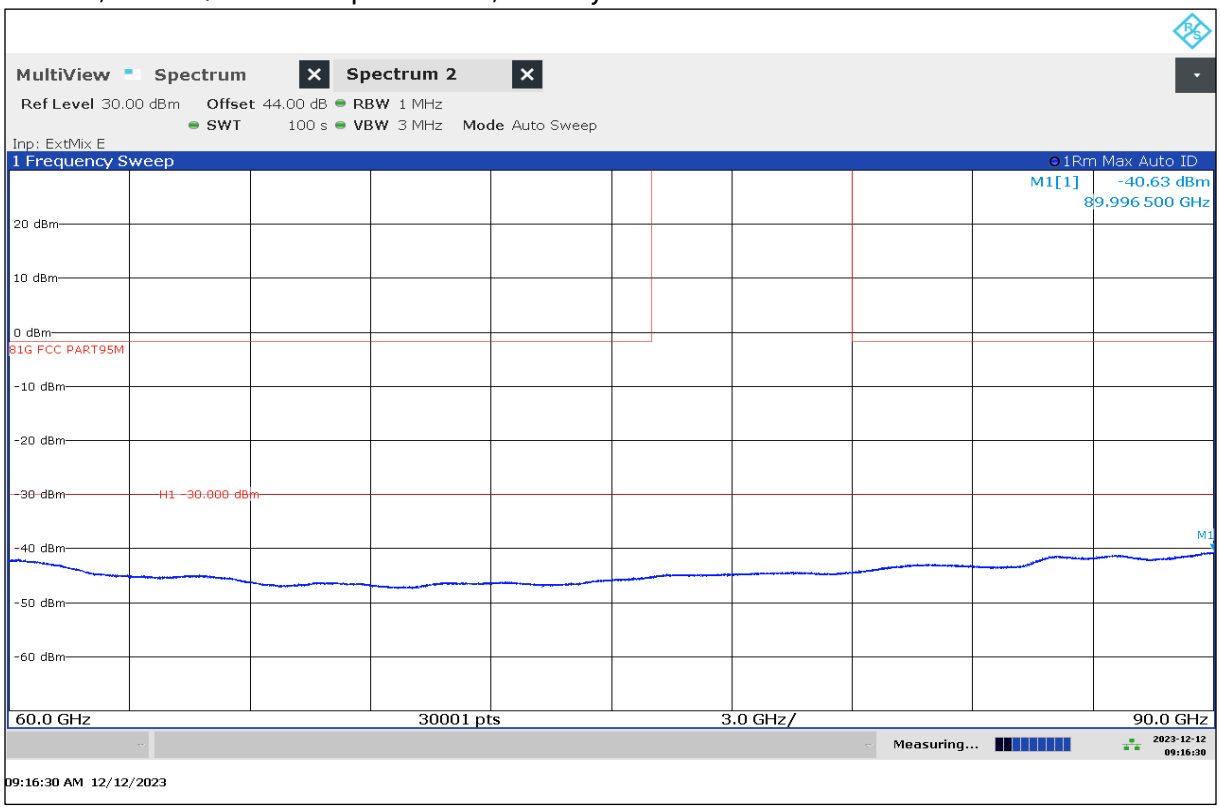
Plot 28: OOB, vertical / horizontal polarization, City Mode 3



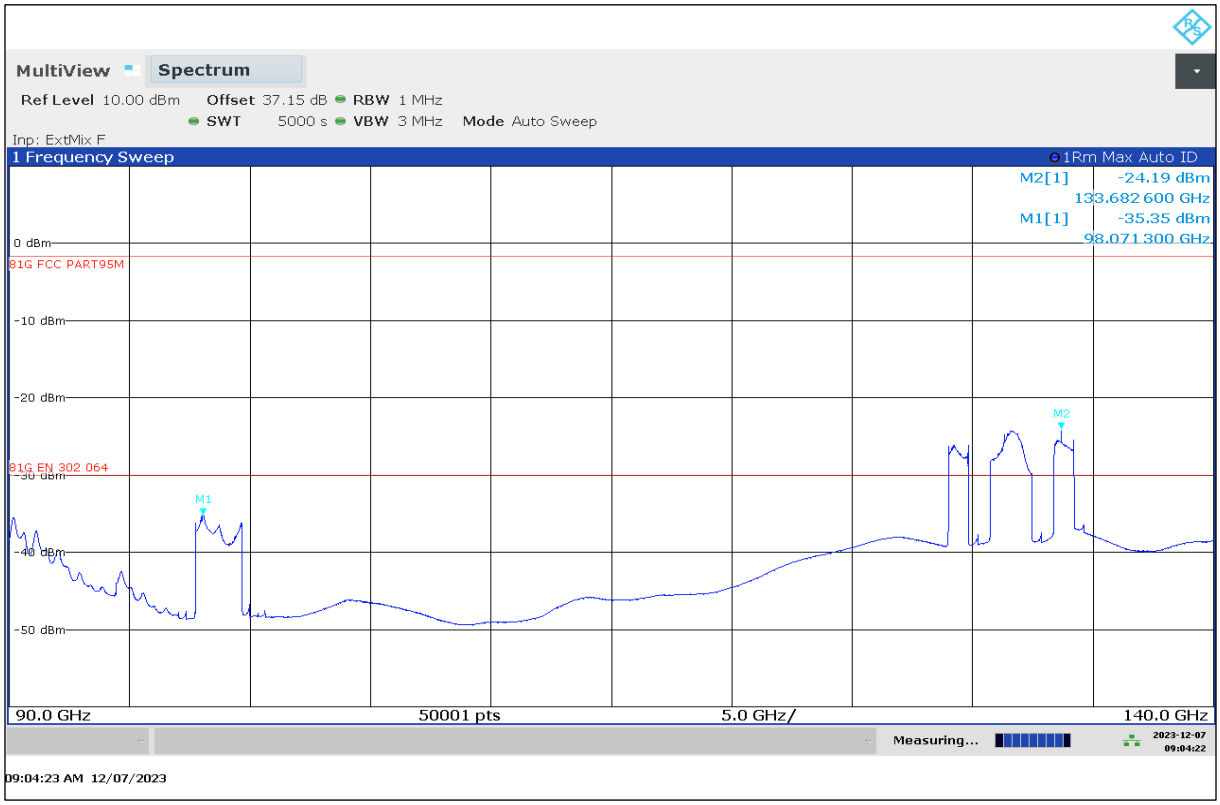
Plot 29: OOB, vertical / horizontal polarization, Highway Traffic Mode 3



Plot 30: OOB, vertical / horizontal polarization, Standby State

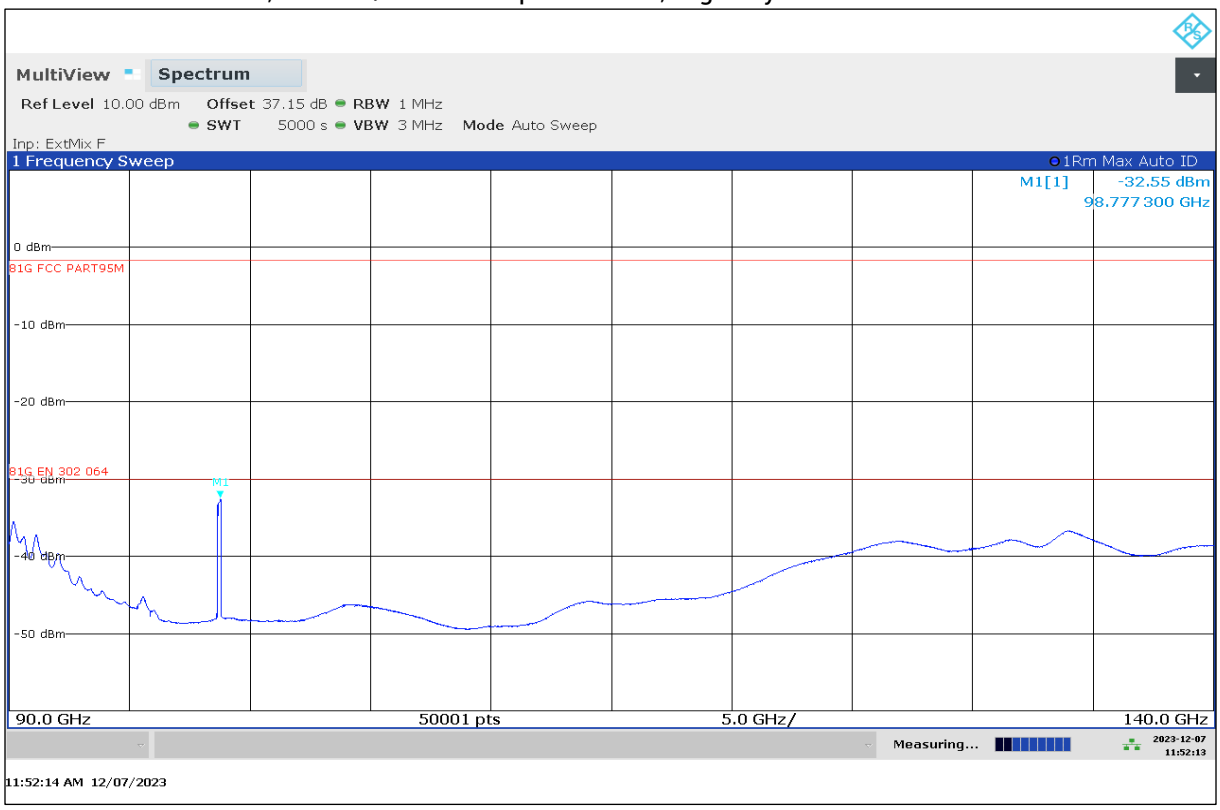


Plot 31: 90 GHz – 140 GHz, vertical / horizontal polarization, City Mode 3



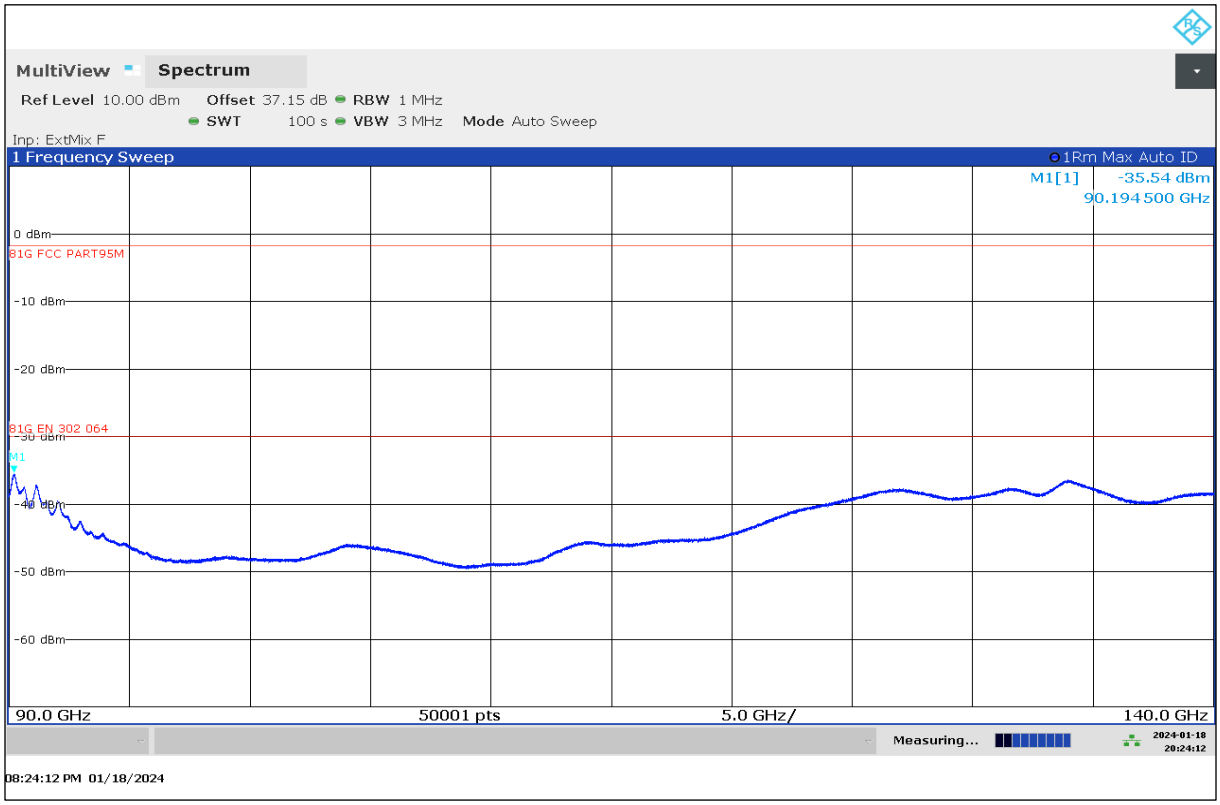
Markers show signal caused by mixer products

Plot 32: 90 GHz – 140 GHz, vertical / horizontal polarization, Highway Traffic Mode 3

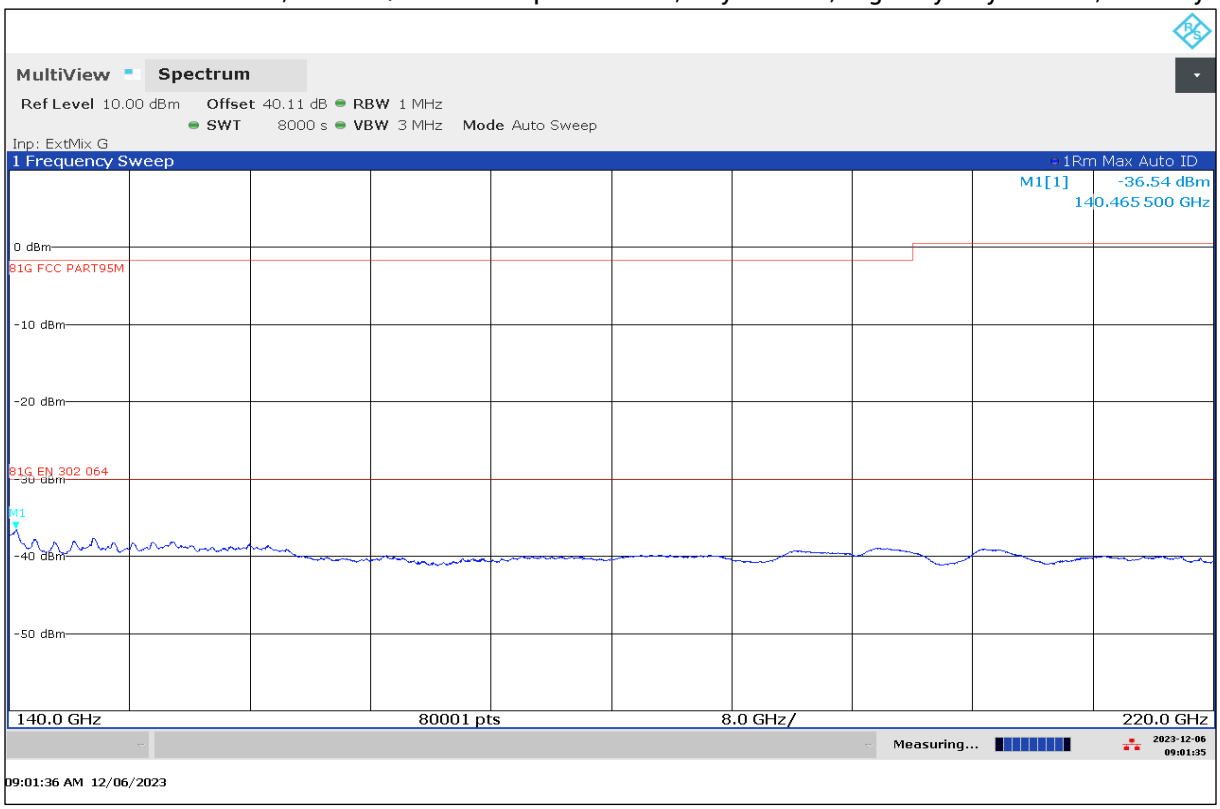


Marker shows signal caused by mixer products

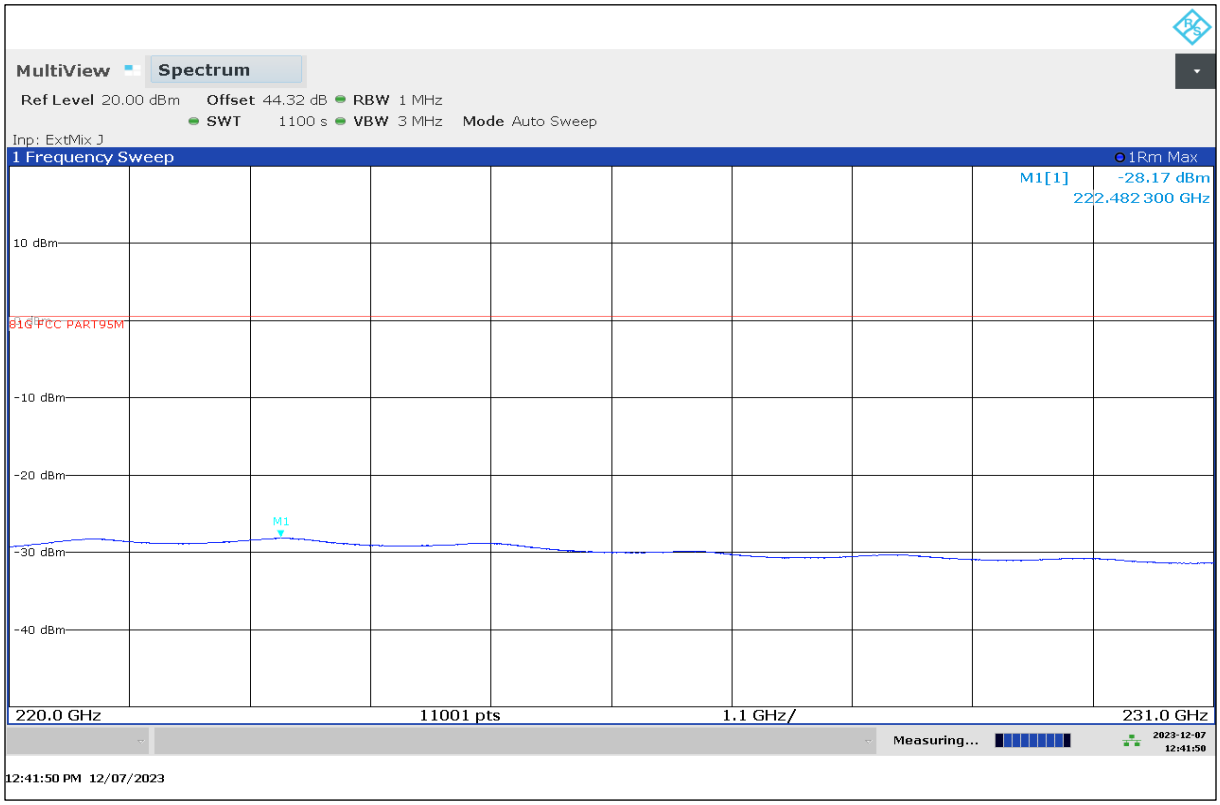
Plot 33: 90 GHz –140 GHz, vertical / horizontal polarization, Standby State



Plot 34: 140 GHz – 220 GHz, vertical / horizontal polarization, City Mode 3, Highway City Mode 3, Standby



Plot 35: 220 GHz – 231 GHz, vertical / horizontal polarization, City Mode 3, Highway City Mode 3, Standby



12.6 Frequency stability

Description:

§95.3379 (b) Fundamental emissions must be contained within the frequency bands specified in this section during all conditions of operation. Equipment is presumed to operate over the temperature range −20 to +50 degrees Celsius with an input voltage variation of 85% to 115% of rated input voltage, unless justification is presented to demonstrate otherwise.

Limits:

FCC §95.3379 (b)
The occupied bandwidth from intentional radiators operated within the specified frequency band shall comply with the following:
Frequency range: 76 GHz – 81 GHz

Measurement:

Parameters	
Detector:	Pos-Peak
Resolution bandwidth:	1 MHz
Video bandwidth:	3 MHz
Trace-Mode:	Max Hold

Measurement results:

Temperature variation

Mode	Temperature in °C	f_L in GHz	f_H in GHz	Bandwidth [MHz]
City Mode 3	-20 °C / V_{nom}	77.510 882	79.990 585	2480
	-10 °C / V_{nom}	77.475 797	79.989 914	2514
	0 °C / V_{nom}	77.920 712	79.988 593	2068
	10 °C / V_{nom}	77.931 272	79.987 585	2056
	20 °C / V_{min}	77.931 168	79.986 429	2055
	20 °C / V_{nom}	77.931 000	79.986 067	2055
	20 °C / V_{max}	77.931 260	79.986 223	2055
	30 °C / V_{nom}	77.930 541	79.985 705	2055
	40 °C / V_{nom}	77.929 528	79.985 164	2056
	50 °C / V_{nom}	77.928 830	79.983 880	2055

Note:

- The EUT is measured in the temperature range from -20°C to 50°C specified by §95.3379 (b).
- The details of the measurements can be found in the measurement report: 1-6402_23-01-02_MR1

Verdict: **Complies**

12.7 Occupied bandwidth interferer (RF 4.2)

Description:
Ability of the transmitter to operate as intended when an interferer occurs that covers the occupied bandwidth of the EUT.

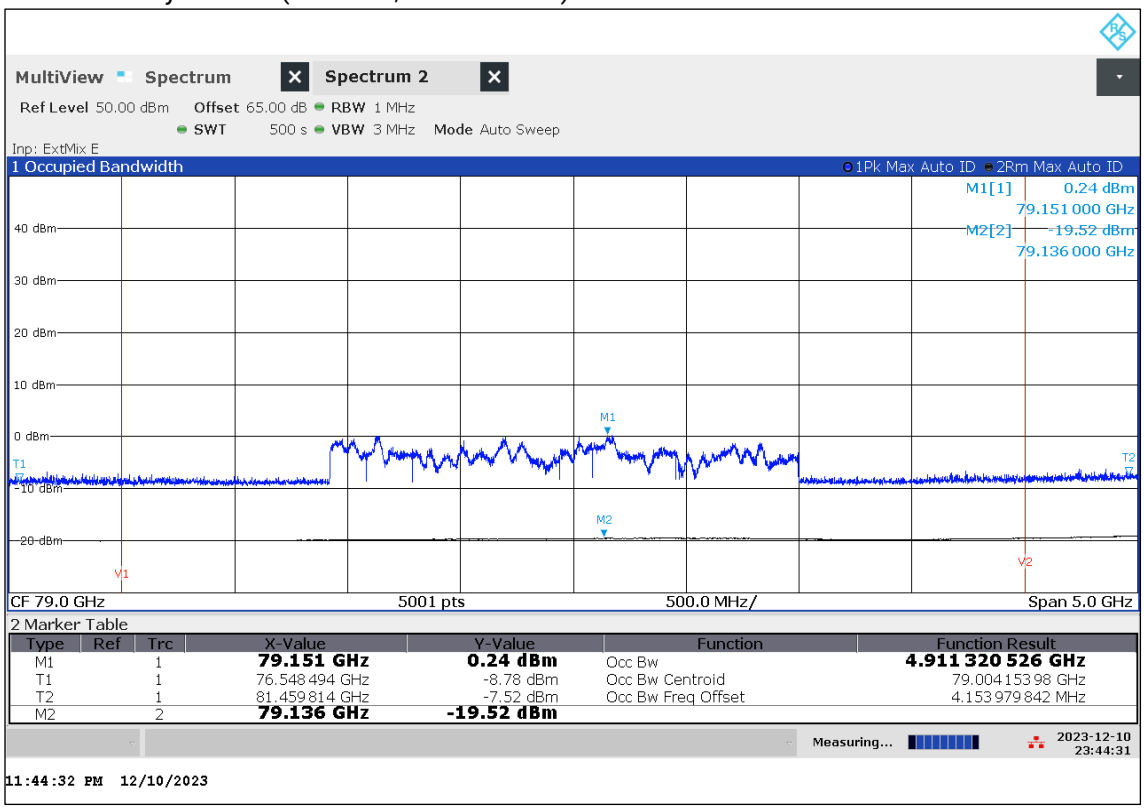
Set-up:
The measurement antenna was placed at a distance of about 6 m to the EUT.
An identical 77 – 81 GHz transmitter was added to the set-up, transmitting towards the EUT with orientation optimized for electrical boresight.
To prevent measuring signal components of the disturbing signal, the disturber was moved closer to the EUT to a distance of about 3 m and additionally shielded from the measurement antenna.

Measurement results:

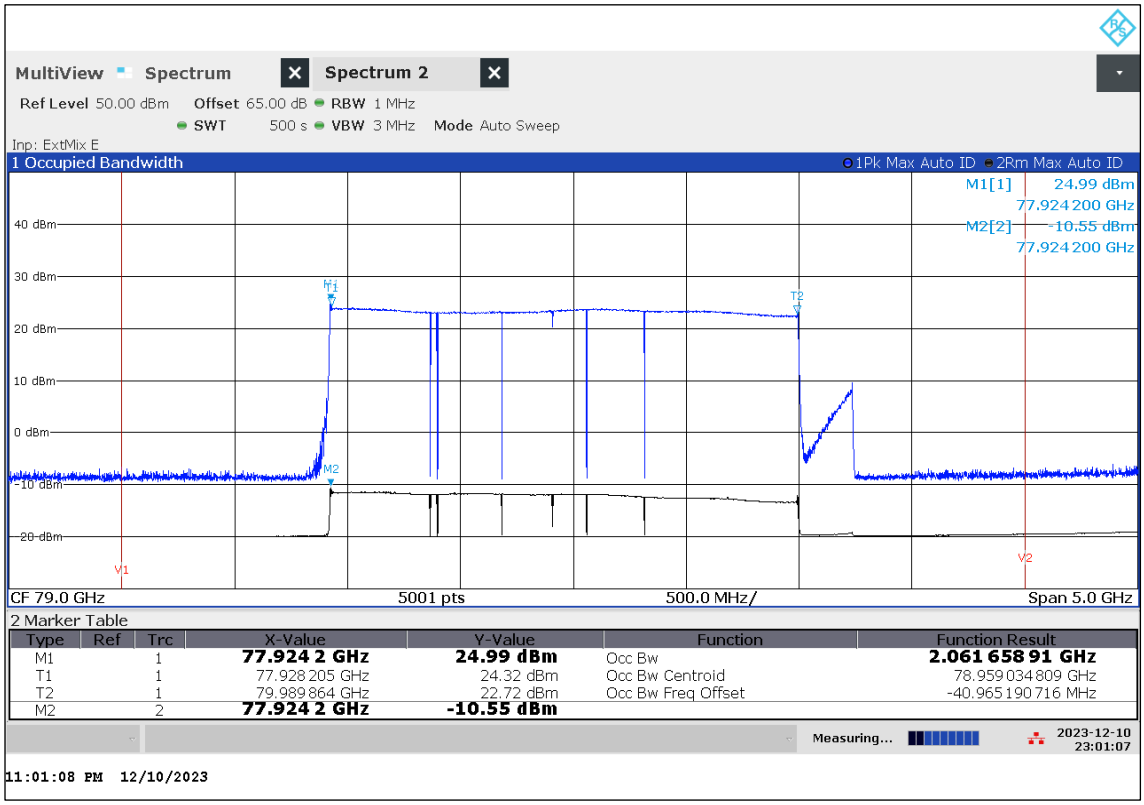
Mode	Peak max [dBm] EUT OFF / Interferer ON	Peak max [dBm] EUT ON / Interferer OFF	Peak max [dBm] EUT ON / Interferer ON
City Mode 3	0.24	24.99	24.38
Highway Traffic Mode 3	1.01	27.42	28.20

Verdict: No influence on the signal spectrum with interferer present could be observed.

Plot 36: OBW with City Mode 3 (EUT OFF, Interferer ON)

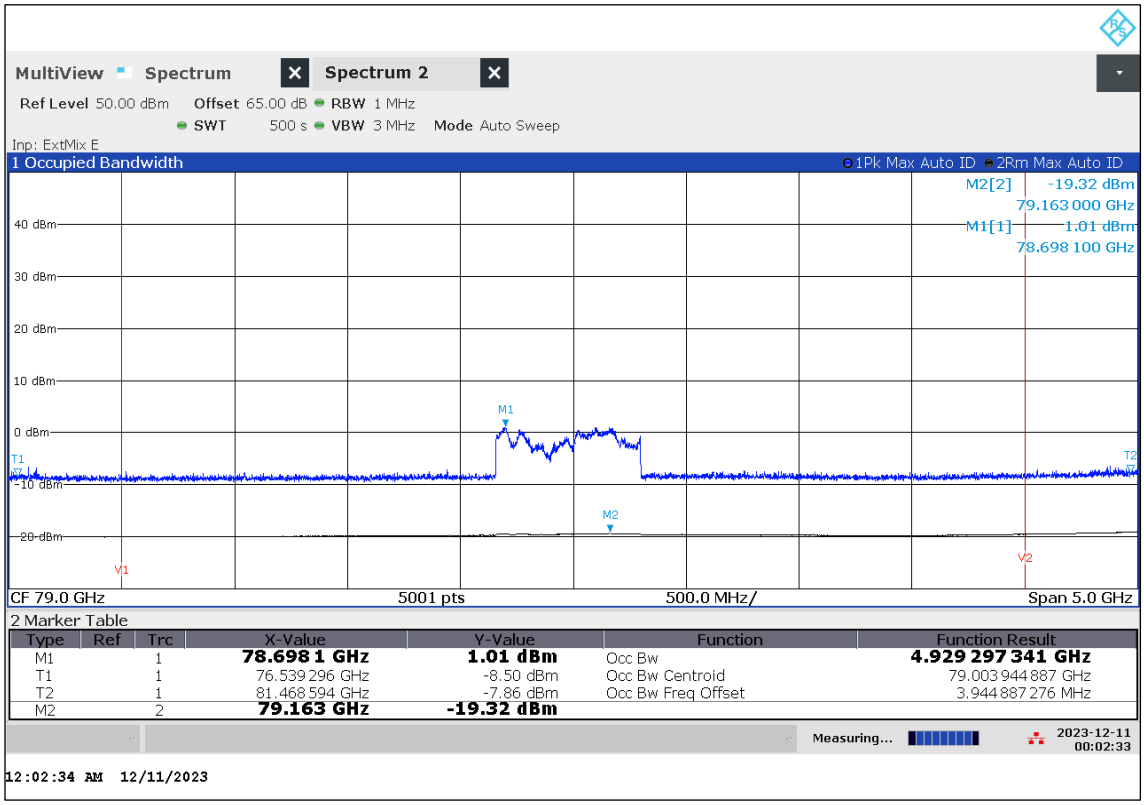


Plot 37: OBW with City Mode 3 (EUT ON, Interferer OFF)

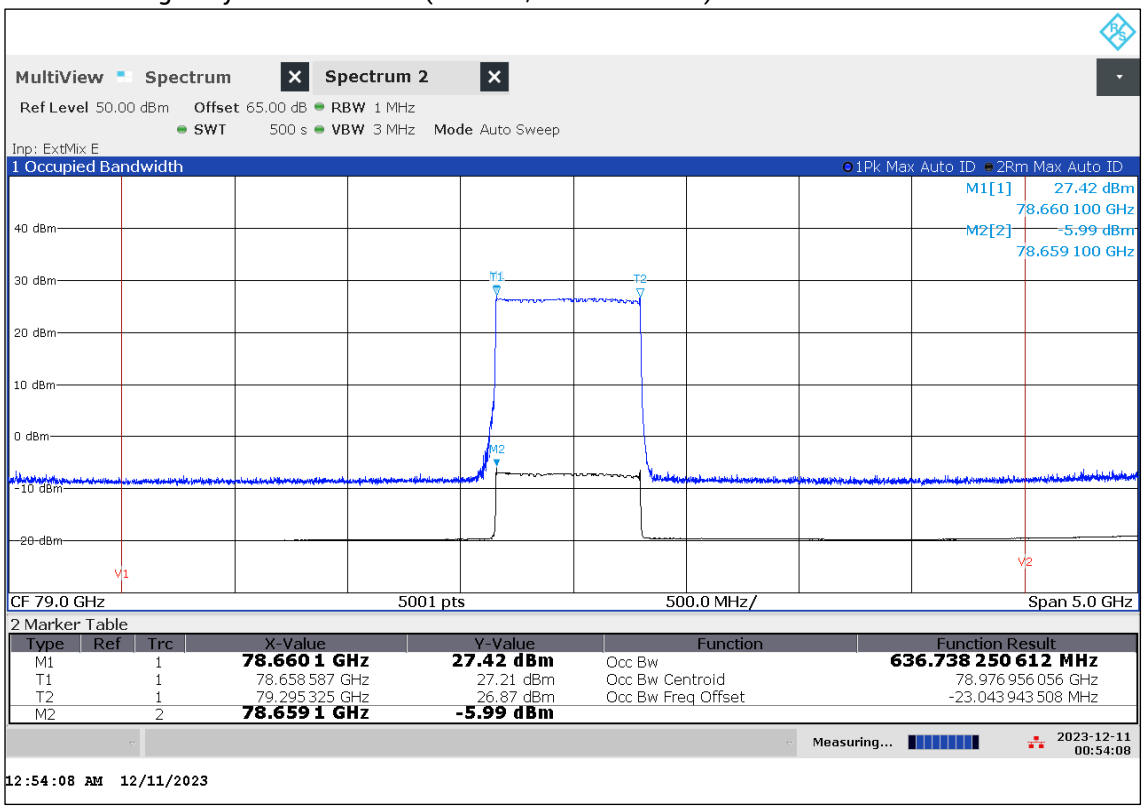


Plot 38: OBW with City Mode 3 (EUT ON, Interferer ON)

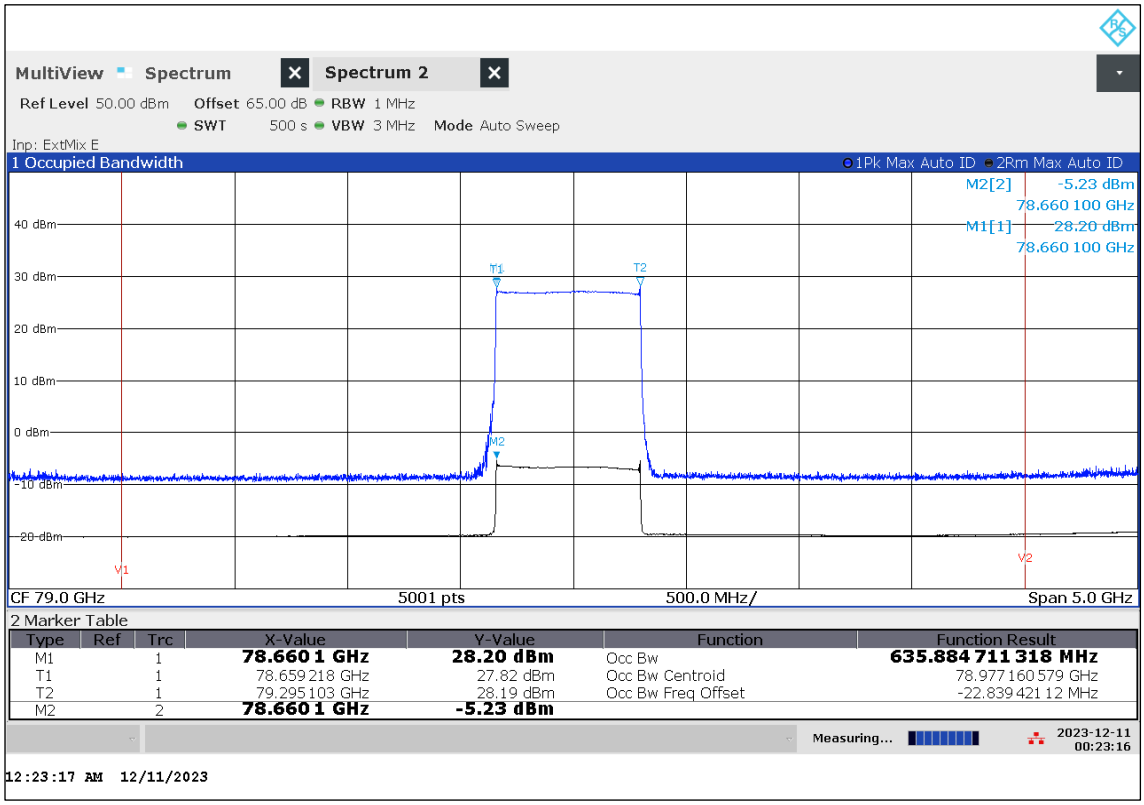
Plot 39: OBW with Highway Traffic Mode 3 (EUT OFF, Interferer ON)



Plot 40: OBW with Highway Traffic Mode 3 (EUT ON, Interferer OFF)



Plot 41: OBW with Highway Traffic Mode 3 (EUT ON, Interferer ON)



13 Glossary

EUT	Equipment under test
DUT	Device under test
UUT	Unit under test
GUE	GNSS User Equipment
ETSI	European Telecommunications Standards Institute
EN	European Standard
FCC	Federal Communications Commission
FCC ID	Company Identifier at FCC
IC	Industry Canada
PMN	Product marketing name
HMN	Host marketing name
HVIN	Hardware version identification number
FVIN	Firmware version identification number
EMC	Electromagnetic Compatibility
HW	Hardware
SW	Software
Inv. No.	Inventory number
S/N or SN	Serial number
C	Compliant
NC	Not compliant
NA	Not applicable
NP	Not performed
PP	Positive peak
QP	Quasi peak
AVG	Average
OC	Operating channel
OCW	Operating channel bandwidth
OBW	Occupied bandwidth
OOB	Out of band
DFS	Dynamic frequency selection
CAC	Channel availability check
OP	Occupancy period
NOP	Non occupancy period
DC	Duty cycle
PER	Packet error rate
CW	Clean wave
MC	Modulated carrier
WLAN	Wireless local area network
RLAN	Radio local area network
DSSS	Dynamic sequence spread spectrum
OFDM	Orthogonal frequency division multiplexing
FHSS	Frequency hopping spread spectrum
GNSS	Global Navigation Satellite System
C/N_0	Carrier to noise-density ratio, expressed in dB-Hz

14 Document history

Version	Applied changes	Date of release
-/-	Initial release - DRAFT	2024-01-19
-/-	Minor changes	2024-02-09